MONOGRAPH

Development of the University of Pennsylvania Smell Identification Test: A Standardized Microencapsulated Test of Olfactory Function

RICHARD L. DOTY,*†‡† PAUL SHAMAN*§ AND MICHAEL DANN*

*Clinical Smell and Taste Research Center, †Department of Otorhinolaryngology and Human Communication
‡Department of Physiology, School of Medicine, University of Pennsylvania
Philadelphia, PA 19104
and §Department of Statistics, The Wharton School
University of Pennsylvania, Philadelphia, PA 19104

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DOTY, R. L., P. SHAMAN AND M. DANN. Development of the University of Pennsylvania Smell Identification Test: A standardized microencapsulated test of olfactory function. PHYSIOL BEHAV 32(3) 489–502, 1984.—The development of the first standardized “scratch ‘n sniff” olfactory test is described. Over 1600 subjects participated in five experiments. In Experiment 1, 50 microencapsulated odorants were rated as to their intensity, pleasantness, irritation, coolness, and familiarity, and two procedures for releasing them were compared. In Experiment 2, the results of the first experiment and other data were used in the development of the test, which was administered to a large number of subjects. Using multiple regression analysis, scores on this test were shown to be significantly related to the subjects’ gender, ethnic background, and smoking behavior. Average test scores decreased as a function of age, with the greatest decline occurring between the sixth and tenth decades of life. These age-related changes were not correlated with scores on the Wechsler Memory Scale. Women performed better than men within all age categories. In Experiment 3, the test was shown to differentiate between subjects with known olfactory disorders (e.g., Kallmann’s syndrome; Korsakoff’s syndrome) and normal controls, and to reliably detect persons instructed to feign total anosmia. In Experiment 4, the test-retest reliability was established (6-month interval; r=0.918, p<0.001), and in Experiment 5 the test was shown to correlate thresholds with odor detection (t=−0.794, p<0.001). This self-administered test now makes it possible to rapidly and accurately assess general olfactory function in the laboratory, clinic, or through the mail without complex equipment or space-consuming stores of chemicals.

THE sense of smell largely determines the flavor of the foods we ingest and the beverages we savor, and serves as an important early warning system for the detection of fire, dangerous fumes, leaking gas, spoiled foods, and polluted environments. Despite these important functions, few physiology or medical textbooks discuss procedures for evaluating this sense, and most fail to emphasize the fact that olfactory disorders commonly occur as a result of accidents, disease states, medical interventions, aging, and exposure to a number of environmental pollutants [14, 20, 29, 59]. Further-

Requests for reprints should be addressed to Richard L. Doty, Director, Smell and Taste Center, 5 Ravdin Building, Hospital of the University of Pennsylvania, 3400 Spruce Street, Philadelphia, PA 19104. A commercial version of the University of Pennsylvania Smell Identification Test is available through Sensonics, Inc.
Experiments I and 2, the empirical bases upon which the stimuli and response alternatives were selected for inclusion in this test are described, along with studies of the influences of variables such as the age and gender of the subject on the test scores. In Experiment 3 an evaluation is made of the utility of the UPSIT in discriminating between persons with and without olfactory dysfunction, as well as persons instructed to feign total anosmia. In Experiment 4 a study of the UPSIT’s test-retest reliability is presented, and in Experiment 5 a correlation determined between the UPSIT test scores and measures from a traditional odor detection task.

**EXPERIMENT I**

Experiment I had four main goals. The first was to quantitatively establish, in subjects with no olfactory dysfunction, the perceived intensity, pleasantness, familiarity, coolness-warmth, and irritation of 50 Microfragrance™ samples of potential use in a standardized olfactory test. (Microfragrance™ is a registered trademark of the 3M Company, Minneapolis, MN.) Such data provided basic information as to the suitability of microencapsulated odorants for human testing, as well as a basis for eliminating stimuli with clear problems of identifiability, irritation, or intensity from the final stimulus set. The second goal was to determine whether such

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Chemosensory in nature [47]. Leigh [37] noted a 7.2% anosmia rate in 1000 consecutive head injury cases admitted to a British military hospital during WWII and Sumner [53] reported a 7.5% incidence of post-traumatic anosmia in a study of 1167 head injury cases observed at the Leeds General Infirmary. Approximately 20% of the tumors of the temporal lobe or lesions of the uncinate convolution produce some form of olfactory disturbance [25], and it is now believed that about a third of schizophrenic patients exhibit olfactory hallucinations of one type or another [8, 45, 49].

A major reason for the dearth of interest on the part of human-oriented basic scientists in this important sensory system has been the lack of a practical, objective, and standardized means for testing its function. Unlike the testing of the visual, auditory, and vestibular systems (where standardized tests are widely applied), the testing of olfaction varies considerably from laboratory to laboratory. Clinically, such tests range from simply asking a patient whether a smell problem exists to the administration of lengthy and impractical threshold tests for which sound normative data are typically lacking.

The present paper describes five experiments leading to the development of the first standardized "scratch 'n sniff" test of olfactory function—the University of Pennsylvania Smell Identification Test (UPSIT; pictured in Fig. 1). In Experiments I and 2, the empirical bases upon which the stimuli and response alternatives were selected for inclusion in this test are described, along with studies of the influences of variables such as the age and gender of the subject on the test scores. In Experiment 3 an evaluation is made of the utility of the UPSIT in discriminating between persons with and without olfactory dysfunction, as well as persons instructed to feign total anosmia. In Experiment 4 a study of the UPSIT's test-retest reliability is presented, and in Experiment 5 a correlation determined between the UPSIT test scores and measures from a traditional odor detection task.
ratings were differentially influenced by two simple means of releasing the stimuli (scratching the odorized surface with a pencil tip or with No. 120 sandpaper) and, if so, whether one procedure was preferable to the other. A third goal was to establish if a sex difference occurs in the obtained intensity and pleasantness ratings of the stimuli, as expected from studies which suggest that women rate a number of odors as more intense and less pleasant than do men [13, 17-19]. The fourth goal of this study was to ascertain the relative identifiability of the Microfragrance™ samples when no verbal or written cues were provided as to their identity. This information, in conjunction with the familiarity ratings obtained in this study and data collected in the next experiment (Experiment 2), was subsequently used to eliminate stimuli that were difficult to identify.

