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Development of a Test to Evaluate Olfactory Function in a Pediatric Population

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Abstract

Objectives/Hypothesis—This study evaluated two versions of a test for olfactory function to determine suitability for use in a pediatric population.

Study Design—Cross-sectional cohort study.

Method—In phase 1, 369 children (ages 3–17 years) and 277 adults (parents) were tested. Children began with identification and familiarity judgments to pictures representing target odors and distractors. Odors were administered via a six-item scratch and sniff test. Each answer sheet contained the correct odor source and three distractors. In phase 2, 50 children (ages 3–4 years) and 43 adults were given a revised version with eight odors judged more representative of the source and familiar to children.

Results—Both completion time and identification accuracy in phase 1 improved with age. Accuracy of children 5 years old and above equaled adults for two of the three best odors. In phase 2, adults' accuracy significantly improved relative to phase 1 (92% vs. 68%), and exceeded that of 4 year olds for four of eight odors and 3 year olds for seven of eight odors.

Conclusions—Children as young as 3 years of age can perform olfactory testing, but take longer than do older children and adults (7.44 vs. 5.66 vs. 3.71 minutes). Identification accuracy also increases as a function of age. The current six-item National Institutes of Health Toolbox Odor Identification Test is a brief, easily conducted test for evaluating olfactory ability. Collection of normative data for children of all ages and adults is needed to determine the clinical utility of the test and its interpretations for pathological conditions.

Keywords

Smell; olfaction testing; pediatrics

Introduction

Loss of olfactory function may occur from a variety of conditions that are common in a pediatric population, including allergies, upper respiratory infection, nasal and sinus

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disease,[1] head injury,[2] and endocrine disorders.[3] Despite this, studies of the prevalence of olfactory dysfunction in the pediatric population are rare. This stands in stark contrast to the routine testing of vision and hearing that is performed for children.[4–6] The sense of smell provides substantial information about the environment for all children. There is evidence that olfactory function and discrimination are linked to learning,[7] and identifying deficits in this age group could be an important marker for developmental issues. Olfaction plays a critical role in safety and prevention of injuries[8].

Tests available for evaluating olfactory function are scarce and may not be suitable for very young children. The Brief Smell Identification Test (B-SIT)[9] is a 12-item scratch and sniff test representing a subset of the items from the 40-item Smell Identification Test (SIT). Items in the B-SIT have been selected to have broad cross-cultural familiarity. The microencapsulated stickers provide an efficient and easy way to administer standardized odor stimuli, and individuals are asked to select from four possible word labels the one that best corresponds to the source of what they smell. The test has excellent reliability (>0.80), and although it has less specificity than its parent (the 40-item SIT), B-SIT can be administered to adults and older children (5–17 years) in under 5 minutes. However, young children are less likely to be familiar with several of the odor stimuli used (e.g., gasoline, smoke, pineapple). Young children also have limited ability to read labels, from which they must select the option that best represents the odor. Moreover, normative data on this test exist only for children ages 5 and older, and performance for children who were between the ages of 5 and 9 years was similar to adults in their 8th decade when true deficits in olfaction are known to exist.[10] This raises the question of whether the test is actually measuring olfactory ability in young children or whether cognitive or language confounds are responsible for their relatively poor performance.

Test reliability for young children requires both measuring olfactory ability and determining whether cognitive or language development are responsible for their poorer performance. Murphy and colleagues[11] developed a version of an odor identification test using grocery store items placed in opaque plastic bottles. In this test, the San Diego Odor Identification Test (SDOIT), eight items familiar to most children are sniffed and matched to the appropriate line drawing (out of 20 pictures). Performance on this test is quite good and reliability is high (>0.80). However, the test uses actual food items, and standardization of stimuli and the need for investigators to prepare the odors themselves proved to be barriers to the use of this test in clinical settings.

