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Odor identification testing in children and young adults using the smell wheel

E. Leslie Cameron [a,*], Richard L. Doty [b]

[a] Department of Psychological Science, Carthage College, USA
[b] Smell & Taste Center, Department of Otorhinolaryngology, Perelman School of Medicine, University of Pennsylvania, USA

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ABSTRACT

Objective: Olfaction is important for nutrition, safety, and quality of life. Detecting smell loss in young children can be difficult, since many children with olfactory deficits do not recognize their problem and may even pretend to smell. The short attention span of some young children precludes testing with longer standardized olfactory tests. Currently there is a dearth of pediatric smell tests. In this study we evaluated the performance of 152 children and young adults on a game-like rotating "Smell Wheel" odor identification test. This forced-choice test, which can be self-administered, was designed to capture the child's imagination and to provide a standardized test measure with odors known to young children using a minimum number of trials.

Method: Thirty 4-5-year olds (10 female), 62 6-7-year olds (17 female), 30 10-11-year olds (18 female) and 30 18-19-year olds (15 female) were tested. Analysis of variance was used to assess the influences of sex and age on the test scores.

Results: All participants completed the simple and rapid test protocol. Test performance and age-related changes analogous to those obtained using longer tests were observed. Test scores of participants who self-administered the test were equivalent to those for whom the test was administered by the experimenter.

Conclusion: Good compliance and olfactory test findings congruent with literature results were obtained using the Smell Wheel, suggesting that this test may be useful in assessing olfactory function in pediatric settings where attentional demands are compromised and test time is limited.

It is well established that the sense of smell is important for nutrition, safety, and quality of life. In one study of 445 persons presenting to a chemosensory disorders clinic, at least one hazardous event, such as food poisoning or failure to detect fire or leaking natural gas, was reported by 45.2% of those with anosmia, 34.1% of those with severe hyposmia, 32.8% of those with moderate hyposmia, and 24.2% of those with mild hyposmia, as compared to 19.0% of those with normal olfactory function [1]. In a longitudinal study of over a thousand non-demented older persons, mortality risk was 36% higher in those with low than with high scores on an odor identification test after adjusting for such variables as sex, age, and education [2].

Although estimates of the prevalence of smell loss in the general population vary considerably [3], there is consensus that smell loss is relatively uncommon in children [4]. A recent analysis of over 1200 consecutive patients presenting to the Smell & Taste Center at the University of Pennsylvania with chemosensory complaints revealed that children 16 and under represented less than 2% of the patients. An earlier study of 750 patients [5] reported that 4% of that patient population had smell loss deriving from childhood. That being said, children who are unable to smell are susceptible to the same hazards as adults. Moreover, olfactory testing can be useful in the early detection of such disorders as Kallmann's syndrome [6], which, although quite rare (affecting 1/8000 males and 1/40,000 females [7]), can be treated if detected early. Furthermore, olfactory testing may prove useful in understanding aspects of some other neurodevelopmental disorders, including autism [8] and attention-deficit/hyperactivity disorder [9]. Given these potential clinical applications, there is clearly a need for a standardized, reliable, and child-friendly test of olfactory function.

While odor identification tests have proven to be the most reliable and practical means of assessing adult olfactory function [10], the use of such tests in evaluating olfactory function in young children has proved challenging, in part because of their limited attention span and the fact that odor concepts require experience with odors [11].

In light of these issues, we evaluated the efficacy of a novel 11-odor scratch and sniff game-like test (the "Smell Wheel", see Fig. 1) in assessing olfactory function in children and young adults. Specifically, we were interested in the speed of testing as well as

* Corresponding author at: Department of Psychological Science, 2001 Alford Park Drive, Kenosha, WI 53140, USA. Tel.: +1 262 551 5843; fax: +1 262 551 6208.
E-mail address: lcameron@carthage.edu (E.L. Cameron).

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Fig. 1. Photograph of the Smell Wheel, a game-like rotating odor identification test. This forced-choice test was designed to capture the child's imagination and to provide a standardized test measure with a minimum number of trials and odors known to young children. Copyright @ 2012, Sensonics Incorporated.

the sensitivity of the test to the effects of age and sex. The Smell Wheel employs odors that are familiar to young children, and the choices are provided as both pictures and words to decrease cognitive load and potentially optimize identification of odors by participants with limited abilities to read [12,13]. This method has been reported to be particularly important in testing children with autism [8].

1. Method

1.1. Participants

One hundred and fifty two children and young adults participated: thirty 4-5-year olds (10 female), 62 6-7-year olds (32 female), 30 10-11-year olds (18 female) and 30 18-19-year olds (15 female). The children were recruited from public elementary schools and a daycare center in Kenosha and Racine, WI and the young adults were recruited from Carthage College in Kenosha, WI. Approximately half of the 6-7-year olds self-administered the test. They were children from a different classroom in the same school where the experimenter-administered testing occurred. An additional 16 children (8 females) between the ages of 4 and 13 years self-administered[1] the test twice with an interval of 7-8 days between testing to assess the reliability of the Smell Wheel. Data from five participants were excluded because they exhibited signs of nasal stuffiness or their parents indicated that they had the symptoms of a cold.