Subjects

Twenty-six men and 26 women (mean age=24.87 years, SD=5.52 years, range=18 to 40 years) of excellent health and with no apparent olfactory problems were selected from a subject pool maintained by the Clinical Smell and Taste Research Center. All but 10 were non-smokers and, of these 10, only two smoked more than 1 pack/day. Forty-four were White Americans and eight were Black Americans, and the majority were college students at the University of Pennsylvania. None had previously participated in chemosensory studies. Each subject received $10.00 for participation.

Odorants

The 50 stimuli used in this and the subsequent experiments were chosen from over one hundred Microfragrance™ samples available from the 3M Company (Minneapolis, MN) on the basis of several criteria: first, that their odors, as judged from preliminary samples sent to the experimenters, were a reasonable first-order approximation of the descriptive label given to them by the manufacturer; second, that they spanned a number of previously-established qualitative odor classes [1,28], including disparate sectors of a multidimensional perceptual space developed using microencapsulated odorants [9]; third, that they included stimuli composed of single as well as multiple components (e.g., licorice is typically a single-component odorant made up of anethole, whereas chocolate is a multiple-component odorant made up of a number of chemicals), given the possibility that the olfactory system codes information on the basis of a multiple profile-multiple receptor site process [43]; fourth, that the majority evidenced no or minimal ability to stimulate non-CN I intranasal or pharyngeal chemosensory systems (e.g., CN V); and fifth, that a few trigeminal stimulants (e.g., menthol) be included to allow detection of at least some types of malingerers [16]. The odorants were embedded in 10-50 μm plastic capsules coated onto adhesive backed labels, as described elsewhere [41].

Procedures

The 52 subjects were divided into 13 groups of four apiece. Within each group there were two males and two females of similar age. The average age was approximately 21 for six of the groups, 25 for three of the groups, 28 for two of the groups, and 31 and 38 for the other two groups. The eight black subjects formed two of the groups. Within each group, one member of each sex released the microencapsulated odorants by scratching the labels with a 2 by 1 inch strip of No. 120 sandpaper, whereas the other used the tip of a No. 2 lead pencil. The instructions were read to each subject by an experimenter who monitored the test session to insure that the correct procedures were followed.

Each subject rated, in individual hour-long test sessions, all of the 50 Microfragrance™ samples on five 9-point category scales with the following adjectives serving as anchors at their extremes: very weak—very strong; very unpleasant—very pleasant; non-irritating—very irritating; very unfamiliar—very familiar; and very cool—very warm. One 3 by 1/2 inch Microfragrance™ sample label was located at the bottom of each page of an 8 1/2 by 11 inch test booklet which contained each of the five 6-inch long scales. The 50 pages were completed in the order in which they were presented. To control for position response biases of the subjects, as well as for order effects in the presentation of the scales themselves, both the order in which the scales appeared on a page and the position of the adjectives on a given scale (e.g., very unpleasant—very pleasant vs. very pleasant—very unpleasant) were counterbalanced across subjects, as in earlier work [16]. In addition, the order in which the stimuli were presented was also counterbalanced across subjects. The subjects were allowed to work at their own rate, but were required to take a 10 minute break halfway through the task (i.e., after the 25th Microfragrance™ sample). A label could be repeatedly scratched, as needed, before moving to the next odorant, although returning to previous odors was not allowed. Following completion of the scales on a given page, the subjects were asked to write down, to the best of their ability, the identity of the odor presented on that page.

Data Analysis

To determine if the procedure used for releasing the stimuli or if the gender of the subjects influenced the psychological ratings, the scale values of each attribute were analyzed by a 2 (sandpaper vs. pencil) by 2 (male vs. female) by 50 (Microfragrance™ sample) analysis of variance (ANOVA). A separate ANOVA was performed for each of the five attributes since it was not clear that the same metric was being used for all scales (e.g., warm-cool and unpleasant-pleasant are bipolar scales, whereas the others are unipolar, although not necessarily of comparable scale).

To quantify the identifiability of the stimuli, as indicated by the written responses provided by each subject, a point was given for every response that was identical to that of the manufacturer's suggested label (e.g., licorice for licorice). In addition, a point was given for responses indicative of products containing the odorant as the major component (e.g., anise for licorice). A half point was given to less specific responses which, nonetheless, were at least remotely related to the odor (e.g., candy for licorice). The sum of the points across the 52 subjects served as an odorant's "identifiability index." In the present context, this simple scoring system seemed preferable to more complex ones noted in the literature (e.g., [11]), in which little subjectivity was required in assigning responses to the specific categories.

RESULTS

The overall mean ratings for each of the 50 Microfragrance™ samples are presented in Fig. 2 for all five psychological attributes. It is evident from this figure that none of the stimuli was rated at the extreme on any of the continua as to warrant its immediate exclusion from consideration in
As expected from previous work, women rated the odors, on the average, as more intense than did men (Table 1; Gender Main Effects: Intensity F(1,49)=8.70, p<0.005). Somewhat unexpectedly, women also rated, relative to men, the odors as less cool, less irritating, and more familiar (Table 1; Gender Main Effects: Cool-Warm F(1,49)=6.80, p=0.012; Irritation F(1,49)=13.24, p<0.001; Familiarity F(1,49)=15.51, p<0.001), suggesting that gender differences are present for attributes in addition to intensity. Women tended to rate the odors as more unpleasant than did men, although the results did not achieve statistical significance, F(1,49)=3.22, p=0.079. Interestingly, the largest relative difference between the sexes was in the rated familiarity of the stimuli.