The goal of the National Institutes of Health (NIH) Toolbox for assessment of Neurological and Behavioral Function[12] is the development of brief but comprehensive measurement tools for assessing the range of normal cognitive function, emotional health, and sensory and motor function across the entire lifespan, placing special emphasis on developing or modifying tests for use in pediatric populations. Additionally, clinicians have noted the lack of a standardized test for assessing olfactory dysfunction in children that could be administered in a clinical setting with limited facilities for stimulus preparation and significant time constraints. The purpose of this study was to evaluate a test of olfactory function that was sensitive to the attention capacity and the cognitive and language development of children. Such a test would comprise standardized, commonly encountered odor stimuli, use both appropriate picture and word responses, and be able to be administered in a brief period of time in a variety of settings. We report the development of an olfactory identification test intended to meet these goals.

Materials and Methods

The study was conducted from 2008 to 2009. Participants tested at the Monell Chemical Senses Center were recruited from local newspapers and websites. For the Nemours participants, parents and their children were recruited from the general waiting room of the preoperative outpatient facility while they were waiting for the children's preoperative intake appointment. Parents who reported that they or their child(ren) were asthmatic or mothers who reported they were pregnant were excluded from participation at both centers. No additional clinical data were collected. All procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania and the Nemours Delaware Institutional Review Board. Informed consent was obtained from each parent or guardian of the child, and assent was obtained from each child 7 or more years old.

In phase 1, we evaluated odor identification accuracy for two versions (six odors each) of a test with a picture response format in children (ages 3–17 years) and a parent in both a research setting and a clinical practice. In phase 2, we modified the test odors by removing poorly recognized odors and adding odors more appropriate for a younger population. This modified test evaluated identification accuracy for eight odors in a group of 3- and 4-year-old children and their parents.

Phase 1

Participants—The study population consisted of 369 children between the ages of 3 and 17 years and 277 adults, all of whom were parents of the children tested. At the Monell Chemical Senses Center (Philadelphia, PA), 187 children (99 girls, 88 boys; mean age, 10.0 years; standard deviation [SD], 3.6 years) and 95 adults (91 mothers, 4 fathers; mean age, 37.3 years; SD, 7.7 years) were tested, and at the Nemours/Alfred I. duPont Hospital for Children (Wilmington, DE), 182 children (105 girls, 77 boys; mean age, 8.6; SD, 3.6 years) and 182 adults (138 mothers, 44 fathers) were tested. Parents at the Nemours site were not asked to provide their age.

Materials—The test was based on the pictorial response format of the San Diego Odor Identification Test (SDOIT)[11] and the scratch and sniff delivery system of the Brief Smell Identification Test (B-SIT).[9] We selected odor stimuli that in prior studies had shown good identification by children of all ages.[11,13] The scratch and sniff test used fragrances that were microencapsulated onto stickers that were then placed onto cards (Print-A-Scent, Chattanooga, TN). There were two versions of the test used: Set 1 used odors representing flower, lemon, Play-Doh, coffee, bubble gum, and peanut butter (362 adults/children). Set 2 included the first five odors in Set 1, but replaced peanut butter with cinnamon (284 adults/children.) The two versions presented odors in different orders. Initially, Set 1 was given to all participants unless the parent indicated a report of peanut allergy, which necessitated using Set 2. Later, the Sets were given in alternating order except as noted above. The list of target odors and distractors are provided in Table I, and the training poster and a sample response sheet are depicted in Figures 1 and 2, respectively.

Procedure—After informed consent and assent (if the child was over 7 years of age) was obtained, each child and adult participant was tested individually in rooms specifically designed for sensory testing by a study administrator at the Monell site. At the Nemours site, all children and parents were tested by a study administrator in an exam room or the waiting room.

Picture identification and familiarity assessment: Prior to the odor identification test, children were assessed for familiarity with the odors and their picture representations (Fig.