1.2. Materials

The newly developed Smell Wheel (Sensonics, Inc., Haddon Heights, NJ) was employed (Fig. 1). This test consists of a cardboard wheel or disk that rotates within an outer jacket, such that only one microencapsulated "scratch and sniff" odorant at a time is exposed for sampling. Positioned along the circumference of the wheel are scratch and sniff labels containing the following odorants – onion, soap, popcorn, bubblegum, banana, cherry, rose, chocolate, smoke, peppermint and cinnamon. Four multiple-choice alternatives (see Table 1) – consisting of both words and pictures – are positioned under each odorant and the participant is required to provide an answer even if no smell is perceived or the answer is unknown (forced-choice testing). Each answer is signified by filling in a small circle next to the intended response alternative. When the test is completed and the disk completely rotated, the correct answers appear as dark dots in a series of holes in the jacket. The number of holes that have marks signify the total test score, i.e., the number of items that were correctly identified.

1.3. Procedure

This study was approved by the Carthage College Institutional Review Board and the Kenosha Unified School District Leadership Council. Prior to data collection, consent forms were completed by the parents of all minors and by the adult participants themselves. The elementary school children were tested in a partitioned corner of their regular classroom. College students were tested in the Cognition & Perception Laboratory at Carthage College. A standardized set of instructions was provided and, in the case where the test was administered by an examiner, the response alternatives were read aloud after the participant had sniffed the odor. To ensure consistent exposure to stimuli when the test was administered by an examiner, the examiner scratched a "Z" pattern on each odor strip to release the odor and placed the stimulus under the participant's nose. The participant was allowed to sniff as many times as desired and to request additional scratches.

The 29 6-7-year olds (15 females) who self-administered the test were instructed to scratch the test in the same manner as noted above. Although the children scratched each odor patch independently, rotated the wheel, and read the choices to themselves, an examiner was always present to be certain that they were following the instructions. Sixteen additional children self-administered the test twice, about a week apart.

2. Results

All participants successfully completed the 11-item test in approximately four minutes. The average test scores for the five groups are presented in Fig. 2. A two-way ANOVA indicated a main effect of age ($F(3, 110) = 29.28$, $p < 0.001$), but not of sex ($F(1, 110) = 2.57$, $p = 0.112$) and no interaction between age and sex ($F(3, 110) = 1.683$, $p = 0.175$). As expected, college-aged participants performed significantly better than 4-5-year olds ($p < 0.001$), 6-7-year olds ($p < 0.001$) and 10-11-year olds ($p = 0.027$), as indicated by Tukey post-hoc comparisons. Both 6-7-year olds and 10-11-year olds performed significantly better than 4-5-year olds ($ps = 0.001$), and 10-11-year olds scored higher than 6-7-year olds ($p = 0.011$). The test scores of the 6-7 year-old group who self-administered the test did not differ from the test scores of the equivalent age group who were administered the test by an examiner ($t = 1.35$, $df = 60$, $p = 0.179$).

Some odorants were more easily identified than others, as indicated by a significant main effect of odorant in an age by odorant two-way ANOVA [($F(8, 114) = 11.63$, $p < 0.0001$)]. Of the 11 odorants, only popcorn and rose were poorly identified[2]. A significant interaction between age and odorant ($F(24,115) = 1.92$, $p = 0.005$) indicated that performance across age groups depended on the odor. A Chi-Square analysis revealed that performance significantly improved with age for all odors (Chi-Square p values ranged between 0.05 and 0.001; see Fig. 3) with the exception of

[1] Three of the children were assisted in this process.

[2] Although it did not impact the conclusions, these odors were excluded from the analyses since their formulations appeared weak.

Table 1
Target odors and options in the Smell Wheel.

	Option 1	Option 2	Option 3	Option 4
Odor 1	onion	banana	chocolate	watermelon
Odor 2	soap	fish	chocolate	peanut
Odor 3	rose	lemon	apple	popcorn
Odor 4	smoke	skunk	bubblegum	onion
Odor 5	banana	fish	cherry	soap
Odor 6	cherry	honey	lime	skunk
Odor 7	peppermint	rose	lime	apple
Odor 8	lemon	chocolate	strawberry	fish
Odor 9	apple	grass	smoke	grape
Odor 10	tomato	peppermint	strawberry	honey
Odor 11	watermelon	cinnamon	smoke	coconut

Note. The 11 target odors (in **bold**) and three other alternative (incorrect) choices provided for each.

bubblegum, which was well identified by participants of all ages. The test-retest reliability of the Smell Wheel, as measured by Spearman's r, was 0.70 and was significant at the $p = 0.01$ level. A t-test revealed no significant difference between the scores on the two test sessions ($t = 0.35$, $df = 28$, $p = 0.73$).