In general, the procedure used to release the stimuli influenced the psychological ratings. Thus, when released by sandpaper, the stimuli were rated, overall, as significantly more familiar and less pleasant (Table 2; Release Procedure Main Effects: Familiarity F(1,49)=7.83, p=0.007; Pleasantness F(1,49)=8.36, p<0.006). Although not reaching the 0.05 level of statistical significance, there was a tendency for stimuli to be rated as less intense and more irritating when released by sandpaper than when released by pencil (Table 2; Release Procedure Main Effects: Strength F(1,49)=3.36, p=0.073; Irritation F(1,49)=3.86, p=0.055). No statistically meaningful influence of the releasing procedure upon the cool/warm ratings was present (Table 2; Release Procedure Main Effect F(1,49)=1.13, p=0.293).

In addition to having a direct effect upon a number of the rated attributes, the release procedure interacted with several of the other variables. Thus, women rated stimuli released by sandpaper as stronger than those released by pencil (respective means=6.51 and 6.26), whereas men rated stimuli released by pencil as stronger than those released by sandpaper (respective means=6.43 and 5.93) (Gender by Release Procedure Interaction F(1,49)=28.51, p<0.001). Similarly, women rated stimuli released by sandpaper as more
familiar than those released by pencil (respective means=6.32 and 5.92), whereas this difference was not apparent for the men (both means=5.84) (Release Procedure by Gender Interaction $F(1,49)=7.83, p=0.007$). Some odorants were rated as slightly more familiar than others when released by sandpaper than when released by pencil (Fig. 2; Release Procedure by Microfragrance$^{TM}$ sample Interaction $F(49,49)=1.67, p=0.038$).

Overall, there was a significant tendency for the familiarity ratings to differ between the sexes as a function of the odorants evaluated (Gender by Microfragrance$^{TM}$ sample Interaction $F(49,49)=1.64, p=0.043$). The few odorants rated more familiar by men than by women (e.g., coconut, root beer, tomato and honey) did not appear to be stereotypically “masculine” odors, or to otherwise systematically differ from the other stimuli.

The data presented in Fig. 3 reveal that the stimuli differed considerably in their ability to be identified. Although a number of the odorants were correctly identified by most of the subjects, this was not true for the majority. Indeed, a few were never or only rarely correctly identified (e.g., pumpkin pie, honey, skunk, tomato, apple, peach, leather, whiskey, and gingerbread).

To ascertain whether the poorly identified stimuli were rated as less intense or less familiar than the others, as well as to determine if any of the Microfragrance$^{TM}$ samples could be judged unsuitable for further consideration on grounds of being too weak, strong, unpleasant or irritating, the means for all psychological attributes were carefully evaluated for all 50 odorants (Fig. 2). In general, those stimuli that were most difficult to identify (Fig. 3) were the ones rated as least familiar (Fig. 4). Furthermore, the stimuli with the lowest identifiability scores tended to be given the lowest relative intensity scores, despite the fact that the intensity ratings and subjective reports of the subjects revealed them to be moderately strong. Thus, of the 15 stimuli with the lowest identifiability scores, approximately two-thirds fell below the median intensity of the entire 50 odorants and nearly half fell within the lowest quartile of the intensity ratings.

It is clear from Fig. 2 that none of the stimuli could be eliminated from further consideration on the basis of being too weak or too strong, although a number were suspect, as indicated above, in terms of familiarity and identifiability. An examination of the pleasantness ratings indicated that slightly over half of the Microfragrance$^{TM}$ samples were rated on the pleasant side of the pleasantness/unpleasantness

<table>
<thead>
<tr>
<th></th>
<th>Intensity</th>
<th>Pleasantness/Unpleasantness</th>
<th>Irritation</th>
<th>Warm</th>
<th>Cool</th>
<th>Familiarity</th>
</tr>
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<tbody>
<tr>
<td>Sandpaper</td>
<td>6.22</td>
<td>4.96</td>
<td>2.34</td>
<td>4.48</td>
<td>2.44</td>
<td>5.01</td>
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<tr>
<td>Pencil tip</td>
<td>6.35 ± 1.89</td>
<td>4.78 ± 2.25</td>
<td>2.42</td>
<td>4.35</td>
<td>2.42</td>
<td>5.08</td>
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See text for details.

*Difference between means significant at $p=0.055$

$^+$Difference between means significant at $p<0.01$.

FIG. 3. Identifiability of the 50 target microencapsulated odorants See text for details.
scale, and that only a few were rated as markedly unpleasant—motor oil, gasoline, natural gas, onion, paint thinner, garlic, and turpentine. With the exception of a few stimuli of questionable identifiability (e.g., honey, tomato), odors rated as pleasant were ones associated with foodstuffs and flowers, whereas those rated as unpleasant were ones associated with certain spices (e.g., black pepper) or non-food objects (e.g., motor oil). Irritation ratings greater than 5 were present for 19 of the stimuli, although none were judged as being extremely irritating. In general, odors rated as unpleasant tended to receive higher irritation ratings than those rated as pleasant. Most stimuli were rated as neither warm nor cool, although the exceptions are noteworthy. Stimuli receiving the largest cool ratings (e.g., mint, menthol) and warm ratings (e.g., cinnamon, clove, gasoline, motor oil, onion, smoke) are ones believed, on other grounds, to produce trigeminal stimulation [4,16].

As indicated in Fig. 2, both the sandpaper and pencil procedures produced clear and similarly-intense release of the odorants. Based on the findings that odors released by sandpaper were judged as more familiar than those released by pencil, and that women rated odors released in this fashion as stronger than did men (in accord with the sex difference noted in other human olfactory work) [13, 17-19], we chose to use sandpaper for releasing the stimuli in subsequent studies. Although several of the MicrofragranceSM samples were difficult to identify, it was conceivable that some would be readily identified in a multiple-choice situation where the subjects' responses are cued by written alternatives (since such a paradigm generally aids recall) [4]. Thus, we decided to gain more information about these stimuli in Experiment 2 before concluding they should be eliminated from the stimulus set.