1). They were shown a poster containing pictures of the sources of all target odors used in the study plus pictures representing other odor sources not used in the test (the distractor images). Children were asked individually if they knew what the particular item in question was, to point to the image of the item on the picture board, and if they knew what said item smelled or tasted like. For example: “Do you know what a banana is? Could you point to a banana? Have you ever smelled/tasted a banana? Do you know what a banana smells/tastes like?” This was done for all target items and distractors used and was scored as a yes/no response. If a child failed to correctly identify the item from the picture, they were told what that item was, and then retested on that item. The start and finish times for the picture identification and familiarity assessment were recorded.

Odor identification test: For each target odor, there were four picture response options shown, one of which was the correct response (Fig. 2). Each picture was also labeled with the name of the odor source, and the names were read to the children at the start of the trial. For the children, the odor cards were scratched and presented to the child by the study administrator. The child was then asked to identify the smell by pointing to a picture of the item from four possible choices. The protocol was identical for the adults tested at Monell, but the adults tested at Nemours were allowed to scratch and sniff the odor cards themselves, and after looking at the labeled pictures on the response card, circled the correct response on an answer sheet. The start and finish times for the odor identification test were recorded.

Phase 2

Participants—The population for phase 2 consisted of 50 children (24 girls, 26 boys) between the ages of 3 (n = 28) and 4 (n = 22) years and 43 adults (41 mothers, 2 fathers), all of whom were tested at the Monell Center. None had participated in phase 1.

Materials—To incorporate the new odor items as distractors as well as targets, a different set of distractors was developed. The targets and distractors formed a closed set (all targets also appeared as distractors and vice versa) so as to minimize the number of pictures and items to be assessed for familiarity. The list of target odors along with their respective distractors is shown in Table II. We eliminated odors that were not well identified by either the adults or older children (peanut butter, coffee), added new odors (banana, popcorn, chocolate), and used different fragrances to represent some of the test items that were not judged to be representative (flower, bubble gum). The new odors were selected from among the distractor odor sources from phase 1, and chosen based on high levels of picture identification accuracy and reported odor familiarity, even among 3- and 4-year-old children (Table IV). The modified version of the odor identification test used in phase 2 consisted of eight stimuli: lemon, flower, bubble gum, Play-Doh, cinnamon, popcorn, chocolate, and banana. Additionally, to ensure the consistency of the odor stimuli, we obtained all new fragrances from a single source (Firmenich, Princeton, NJ), which required replacing the fragrances representing lemon and cinnamon. The odor of Play-Doh remained the same as in phase 1. All of these new fragrance stimuli were microencapsulated (Print-A-Scent, Chattanooga, TN).

Although our goal was to develop a six-item test, two additional items were included to allow us to determine the most appropriate six odors for the youngest children. Because identification accuracy of children age 5 and older did not significantly differ from adult accuracy on two of the three best identified odors from phase 1 (lemon and cinnamon), and because little data on odor identification accuracy exists for very young children, we evaluated the utility of this revised test among 3- and 4-year-old children and their parents only. Given concerns about attention capacity and cognitive loads in this cohort,[14] we also evaluated whether identification accuracy would improve with fewer response options; thus, we developed three versions of the identification task, with two-, three-, and four-response alternatives. Participants took each of the three versions of the test, which were administered in counterbalanced order to control for practice effects. To evaluate the role of early educational experiences on odor identification test performance, parents were also queried about whether their child had attended daycare or any other preschool program.

Procedure—All instructions and procedures within a test were identical to those used in phase 1 at the Monell Center.

Data Analyses

In both phase 1 and 2, the primary data consisted of the length of time it took participants to complete the familiarity and odor identification sections of the tasks as well as whether the odor was correctly identified. From the latter data, we calculated correct odor identification percentages for individuals in each age group. In phase 2, we also evaluated whether the number of distractors and educational experience affected identification accuracy. Data were analyzed using Statistica 9.0 (StatSoft, Tulsa, OK). Repeated measures analysis of variance (ANOVA) was used to analyze identification accuracy as a function of age group and odor item and significant differences were evaluated with post hoc tests (uneven N honestly significant difference (HSD)) at $\alpha = .05$.