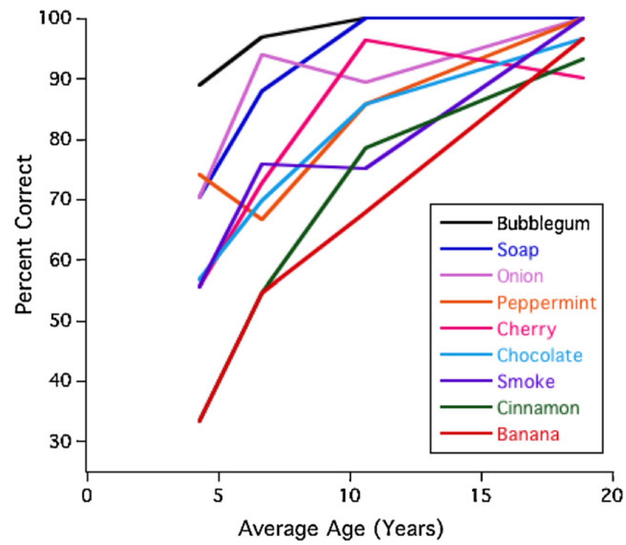

Fig. 3. Mean percent correct as a function of average age of each of four groups. For comparative purposes, the data are from groups in which the experimenter administered the test.

3. Discussion

The present study found that the Smell Wheel worked well as a simple and rapid test of olfactory function in children and young adults. The game-like format facilitated testing and provided an attractive alternative to the booklet-style scratch and sniff tests that are currently available. Performance on the Smell Wheel was influenced by age in a manner seen using much longer tests [11,14–19]. The findings are in accord with prior studies that have shown that by the age of 6 years American girls can correctly identify three–quarters of 40 University of Pennsylvania Smell Identification Test (UPSIT) odors, and American boys can correct identify about two-thirds of such odors. By the age of 10, the performance of children approaches that of adults [20].

Although the early age-related effects observed in this and other odor identification studies likely reflect, to a large degree, knowledge of common odors, one cannot rule out the possibility that post-natal development of the olfactory system, including the olfactory bulbs [21] and such central elements as the orbitofrontal cortex [22], is occurring at this time. Thus, early age-related effects similar to those observed for tests of odor identification have been observed for tests of odor discrimination – tests which do not require knowledge of an odor or its source [23,24]. While odor threshold measures similarly do not require knowledge of the identity of odors, results from such tests have been variable, reflecting, in part, reliability issues and the influences of repeated testing. For example, Dorries et al. [25] found no consistent age-related pattern in odor thresholds for the unpleasant-smelling odorant pyridine for either boys or girls, although thresholds for the sweat-like odorant androstenone appeared to increase with age in males and decrease in females. While Koelega and Köster [26] found prepubescent children unable to detect two musk-like odorants (e.g., pentadecanolide or oxahexadecanolide) – odorants detectable by most adults – adult-like thresholds to the banana-like smelling amyl acetate were present. More recently, Monnery-Patris et al. [18] found no decrease in thresholds with age for the odor of R-(+)-Carvone (chewing gum), but did observe an age-related decrease in threshold for the odor of tetrahydrothiophene (a gasoline additive used in France). Some investigators have reported no differences in thresholds between children and young adults [14,17].

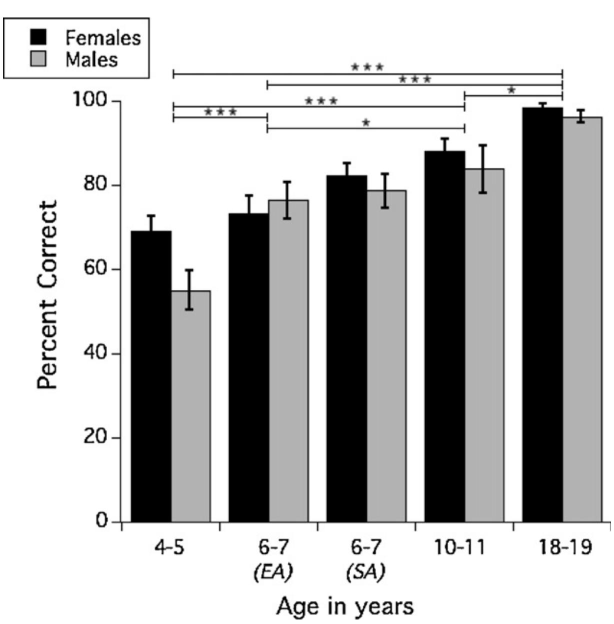

Fig. 2. Mean percent correct ± standard error of the mean as a function of age and gender. For comparative purposes, the ANOVA was calculated for groups in which the experimenter administered the test. Statistically significant comparisons (*$p < .05$; **$p < .01$; ***$p < 0.001$). *EA = Experimenter Administered; SA = Self Administered.*