**EXPERIMENT 2**

Experiment 2 had three main goals: First, to ascertain whether the odorants with poor identifiability tested in Experiment 1 were more readily identified in a multiple-choice response situation where response alternatives were provided; second, to use this information, along with the information from Experiment 1, to eliminate stimuli from inclusion in the final version of the UPSIT which were not correctly responded to by the majority of a large number of normal individuals; and third, to evaluate, using multiple regression analysis, the relative influences of several subject variables, both alone and in combination, on UPSIT scores of a rather large and heterogeneous group of subjects. Variables of particular interest were those of gender, age and smoking. Although most studies suggest that olfactory ability decreases with age [6, 36, 32, 54], exceptions exist [48,51], and one recent reviewer suggests the issue is not yet resolved [24]. Similarly, general consensus is not present as to whether gender and smoking behavior influence smell ability. For example, some studies report a relation between decrease olfactory performance and smoking behavior [30, 34, 42], whereas others report no such relation [24, 40, 54].

**Subjects**

In the initial segment of Experiment 2 (where the identifiability of the stimuli was established), 1198 volunteers were tested. These individuals were comprised of (a) participants of regional health fairs and public events, (b) primary and secondary public school students, (c) university students, (d) employees of the Hospital of the University of Pennsylvania, and (e) residents of homes for the elderly. Only persons who reported no smell abnormalities and who were able to correctly identify at least half of the odorants presented to them were included. Seventy-three percent of the group were White Americans and 21% Black Americans, with most of the remainder failing to indicate their ethnicity. Sixty-two percent were female and 38% male. Eighty percent reported being current non-smokers and 19% reported being smokers, with the remainder not providing this information. Although a wide spectrum of ages was well represented in this group, disproportionately more of the subjects fell within the younger age categories, as indicated by the following summary statistics: mean age=35.24, SD=19.21; modal age=19.0; median age=29.29; 25th percentile=18.88; 75th percentile=50.3). In general, the average ages of the two sexes, of the two major ethnic groups, and of the smokers and non-smokers were similar (e.g., male mean age=34.36 (SD=18.36); female mean age=35.79 (SD=19.72); White mean age=36.12 (SD=20.06); Black mean age=35.22 (SD=16.82); smoker mean age=38.50 (SD=16.22); non-smoker mean age=34.57 (SD=19.69).

In the second segment of Experiment 2 (where the relative influences of factors such as age, gender, race and smoking habits were evaluated using multiple regression analysis), the data from most of the aforementioned subjects and an additional number of persons (mostly elderly) were subjected to analysis. Although, as indicated in the results section, UPSIT scores of 1365 individuals were evaluated in the initial multiple regression studies, data from 26 with apparent anosmia or dysosmia were omitted from the data set upon which our final regression equation was computed.

**Odorant Presentation Format**

A preliminary 5-booklet 50-item version of the UPSIT, identical in general format to the 40-item version, was developed and administered in this experiment. The order of presentation of the odors within the booklets (10 odorants per booklet) was determined randomly, with the exception that odors of similar psychological quality (e.g., onion, garlic) did not directly follow one another. Although a large number of...
potential descriptors were considered for use as response alternatives [21,28], the 50 descriptors assigned by the manufacturer to the Microfragrance™ samples were finally chosen, as they were relatively unambiguous and non-esoteric. One additional descriptor, "cola," was also included in this group to help achieve specific criteria outlined below.

To aid in the selection of sets of distinct descriptors for each stimulus, the names of all 51 descriptors were typed on small cards. These cards were then arranged by two female research technicians spatially on a table top with the goal of making the distances between them reasonably proportional to the psychological similarity of the odor items. For example, the onion and garlic labels were placed close to one another, whereas the chocolate and gasoline labels were placed apart from one another and at differing distances from those of onion and garlic. The general arrangement agreed upon by the two technicians was subsequently evaluated by one of the experimenters (RLD), who concurred with the general arrangement. This simple procedure resulted in a two-dimensional space from which the three “distractor” items were selected for each odorant so as to maximize their distinctiveness from one another as well as from the target stimulus.

In addition to selecting response alternatives as distinct from one another as possible, we sought to use each of the descriptors equally often and approximately the same number of times in the a, b, c and d response category positions. Unfortunately, it was not possible to achieve all of these aims simultaneously. Nonetheless, we approached this ideal. Thus, 36 of the 51 descriptors appeared four times apiece, eight three times apiece, five five times apiece, one six times, and another once. No descriptor ever appeared more than twice in any of the response category positions (i.e., a, b, c or d).

Procedures

Each subject was instructed to complete the five booklets in order. A response was required for each item, even if no odor was perceived (i.e., the test was forced-choice). In most cases subjects were observed while taking the test and, in a few instances where the instructions were not understood, they were clarified. Following completion of the tests, they were checked to insure that all items had been answered. In cases where an item was skipped, a subject was instructed to complete the missing item.

Although the test was self-administered in most cases, an experimenter administered the test in situations where the person being tested was incapacitated or quite old. In these cases, the response alternatives were read aloud to the subject both before and during the sniffing of each stimulus, which was held directly underneath the subject’s nose.

RESULTS

Odor Identifiability

Even though the responses were cued by printed alternatives, a number of stimuli were still poorly identified by the majority of the subjects (Fig. 5). For example, less than 50% of the subjects correctly identified the so-called honey and whiskey fragrances, and less than 75% were able to correctly identify the skunk, pumpkin pie, tomato, chili, black pepper, and apple odors. In general, the stimuli that were poorly identified in this study were the same ones that were poorly identified in Experiment 1. For example, of the 15 least identifiable odorants in Experiment 1 (Fig. 3), 13 were amongst the 15 most poorly identified odorants in Experiment 2 (Fig. 5). Despite this fact, however, the inclusion of response alternatives did result in a higher relative identifiability of most of the stimuli, as was expected from previous work [4]. In addition, as was also expected from previous studies [4, 13, 17–19], women performed better than men in correctly identifying most of the odorants (Fig. 5).

Based on these data and the identifiability data of Experiment 1, the following stimuli were eliminated from inclusion in the 40-item UPSIT: apple, black pepper, chili, honey, musk, pumpkin pie, skunk, tomato and whiskey. In addition, garlic was eliminated from the final test due, in part, to its psychological and chemical similarity to onion.