In phase 1, subjects were grouped by age into epidemiological subsets as follows: 3 to 4 years (n = 37), 5 to 8 years (n = 132), 9 to 11 years (n = 93), 12 to 14 years (n = 70), 15 to 17 years (n = 35), and 18 to 59 years (n = 277), comprising the adult group. Two of the children from the Nemours site were excluded from analyses because no information on the children's age was obtained, whereas one child from Monell was excluded due to failure to complete the test. Two parents tested at Nemours were excluded due to missing data.

Logistic regression analysis was used to determine if there were differences in identification accuracy between the sets and sites. Responses to each odor were scored as a 1 if correctly identified and 0 if incorrectly identified. Correct identification performance differed on the common items between sets 1 and 2, χ^2 (1) = 31.9, $P < .001$. Additionally, there were significant overall differences in performance on the test across the two sites, χ^2 (1) = 7.24, $P = .007$ (66% vs. 71% at Nemours and Monell, respectively). Due to the nature of the recruitment process, especially at the clinical site where every eligible child was approached for testing, the distribution within the age groups at each site varied significantly (Kolmogorov-Smirnov Test, $P < .001$). Thus, to evaluate the effect of age group on identification performance, the data were pooled across the common items from each set and across the two sites.

Results

Phase 1

The time to complete the familiarity assessment and the odor identification test as a function of age group is shown in Table III. There was a significant effect of age group on the time to complete the odor identification task ($P < .001$). As expected, identification of the pictures took longer (on average) for 3- to 4-year-old children than for older children ($P < .006$). As well, 5- to 8-year-old children also took longer to complete the task when compared to older children ($P < .005$). Except for two pictures (bread and cinnamon), more than 90% of the children age 5 and older correctly identified the pictures on the first trial (Table IV). Picture identification accuracy of children age 3 and 4 was lower than that of older children for some odor sources (e.g., lemon, peanut butter, cinnamon) but equally accurate for others (flowers, bananas and grapes). Thirteen children out of 366 (all 3–6 years old) were unable to identify one or more items when retested after failing to identify the picture on the first trial.

Odor identification accuracy is shown in Table V stratified by odor and age groups. We first looked to see which odors were correctly identified by the majority of adults, on the assumption that these stimuli were good representations of the odor sources. From this evaluation, we observed significant disparity among the levels of identification accuracy for the odors. Among adults, the odors representing lemon and Play-Doh had the highest levels of identification (95% and 88%, respectively), followed by cinnamon (77%), coffee (64%), bubble gum (60%), flower (57%), and peanut butter (20%). Because it was evident from the adult data that the odors varied in how representative they were of the odor source, we chose to analyze identification accuracy for only the three odors (lemon, Play-Doh, and cinnamon) that were each correctly identified by more than 70% of the adults tested.

A repeated measures ANOVA restricted to the identification scores for lemon and Play-Doh as a function of age group showed a main effect of age group ($F_{(5,635)} = 17.05$, $P < .001$), a main effect of odor ($F_{(1, 635)} = 41.30$, $P < .001$), and an age by odor interaction ($F_{(5, 635)} = 4.90$, $P < .001$). Post hoc tests on the main effect of odor revealed that identification accuracy among 3- to 4-year-old and 5- to 8-year-old children was significantly lower than accuracy for children 9 years and above and adults. However, in a post hoc analysis of the interaction effect, it was found that all of the children performed equally well with the lemon odor ($P > .10$), whereas the 3 to 4 year olds and 5 to 8 year olds performed significantly worse on the Play-Doh odor ($P < .05$).

A one-way ANOVA performed on the identification scores for cinnamon, which was only tested in version 2 of the test, also showed a main effect of age group ($F_{(5, 275)} = 6.51$, $P < 0.0001$). Post hoc tests revealed that identification accuracy for cinnamon among 3- to 4-year-old children was lower than accuracy for adults and children 9 years and older. Accuracy for children ages 5 to 8 years did not, however, differ from any other age groups.