It is noteworthy that the two odors that were least well identified by children (cinnamon and banana, see Fig. 3) were the same two odors of this target odor set that were least well identified in a study of nearly 2000 adults [27]. In addition, the familiarity ranking of the adults in that study correlated with the percent correct values of the youngest children tested in the current study (Spearman $r = .41$), although individual data were not available to allow for establishing a p-value. This suggests that the relatively poor performance on cinnamon and banana reflects less familiarity with these odors.

There was no significant effect of gender on the test scores of the current study, although it is apparent from Fig. 2 that in four of the five age groups there was a tendency ($p = 0.11$) for the females to outperform the males. The relatively small sample size may account for the lack of a significant sex difference – a difference that may appear when more statistical power is present. On the other hand, several other factors should be considered in this regards. First, most of the odorants items used in this study have been shown in other studies not to exhibit sex differences which, when present for other odorants, are usually small [28]. For example, no sex differences were present in a study of 1198 persons for the odors of soap, smoke, onion, chocolate, peppermint and banana – odors which comprised over half of the those of the Smell Wheel [see Fig. 5 in 27]. Second, in some studies sex differences in odor identification have been associated with verbal fluency [18]. It may be that the addition of pictures in the current test reduced reliance on semantics, thereby mitigating any potential sex difference. Third, many of the sex differences that have been reported in the olfactory literature have been confined to the perception of specific single-chemical odorants [25]. In this study, the odorants were all made up of multiple chemicals known to better mimic true odorants of the environment. Finally, the largest sex differences are typically found after the age of 65 [15].

The test-retest reliability observed in this study is analogous to that observed for tests of similar length that have been administered to adults. For example, the test-retest reliability of the 12-item Brief Smell Identification Test, a microencapsulated odorant test that presents odors in booklet form, has been reported to be 0.73 in adults [29]. The test-retest reliability of the identification component of the ‘‘Sniffin’ Sticks Test’’, a 16-item test that uses pen-like devices, was reported to be 0.73 in adults [30]. Similar levels of reliability have been noted for the 13-item Japanese ‘‘Odor Stick ID Test’’ ($r = 0.77$) [31] and the 16-item ‘‘Scandinavian Odor ID Test’’ ($r = 0.79$) [32]. In general, reliability is related to test length by the Spearman-Brown prophecy formula [33,34].

It should be noted that while we did not specifically test anosmic children, it is apparent that the Smell Wheel would detect children with no sense of smell in the same manner as observed for olfactory tests of similar length [29]. The fact that the test was sensitive to age accords with the concept of construct validity as the same general age-related pattern has been seen in other tests of odor identification [27]. Interestingly, the five children whose data were omitted because they exhibited nasal stuffiness or their parents indicated that they had symptoms of a cold also had very low Smell Wheel test scores (1, 2 and 3 in the three affected 4-5-year olds and 4 and 4 in the two affected 10-11-year olds), demonstrating that the test is sensitive to smell loss.

The Smell Wheel could profitably be used in clinical populations in which differences in sensory processing are thought to exist. For example, the Smell Wheel may prove effective at evaluating smell function in children with autism. Although questionnaire studies indicate that children with autism exhibit more ‘‘sensory symptoms’’, which may reflect either hypo- or hyper-sensitivity [35,36], studies actually measuring smell function are inconclusive as to whether autism is associated with altered smell function. Whereas one study reported reduced odor identification ability among children with autism [8], others have reported no effect of autism on the ability to identify odors [37,38]. Future studies using the Smell Wheel may clarify these discrepancies.

As pointed out by Laing et al. [13], there is currently ‘‘no suitable clinical test’’ (p. 74) to measure olfactory function in children. Nonetheless, there are olfactory tests that have been administered to children [11–13,23,39], and, as pointed out by Oozeer et al. [4], loss of smell function in children has ‘‘generated a large amount of scientific interest and research in the development of child-friendly screening olfactory tests’’ p. 499). The Smell Wheel enjoys three advantages over most other published methods of testing children: (1) the odors were selected to be ones with which children are familiar; (2) both pictures and words are provided in the four-alternative forced choice task to reduce cognitive/linguistic load and potentially to improve performance; and (3) the test has a game-like quality that engages children. These qualities make the Smell Wheel a particularly attractive method of testing children’s olfactory function and provide a testing format that appears to overcome attentional and other problems often associated with such testing.

Disclosure

RLD is president and major shareholder in Sensonics, Inc., the manufacturer of the Smell Wheel and other taste and smell products.

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