Relationship of Age, Gender, Race and Smoking Habits to UPSIT Scores

All subsequent studies were performed using only the 40-stimuli included in the final version of the UPSIT. To examine to what extent a number of demographic factors account for the variability observed in the UPSIT scores, we performed a series of multiple regression analyses on data from 1339 to 1365 subjects, depending upon the information available (i.e., missing data for some variables necessitated using fewer subjects). Because we wished to consider only subjects with reasonably normal smell function, persons with UPSIT scores less than 20 were excluded from most of our analyses (inclusion of such individuals has the potential for greatly increasing the variance and producing a spurious R² value). The fitted regression equation (for 1339 subjects) which excluded such persons and included only variables statistically significant at the 0.05 level (F-test) was as follows:

\[ Y = 33.399 + 1.055X_1 + 0.217X_2 - 0.003X_3 - 0.489X_4 + 1.008X_5 - 1.040X_6 - 2.172X_7 + e. \]

where: 
- \( X_1 = 1(0) \) if the subject is female (male);
- \( X_2 = \text{age of subject in years}; \)
- \( X_3 = 1(0) \) if the subject does (does not) currently smoke;
- \( X_4 = 1(0) \) if the subject does (is not) nonwhite;
- \( X_5 = 1(0) \) if the subject does (does not) report a smell problem;
- \( X_6 = 1(0) \) if the subject does (does not) belong to an elderly sub-file (i.e., persons primarily in old-age homes who are over 65 years of age);
- \( e = \text{error term}. \)

The value of R² for this equation was 0.411 (SE = 3.318). The standard errors of estimate for the seven variables were: \( X_1 = 0.188; X_2 = 0.023; X_3 = 0.0003; X_4 = 0.238; X_5 = 0.222; X_6 = 0.302; \) and \( X_7 = 0.525. \)

We carried out several regression analyses with an additional dummy variable to permit inclusion of the twenty-six subjects who reported a smell problem and scored less than 20 correct. A fitted model comparable to the one above (with an n of 1365) yielded an R² value of 0.608, although the estimate of the standard deviation of the error term (SE) was 3.345, nearly identical to the aforementioned model’s value.

These data indicate that gender, age, ethnic background, and smoking habits all significantly correlate, in varying de-
FIG. 5. Percent of individuals correctly identifying the 50 microencapsulated odorants in the 4-alternative forced-choice response paradigm. Note that women performed better than men on this task for 44 of the stimuli.

FIG. 6. Relation between UPSIT scores, age, and gender in a large heterogeneous group of subjects. Numbers by data points indicate sample sizes.

gree, with scores on the UPSIT. The relation of gender and age to median UPSIT values is clearly depicted in a recent analysis of 1447 subjects (Fig. 6). Note that women evidenced higher average UPSIT scores than did men across nearly all age groups. A systematic decrease in test performance was present for both sexes beginning in the seventh decade of life and continuing until the tenth decade, with a more marked decrease occurring in men.

Although we regressed interaction terms such as smoking by sex and smoking by age, such terms did not contribute significantly to the overall regression measures and, thus, were not included in our final regression models. Interestingly, an analysis within the smoking group found no significant relation between the number of packs smoked per day and the UPSIT values, despite the fact that smoking, per se, correlated significantly with the UPSIT scores. More specific measures of smoking behavior (e.g., years of smoking or years since smoking) in both the smoking and non-smoking groups may be needed to detect subtle effects of smoking upon UPSIT scores (such as interactions with age), if indeed they are present.
To determine whether the decrease in the UPSIT scores across the older ages was due, whole or in part, to a decrement in memory, we administered the Wechsler Memory Scale Form II [56] to 47 of the elderly subjects (mean age=81.32, SD=7.75) within a day of the olfactory tests. Because 16 of these individuals evidenced probable total anosmia (i.e., UPSIT scores less than 20), only the data from those persons scoring 20 or above were used in our analyses. Although the UPSIT and the Wechsler Memory Scale (total raw score) each correlated significantly with age (respective rs: −.511 (p<0.001); −.433 (p<0.01), they did not significantly correlate with one another (r=.242, p>0.20). A partial correlation between UPSIT scores and the total raw scores of the Wechsler after removal of the age factor was small and nonsignificant (r=.027), whereas that between UPSIT scores and age after removal of the memory factor was clearly significant (r=−.465, p<0.005). Even though the UPSIT did not significantly correlate with any of the Wechsler subscales, its correlation with the Visual Reproduction subscale (VII) approached significance (r=.295, 0.05<p<0.06). Again, however, a partial correlation between the UPSIT scores and the scores on this subscale revealed no clear relation after removal of the effects of age (r=−.021). These data suggest that the major decline in performance on the UPSIT across the older age range is not due to a decline in memory, but likely reflects a true sensory decrement.

**EXPERIMENT 3**

The purpose of Experiment 3 was to establish the utility of the UPSIT in distinguishing between (a) persons with normal olfactory function, (b) persons with known or suspected olfactory dysfunction, and (c) persons instructed to feign total anosmia under the make believe condition of receiving a large sum of money if they successfully did so.

**Subjects and Procedures**

The UPSIT was administered to several groups of subjects. These groups, along with the rationale for their testing, are described in detail below.

**Persons With Normal Olfactory Sensitivity and No Known Disease States**

This group of subjects was comprised of the study population described in Experiment 2 minus persons over the age of 65 and consisted of 1215 persons (481 men, 734 women; mean age=33.69 years, SD=17.69), including 890 White Americans and 252 Black Americans (the remaining 73 were either of other ethnic background or did not provide this information). Persons older than 65 years of age were omitted because a disproportionate number evidenced anosmia or other forms of olfactory pathology.