Phase 2

A repeated-measures ANOVA on scores adjusted for chance showed that among the children, performance on the two-choice version differed significantly from the three- and four-choice versions (HSD, P < .001). However, odor identification accuracy on the four-alternative choice test did not significantly differ from the three-alternative choice version when adjusted for chance (HSD; P > 0.10), and the use of a four-choice version not only lowered the probability that correct identification would occur by chance but was also consistent with the planned adult format of the test. For these reasons, we report here only the data for the four-alternative choice test.

All but three children (two 3 year olds and one 4 year old) and all adults completed the test, so data are presented for 47 children and 43 parents (unless otherwise noted). The 3-year-old children were slower to complete the familiarity assessment ($F_{(1,45)} = 4.74$, $P = .03$) than the 4-year-old children, but did not differ on the time to complete the odor identification task ($P = .77$). The 3-year-old children completed the familiarity assessment in an average of 3.2 (standard error [SE], 0.24) minutes (maximum, 7 minutes), and the odor identification task in an average of 4.5 (SE, 0.24) minutes (maximum, 7 minutes). Data for start and end times for familiarity task was missing for one 3 year old, therefore this analysis was based on N = 25. Four-year-old children completed the familiarity assessment in an average of 2.5 (SE, 0.16) minutes (maximum, 4 minutes) and the odor identification in an average of 4.3 (SE, 0.21) minutes (maximum, 6 minutes). Adults did not participate in the familiarity assessment, but as expected, were faster on odor identification than either 3 or 4 year olds, completing the test in an average of 2.9 (SE, 0.12) minutes (maximum, 5 minutes) ($F_{(2,86)}$ = 26.0, $P < .001$). Data for start and end times for odor identification task was missing for one adult, therefore this analysis was based on N = 42.Overall accuracy of picture identification for the common items was 76% versus 91% for phase 1 and 2, respectively. Consistent with the earlier results, except for cinnamon (81%) and Play-Doh (89%), the pictures of all items were correctly recognized by more than 90% of the children (Table VI). However, familiarity with the odor of these items was reported at a significantly lower rate ($F_{(1,81)}$ = 3.79, $P = .003$). Compared with phase 1, fewer 3- to 4-year-old children in this phase responded “yes” to the question, “Have you ever smelled/tasted” for every item except cinnamon and popcorn.

Identification accuracy for the odors is shown in Table VII. Improved levels of adult accuracy from phase 1 to phase 2 affirmed the success of the modifications for both the odor items and the fragrances (68% vs. 92% for phase 1 and 2, respectively). The percentage of adults who were able to accurately identify the eight odors ranged from a low of 77% (banana) to a high of 100% (flower, Play-Doh, chocolate). The accuracy of the 3 year olds on the eight items ranged from a low of 19% (flower) to a high of 73% (popcorn). The accuracy of the 4-year-old children ranged from a low of 19% (cinnamon) to a high of 76% (chocolate and bubble gum).

A repeated-measures ANOVA performed on correct identification percentage for each odor as a function of age group (3 years, 4 years, and adults) showed a main effect of age ($F_{(2,87)}$ = 89.12, $P < .001$), a main effect of odor ($F_{(7, 609)}$ = 9.77, $P < .001$), and an age by odor interaction ($F_{(14, 609)}$ = 3.89, $P < .001$). Post hoc tests revealed that overall accuracy for children ages 3 years and 4 years was significantly lower than accuracy for adults ($P < .001$), and 3 year olds tended to perform with less accuracy than 4 year olds ($P = .09$). Parents' accuracy was significantly higher than 3-year-old children on every odor except popcorn ($P = .80$) but significantly exceeded the accuracy of 4-year-old children on only four of the odors (e.g., flower, banana, lemon and cinnamon; $P < .05$).

We also looked at the data to determine whether children had a position bias when choosing an incorrect odor. Of the eight trials in this study, four of the correct responses appeared on the right side of the picture sheet, and the other four were located on the left side. Children were as likely to choose incorrectly when the image of the correct odor was located on the right versus the left side. When the image of the correct odor was on the left side, 56% of the time it was not identified, and when on the right side, 55% of the time it was not identified. When children chose an incorrect image, which happened 209 out of 376 times (47 children × 8 odors), they were significantly more likely to choose an image located on the right side (61%) than on the left side (39%; $P = .002$).