**Persons With Total Anosmia**

The total anosmia validation group consisted of 51 individuals (mean age=40.76 years, SD=20.75). Fifteen of these anosmics had Kallmann's syndrome, a congenital hypogonadal disorder whose associated anosmia is believed due to agenesis of sectors of the olfactory system [10,35]. All had the typical endocrine manifestations of Kallmann's syndrome, as detailed elsewhere [50]. Nine of these subjects were patients of Dr. Peter J. Snyder of the Endocrine Section, Department of Medicine, and seven had served in earlier studies in our laboratory [12,16]. The other six were patients of Drs. Howard Kuhn and Richard J. Santen of the Department of Endocrinology of the Hershey Medical Center in Hershey, PA. The remaining anosmics had been diagnosed as totally anosmic at our center on the basis of a very stringent odor detection threshold criterion (furfural or phenylethanol thresholds above 10⁻¹ vol/vol concentration; see procedure section of Experiment 5), and had congenital total anosmia (n=3) or total anosmia secondary to head trauma (n=16), viral infection (n=6), anterior craniotomy (n=1), sinusitis (n=2), allergy (n=1), polyposis (n=3), or unknown factors (n=4).

**Persons With Korsakoff's Syndrome**

To determine if the UPSIT was sensitive to a well-documented odor recognition dysfunction of probable CNS origin, we tested 21 men with Korsakoff's psychosis (mean age=57.05, SD=8.13), an organic brain syndrome associated with (a) a consistent pattern of lesions in the midline areas of the brainstem and diencephalon and (b) impairment on numerous tests of olfactory function [32, 33, 38]. Thirteen were patients of Dr. Thomas Skaloda of the Veterans Administration Medical Center in Coatesville, PA, whereas eight were patients of Drs. Robert Mair and William J. McEntee of the Veterans Administration Medical Center in Providence, RI. This latter group had met a stringent set of diagnostic criteria, including a verified Wernicke stage and no history of cerebral anoxia or stroke. Although these patients were of relatively normal intelligence (I.Q.'s above 90), they evidenced clear-cut memory deficits (Wechsler M.Q. values less than 24 points below the I.Q. values; scores on the New York University Memory Test falling 2 SD's below the mean).

**Persons With Multiple Sclerosis**

We tested 31 persons with multiple sclerosis (14 men, 17 women; mean age=49.03, SD=12.36), a disease having serious motor and sensory pathologies. These individuals were volunteers from various MS Society chapters in the Delaware Valley. Unlike the case with vision, the neural demyelination associated with this disease reportedly spares the olfactory system (at least in the large majority of cases), as evidenced by (a) a notable absence of specific olfactory tract pathology at autopsy and (b) olfactory detection thresholds equivalent to those of matched normal controls [2]. Despite the general belief that olfactory function is normal in MS patients, there is at least one clinical report which suggests that the ability to identify odors may be affected in some individuals [57].

The mean estimated duration of the disease was available for 25 persons of this group and was 15.92 years (SD=10.80). Two of the subjects were blind, four reported being unable to read, two reported difficulty in reading, and the remainder noted no major problems with vision. No data were available on this point for three of the subjects. Nine of the subjects reported being able to walk with minimal assistance and did not use a wheelchair, twelve reported some walking but reliance on a wheelchair at least some of the time, and five noted a major dependence upon a wheelchair. Ambulatory information was not available for the remaining five subjects.

**Persons Instructed to Feign Total Anosmia**

Ninety-six women and sixty-two men (mean age=28.30 years, SD=10.44) served as "cheaters" who were instructed to feign total anosmia on the test. One hundred and three of
these persons had at least one year of college, whereas the remainder had a high school education or less. All were in apparent good health and none reported having any problems with smell function. The inclusion of both college-educated and non-college educated individuals was done to ascertain if the strategy adopted to feign total anosmia was related to education level.

RESULTS

On the average, persons with total bilateral anosmia performed as expected on the smell identification test; namely, their total correct responses were distributed around a value close to that expected on the basis of random responding (i.e., 10). Because several stimuli were included which elicit non-olfactory intranasal trigeminal sensations, the average scores of the totally-anosmic group were slightly above the expected number (Mean=12.25, SD=3.04, Median=13.00; Fig. 7). Although the data set is comparatively small, the distribution of responses appears reasonably normal.

The majority of Korsakoff patients evidenced clearly aberrant scores, as was expected from previous studies of such persons. Furthermore, as was also expected from previous studies, a wide range in the degree of deficit was found (Mean=15.95, SD=7.97, Median=14.00, Range=5 to 37; Fig. 7). The recent demonstration of a high correlation between scores on the UPSIT and lumbar CSF levels of 4-methoxy-3-hydroxy-phenyl glycol (a major noradrenergic metabolite) in a subgroup of these patients suggests that the wide range of scores may be a reflection of the degree of damage in CNS noradrenergic pathways [39]. Metabolites of dopamine and serotonin were not similarly related.

In general, persons with multiple sclerosis scored within the normal range, although a disproportionate number fell into the lower section of the normal range, and two fell outside this range (Fig. 7). A close evaluation of the data suggests that a subtle relation may exist between UPSIT scores and the estimated duration of the disease. Thus, for the 25 persons for whom duration data were available, UPSIT scores correlated -.489 (p<0.025) with duration. Since age was related to the estimated duration of the disease (r=-.425, p<0.05), we performed a partial correlation between the UPSIT scores and the estimated duration of the disease after controlling for the effects of age. The correlation (r=-.428, p<0.05) was still present. A partial correlation in which the relation between age and scores on the UPSIT was established after controlling for the effects of the duration of the disease was not statistically significant (r=-.084, p>0.20).

The subjects instructed to feign total anosmia reported fewer correct responses on the UPSIT than expected on the basis of chance, with the modal number correct being zero (Fig. 7). Overlap between the distribution of the "cheaters" with the distribution of the total anosmics occurred in only a minority of cases. No clear differences were present between the responses of the college-educated and non-college educated subjects. (Based upon the cheating strategies of experimental subjects and the combined probabilities of detection by anosmics of specific sets of trigeminal stimulants contained in the UPSIT, we have developed a "malingering scale" for the UPSIT. This scale, which is available to practitioners who clinically evaluate olfactory function, is not presented here.)

EXPERIMENT 4

A major factor which determines the usefulness and validity of a perceptual test is its reliability or stability over time, i.e., its ability to consistently measure what it is intended to measure. The purpose of Experiment 4 was to quantitatively determine the test-retest reliability (after a minimum of 6 months between test administrations) of the UPSIT in a group of subjects composed of persons with various degrees of olfactory function.

Subjects and Procedures

Fifty three persons (23 women, 30 men; mean age=44.13 years, SD=19.98) were selected from our subject population for readministration of the UPSIT at an interval exceeding six months from the time of their initial test. To allow for a valid computation of the test-retest correlation coefficient, we selected persons who represented the entire continuum of UPSIT scores on the initial test. This study group
consisted of five persons with scores on the initial test between 6 and 10, seven with scores between 11 and 15, four with scores between 16 and 20, thirteen with scores between 21 and 25, five with scores between 26 and 30, eight with scores between 31 and 35, and eleven with scores between 36 and 40, inclusive.

RESULTS

The UPSIT scores from the two test administrations are presented in Fig. 8, along with the least squares regression line fitted to these data. Despite the long interval between the two test administrations, the scores were extremely stable (Pearson $r = .918, p < .001$), which suggests that the short-term reliability of this test may be even higher. The value of the intercept (1.409) suggests at least some of the subjects improved their performance slightly on the second administration of the test. Whether this phenomenon reflects a change in the olfactory function of some subjects or is simply due to experience in the situation or to sampling artifacts requires further study.

EXPERIMENT 5

The purpose of Experiment 5 was to determine whether subjects' scores on the UPSIT correlate significantly with measures from a traditional odor detection threshold task. Theoretically, scores on a suprathreshold odor identification task need not correlate with detection threshold values, although some degree of correlation would be expected if they both measure a common underlying dimension of olfactory function. A significant correlation between UPSIT scores and threshold values provides an additional verification of the UPSIT's measuring capacity.

Subjects

Sixty-four men and women (mean age = 42.41; SD = 18.93) were tested. With the exception of six college students, all of these persons were patients of our Center, with a number having at least some degree of olfactory dysfunction. Because of this, they evidenced a comparatively broad range of scores on both the UPSIT and the threshold test, allowing for a valid correlation coefficient to be determined between these two tests.

General Procedures

The subjects were administered the UPSIT and the olfactory threshold task on the same day. The threshold task consisted of a forced-choice single staircase procedure similar to that described by Ghorbanian et al. [26]. In the present context, a trial consisted of the presentation of two 100 ml glass sniff bottles in a rapid succession to the subject. The bottles were opened and held over the subject's nose in a standardized manner pictured elsewhere [16]. One bottle contained a given concentration of perfume-grade phenyl ethyl alcohol (a rose-like odorant with minimal trigeminal stimulative ability relative to other commonly-used compounds) dissolved in 20 ml of propylene glycol, whereas the other contained 20 ml of the propylene glycol alone. The subject's task was to report which of the two randomly-presented bottles evoked the stronger sensation. Even if no sensation was present, the subject was required to choose one or the other bottle. No feedback was provided as to the correctness of the responses.

The staircase was begun around the −6.0 log concentra-

FIG. 8. Test-retest relation between UPSIT scores determined in the same individuals on two administrations separated by a minimum of 6 months (see text for details).

tion step of a half-log step (volume/volume) dilution series extending from −6.50 to −1.00 log concentrations, and was moved upward in 1.00 log steps (two trials per step) until correct detection occurred on both trials. At this point, two additional trials at that concentration level were given to decrease the likelihood of chance detection at that concentration. If a correct response was not made on both of these trials, the staircase was again moved upward in 1.00 log steps until detection was evidenced on four consecutive trials at a given concentration. When correct responses occurred on all four trials, the staircase was reversed and subsequently moved up or down in 0.50 log increments or decrements, depending upon the subject's performance. Thus, the staircase was moved up 0.50 log units if an incorrect response occurred on either of the two trials, and down 0.50 log units if a correct response occurred on both trials. If an incorrect response occurred on the first of the two trials, the second trial was not run and a new pair of trials was begun at the appropriate next higher concentration. A minimum of 20 seconds was interposed between the pairs of trials. The geometric mean of the first four staircase reversal points following the third staircase reversal was used as the threshold estimate. For cases where a subject's threshold was located outside the −6.50 to −1.00 log concentration range, the procedure of assigning the subject either the −6.50 or the −1.00 log step value, as appropriate, was adopted.

RESULTS

The UPSIT and detection threshold values are presented in Fig. 9. Although the correlation coefficient between these two sets of measures was remarkably strong (Pearson $r = −0.89, p < 0.001$), it was likely inflated by the large number of scores of total anosmics which clustered at the lower end of the continua. When these scores (see box in Fig. 9) were omitted from the computation, the correlation
factory function. For example, no statistically significant
considerable controversy as to whether smoking influences ol-
several noteworthy findings have emerged from this work
some equipment or stores of chemicals.
olfactory function without the problems imposed by cumber-
development of a quantitative and reliable means for testing
[14]. The advent of microencapsulation has allowed for the
the first OIuthor in which liquid chemicals were employed
demaker [60]. The technique presented here departs radi-
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possibility that women may be less sensitive than men to
findings that women, relative to men, find such odors less
ment with numerous other olfactory studies, including ones
of breath odor [19] and axillary odor [18]. Our additional
findings that women, relative to men, find such odors less
cool and less irritating have, to our knowledge, no precedent
in previous literature. These unique findings suggest the
possibility that women may be less sensitive than men to
trigeminal stimulation, although more data are needed on
this point. Caution is clearly warranted in assuming, however,
that perceptual sex differences are restricted to intranasal
chemosensory systems. For example, numerous food pref-
erence surveys indicate that women report a larger number of
food aversions than do men, and women excel in sorting low
concentrations of tastants into perceptual categories such as
sweet, sour, bitter and salty [15]. Likewise, superior female
performance has been noted in a number of auditory and
visual tasks [15], and women consistently exhibit shorter
reaction times for auditory and visual tasks [15].

FIG. 9. Relation between detection thresholds for phenyl ethyl alcohol and UPSIT scores (see text for details). Note that y-axis is inversely plotted.

coefficient was -0.794 (p <0.001). The least squares regression line through this latter set of points is presented in Fig. 9.