Because even this simplified test format involved attention and cognitive skills (i.e., matching to sample), we explored whether prior experience in a daycare or preschool setting was associated with performance on the test. Identification accuracy (based on a composite score of the number of correct responses out of eight) was significantly better among children who had attended either a preschool program or daycare (49% vs. 30%; $F_{(1,45)}$ = 7.30, $P = .01$).

Discussion

We evaluated two tests of olfactory function to determine their suitability for use in a pediatric population age 3 years and older. In the first phase, we determined that even very young children could understand the task and successfully match odors to pictures when the odors were familiar (i.e., lemon). Identification accuracy in this test, however, was low even among adults, suggesting that the odors were not good representations of their respective sources. Thus, in phase 2, we 1) modified the stimuli by eliminating poorly recognized odors, 2) added odors more familiar to children, and 3) obtained fragrances from a single source. This resulted in improved identification accuracy among the adults for the odors and good accuracy for the most familiar odors among the 3- and 4-year-old children. The results of this second phase showed that children as young as 3 years of age were able to understand and complete the task. Identification performance and time for completion tended to improve with age. Adult identification accuracy exceeded the performance of 4 year olds on four out of eight odors and that of 3 year olds on seven out of the eight odors tested.

One issue to be addressed is the discrepancy between the identification accuracy in 3- to 4-year-old children for the odor of lemon in phase 2 (30%) and in phase 1 (78%). Although we substituted a different fragrance for the lemon item, the consistency of the adult performance in both tests (95% vs. 93% as reported in Table V and VII) suggests that the fragrance itself was still an accurate representation of the odor source. We also note that the percentage of children who said they had “ever smelled or tasted lemon” was lower in phase 2 than in phase 1 (72% vs. 94% as reported in Tables IV and VI), which may also have contributed to the different outcomes. Given the difference in performance on the lemon fragrance from phase 1 to phase 2, we recommend using the lemon fragrance from the first phase, as it appeared to be a better representation for lemon odor among the younger children.

Another factor to take into consideration by those administering this test in the future is the difference observed between sites. As noted earlier, testing at the Monell site was done individually for both adults and children in rooms specifically designed for sensory testing, whereas at the Nemours site, children were tested by a study administrator in a small room adjacent to the waiting room, and adults self-administered the test in the waiting room. The lower performance among the adults and children tested at Nemours relative to Monell could have resulted from 1) self-administration of the test at this site (adults only), 2) stress experienced due to the nature of the presurgical intake visit, 3) competing environmental odors in the clinical setting of Nemours, or 4) differences in the populations tested. Additionally, it is possible that some of the children being tested at Nemours were being evaluated/treated for a clinical condition associated with impaired olfactory ability (i.e., enlarged adenoids or prior head trauma; data not collected). Although we can only speculate on the impact of these factors in the present study, features of the test site that lead to methodological differences in test administration as well as systemic variations in the study cohort (cultural or clinical) will be evaluated in future studies.

Future test administrators should also be aware of (and evaluate) the general tendency for children to exhibit position bias in their response choices, which we observed in the current study. Although images of the correct responses were equally distributed across right and left sides of the response sheet, when making an incorrect response, children chose an image on the right more often than on the left (61% vs. 39% of the time).

As planned, we recommend eliminating two odors to bring the total number of items down to six. We first recommend eliminating the flower odor. Overall, the flower odor (although well identified by the adults) had the lowest accuracy among the young children, and performance did not differ from chance. This may have been due to the fact that children's exposure to floral scents derives mostly from perfumes, candles, or air fresheners that are not represented by the image of a flower. We also recommend eliminating the banana odor after discovering that when microencapsulated it was subject to more rapid degradation than any of the other stimuli, thus making it less suitable for inclusion in a test that might need to be stored for any length of time. Finally, from reviewing the data in phase 1, near-perfect levels of picture identification accuracy for children age 9 years and above leads us to recommend elimination of the initial picture familiarity assessment in children of these ages, thereby shortening the overall evaluation time and rendering a benefit to both the Toolbox initiative and clinical practice.