GENERAL DISCUSSION

In the present series of studies we have described the development of the first easy-to-administer standardized test of human olfactory function. We have shown the test to be reliable, to correlate significantly with traditional odor detection thresholds, and to provide several means for detecting malingering. Furthermore, we have demonstrated that this test clearly differentiates between persons with normal olfactory ability and well-documented groups of persons with olfactory dysfunction. In the largest group of subjects ever tested quantitatively for smell ability, we have demonstrated this test to be sensitive to a number of subject variables, including age, gender, smoking habits, and ethnic background.

Traditionally, olfactory function has been quantified in the clinic or laboratory by using one or a few odorants and determining the lowest concentration level (or some derivative of concentration level) at which detection or recognition occurs. Classic examples of this approach include the “blast-injection” procedure developed by Elsberg [23] (which has been shown to be unreliable and to confound pressure with recognition factors) [58] and the ingenious, but somewhat unquantitative, slide olfactometry procedure of Zwaardemaker [60]. The technique presented here departs radically from these traditional approaches, and represents an extension of an earlier odor identification test developed by the first author in which liquid chemicals were employed [14]. The advent of microencapsulation has allowed for the development of a quantitative and reliable means for testing olfactory function without the problems imposed by cumbersome equipment or stores of chemicals.

Even though the goal of the present paper was to describe the development, rather than the application, of the UPSIT, several noteworthy findings have emerged from this work that bear on controversial issues in the olfactory literature. First, as indicated earlier in this paper, there has been considerable controversy as to whether smoking influences olfactory function. For example, no statistically significant differences in the odor detection performance of smokers and non-smokers have been found by a number of investigators [40,54], whereas others report such differences [30,34]. While some of the earlier negative results may reflect factors such as the specific odorant evaluated or the psychophysical procedure or task employed, the possibility of a type II statistical error due to small sample sizes cannot be ruled out. In any event, the present study clearly demonstrates that current smoking behavior is significantly related to UPSIT scores, although the degree of relationship is not marked. An analysis as to whether this effect is accounted for by only some of the Microfragrance™ samples is currently under way.

A second controversy in olfactory physiology on which the results of this work bear is the relationship of age to olfactory function. As with smoking, some investigators report no influence of aging on human olfactory function [48,51], whereas others note such influences [6,36,52,54]. Since different odorants and psychophysical paradigms have been employed, the basis for these discrepancies is difficult to establish. Unpublished suprathreshold scaling data from our laboratory are in accord with the suprathreshold scaling data of Rovee et al. [48] in nur demonstrating an age effect. However, we found detection thresholds in these same persons to significantly decrease as a function of age, suggesting that some of the discrepancies in the literature are likely due to the psychophysical measures employed. The present results clearly demonstrate that UPSIT scores systematically decline with age (Fig. 6). In addition, we demonstrate that this decline is not likely due to central memory factors, per se, which also are known to decline with age. Given the close relation between UPSIT scores and CSF levels of the noradrenergic neurometabolite 3-methoxy-4-hydroxy-phenylglycol in Korsakoff’s psychosis [39], and reports suggesting a decrease in noradrenergic activity in the aged, it is conceivable that the age-related decrease in UPSIT scores reflects decreased noradrenergic activity. At the present time, however, evidence to substantiate or refute this hypothesis is not available. Furthermore, it must be kept in mind that the changes noted in the elderly may reflect factors correlated with aging (e.g., more extensive damage to the olfactory epithelium as a result of increased numbers of viral insults or less resistance to such insults) rather than the effects of aging, per se.

Our finding that women consistently rated the Microfragrance™ samples as more intense than did men is in agreement with numerous other olfactory studies, including ones of breath odor [19] and axillary odor [18]. Our additional findings that women, relative to men, find such odors less cool and less irritating have, to our knowledge, no precedent in previous literature. These unique findings suggest the possibility that women may be less sensitive than men to trigeminal stimulation, although more data are needed on this point. Caution is clearly warranted in assuming, however, that perceptual sex differences are restricted to intranasal chemosensory systems. For example, numerous food preference surveys indicate that women report a larger number of food aversions than do men, and women excel in sorting low concentrations of tastants into perceptual categories such as sweet, sour, bitter and salty [15]. Likewise, superior female performance has been noted in a number of auditory and visual tasks [15], and women consistently exhibit shorter latency and larger amplitude responses than men to the auditory evoked potential brainstem response [31]. An analysis of our data suggests that the sex differences in UPSIT scores
appear before the time of puberty, indicating they are unlikely a reflection of the increased levels of gonadal hormones occurring at that time.

In the present work we chose to use the UPSIT to quantify overall bilateral olfactory function. We did this because (a) most cases of significant olfactory dysfunction involve both nostrils, (b) many patients do not notice subtle unilateral problems of olfactory function, and (c) the periodic changes in nasal airflow from one nostril to the other (the "nasal rhythm") [44] make such determinations problematic in some individuals. However, the UPSIT can be administered unilaterally as well as bilaterally, and we are now engaged in studies (in which nasal airflow parameters are taken into account) to determine if unilateral testing significantly characterizes olfactory dysfunctions of patients encountered in our clinic.

A useful feature of the UPSIT is its ability to detect olfactory malingering. By using a forced-choice response format, we have shown that the majority of individuals instructed to feign total anosmia provide fewer correct responses than do general anosmics. By examining the probabilities of the detection of certain sets of subtle trigeminal stimuli in totally anosmic subjects, we have also developed an additional means of detecting malingering behavior. Traditionally, olfactory malingering has been inferred by physicians primarily from denials of intranasal sensations produced by strong irritants, such as ammonia. While, on the surface, the use of such stimulants seems logical, we have yet to find anyone instructed to malinger, to deny. With the exception of the rare patient who lacks CN I, CN V, CN IX, and CN X function, the approach adopted by our test—namely, the use of response strategy analysis and subtle trigeminal stimulants in a forced-choice format—probably increases the detection of true olfactory malingering.

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