Conclusion

Our study confirms that children as young as 3 years of age can understand and successfully perform an odor identification task. Time for testing is longer in younger children <5 years of age (7.44 vs. 5 minutes or less). In addition, the choice of odors, their pictorial representations, and how authentically the pictures and the odors represent the odor source affected performance accuracy. Age (<5 years) affects performance accuracy, which among very young children can be mediated by early daycare or preschool experience. This observation suggests that the ability to associate an odor percept with its appropriate source occurs as part of normal development. Thus, the test has the potential to highlight differences within a range of normal function across the lifespan, which is the primary goal of the NIH Toolbox initiative. We currently recommend the six-item NIH Toolbox Pediatric Odor Identification Test as a brief, self-contained test that holds promise for evaluating olfactory function in children in both research and clinical settings. At the present time, however, the six-item test requires a larger set of normative data to determine the range of normal functioning for each age group and use it for identifying clinical pathologies in olfaction for children.

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Fig. 1.

Picture board used to evaluate familiarity and accuracy of the target and distractor pictures in phase 1. Children were asked if they could point to the appropriate picture when the experimenter named each of the 13 images (from left to right and top to bottom: banana, coffee, lemon, peanut butter, grapes, cinnamon, Play-Doh, bubble gum, chocolate, flower, mint, popcorn, and bread).

Fig. 2.
Sample layout of four response choices for the target odor (cinnamon) and three distractors (bubble gum, grape, and mint). Children (and adults at Monell) were asked to point to the picture that best matched the odor they smelled. Adults at the Nemours site viewed the pictures and then circled the name of the item on a separate sheet.

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Table I

Target odors and the distractors used in Phase 1.

Target Odor		Distractors	
Lemon	Grape	Bread	Peanut Butter[2] Banana[1]
Flower	Lemon	Popcorn	Cinnamon
Bubble Gum	Mint	Banana	Coffee
Play-Doh™	Mint	Bread	Chocolate
Coffee	Play-Doh™	Flower	Chocolate
Peanut Butter[1]	Banana	Popcorn	Flower
Cinnamon[2]	Bubble Gum	Grape	Mint

[1]Odors and distractors used in Set 1

[2]Odors and distractors used in Set 2

Table II

Target odors and the distractors used in Phase 2.

Target Odor		**Distractors**	
Lemon	Banana	Play-Doh™	Cinnamon
Flower	Play-Doh™	Banana	Bubble Gum
Bubble Gum	Play-Doh™	Lemon	Popcorn
Play-Doh™	Bubble Gum	Chocolate	Popcorn
Cinnamon	Popcorn	Lemon	Flower
Popcorn	Cinnamon	Flower	Chocolate
Chocolate	Banana	Bubble Gum	Lemon
Banana	Chocolate	Flower	Cinnamon

Table III

Phase1: Amount of time in minutes (SEM) [Max] subjects took to complete the picture and odor identification tasks. Data are combined across both Monell and Nemours sites.

Age Group	Picture Identification Task	Odor Identification Task	Total Time
3-4 years	4.06 (0.30) [8]	3.39 (0.22) [6]	7.44 (0.41) [13]
5-8 years	2.92 (0.16) [12]	2.74 (0.10) [9]	5.66 (0.22) [15]
9-11 years	2.17 (0.11) [7]	2.74 (0.17) [15]	4.91 (0.23) [20]
12-14 years	2.10 (0.10) [5]	2.50 (0.10) [6]	4.60 (0.18) [11]
15-17 years	1.86 (0.15) [4]	2.17 (0.14) [4]	4.03 (0.23) [7]
Adults (18 years & older)		3.71 (0.13) [14]	3.71 (0.13) [14]

Table IV

Phase1: Percent of participants in each age group who correctly identified the pictures of the target odors and distractors and who reported familiarity with the odor of those items.

	Picture Identification					Odor Familiarity				
Age Group	**3–4 years**	**5–8 years**	**9–11 years**	**12–14 years**	**15–17 years**	**3–4 years**	**5–8 years**	**9–11 years**	**12–14 years**	**15–17 years**
Flowers	97.2	99.2	100.0	100.0	100.0	91.7	94.7	100.0	94.2	97.1
Popcorn	91.7	99.2	100.0	100.0	100.0	97.2	99.2	100.0	100.0	100.0
Bread	86.1	88.6	100.0	98.6	97.1	100.0	100.0	100.0	100.0	100.0
Peppermint	80.6	94.7	100.0	100.0	100.0	94.4	95.5	100.0	100.0	100.0
Peanut Butter	63.9	92.4	100.0	98.6	100.0	97.2	97.0	98.9	100.0	100.0
Grapes	97.2	99.2	100.0	100.0	100.0	100.0	98.5	98.9	100.0	97.1
Cinnamon	33.3	82.6	95.7	98.6	100.0	63.9	82.6	100.0	98.6	100.0
Lemon	63.9	94.7	100.0	100.0	100.0	94.4	95.5	100.0	100.0	100.0
Bananas	100.0	99.2	100.0	100.0	100.0	94.4	95.5	98.9	100.0	97.1
Bubble Gum	80.6	97.0	100.0	100.0	100.0	88.9	93.9	100.0	98.6	97.1
Coffee	80.6	91.7	95.7	97.1	97.1	86.1	83.3	93.5	94.2	97.1
Play–Doh™	83.3	98.5	100.0	100.0	100.0	100.0	96.2	100.0	98.6	97.1
Chocolate	75.0	96.2	97.8	100.0	100.0	100.0	98.5	100.0	100.0	100.0

Table V

Phase 1: Percent of participants in each age group who correctly identified the target odors.

	3–4 years n=36	5–8 years n=132	9–11 years n=93	12–14 years n=70	15–17 years n=35	Adults n=275
Lemon	77.8	89.4	97.8	92.9	100.0	94.9
Flower	33.3	50.0	54.8	55.7	51.4	57.0
Bubble Gum	25.0	30.3	37.6	50.0	51.4	59.9
Play–Doh™	55.6	61.4	80.6	85.7	94.3	88.1
Coffee	58.3	65.2	75.3	74.3	74.3	63.9
Cinnamon	15.4	57.1	66.7	64.7	92.9	77.1
Peanut Butter	34.8	34.2	22.2	22.2	42.9	20.1

Note: Data are combined across sites and for common items from Set 1 and Set 2

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Table VI

Phase 2: Percent of 3 and 4 year old participants who correctly identified the pictures of the target odors and who reported familiarity with the odors of those items.

	Percent of Children Who Correctly Identified Pictures Representing Target Odor	Percent of Children Familiar with the Target Odor
Target Odor		
Flowers	97.9	78.7
Popcorn	100.0	95.7
Cinnamon	80.9	66.0
Lemon	93.6	72.3
Banana	97.9	87.2
Bubble Gum	93.6	61.7
Play-Doh™	89.4	63.8
Chocolate	95.7	83.0

Table VII

Phase 2: Percent of participants in each age group who correctly identified the odor.

	3 years n=28	4 years n=22	Adults n=22
Lemon	26.9	33.3	93[a]
Flower	19.2	38.1	100[a]
Bubble Gum	38.5	76.2	81.4[b]
Play-Doh™	38.5	61.9	100[b]
Cinnamon	38.5	19.0	88.4[a]
Popcorn	73.1	66.7	97.7
Chocolate	50.0	76.2	100[b]
Banana	30.8	33.3	76.7[a]

[a]= Significantly different from 3 and 4 year olds

[b]= Significantly different from 3 year olds