

Original Article

A Cross-Cultural Adaptation of the Sniffin' Sticks Olfactory Identification Test for US children

Annachiara Cavazzana^{1,2,3,*}, Christiane Wesarg^{1,*}, Valentin A. Schriever^{3,4}, Thomas Hummel³, Johan N. Lundström^{1,5,6} and Valentina Parma^{1,5,7,8}

¹Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA, ²Department of General Psychology, University of Padova, Via Venezia, 8, 35131 Padova, Italy, ³Interdisciplinary Center on Smell and Taste, Department of Otorhinolaryngology, University of Dresden Medical School, TU Dresden, Fetscherstrasse 74, 01307 Dresden, Germany, ⁴Department of Neuropediatrics, TU Dresden, Fetscherstrasse 74, 01307 Dresden, Germany, ⁵Department of Clinical Neuroscience, Karolinska Institutet, Nobels väg 9, 17177 Stockholm, Sweden, ⁶Department of Psychology, University of Pennsylvania, 3720 Walnut Street, Philadelphia, PA 19104, USA, ⁷Center for Autism Research, 3535 Market Street, Philadelphia, PA 19104, USA and ⁸Neuroscience Area, International School for Advanced Studies (SISSA), Via Bonomea 265, 34100 Trieste, Italy

*These authors contributed equally to the work.

Correspondence to be sent to: Valentina Parma, Neuroscience Area, International School for Advanced Studies (SISSA), Via Bonomea 265, 34100 Trieste, Italy. e-mail: vparma@sissa.it

Editorial Decision 19 October 2016.

Abstract

Disorders associated with smell loss are common in adolescents. However, current odor identification tests focus on children from age 6 and older and no cross-cultural test has to date been validated and fully implemented. Here, we aimed to investigate how 3-to-11-year-old US children performed to an adapted and shortened (11 odors instead of 14) version of a European odor identification test—the Sniffin' Kids (Schriever VA, Mori E, Petters W, Boerner C, Smitka M, Hummel T. 2014. The "Sniffin'Kids" test: a 14-item odor identification test for children. *Plos One*. 9:e101086.). Results confirmed that cued odor identification performance increases with age and revealed little to no differences between girls and boys. Scores below 3 and below 6 may raise hyposmia concerns in US children aged 3–7 years and 8–10 years, respectively. Even though the completion rate of the task reached the 88%, suggesting that children below age 5 were able to finish the test, their performance was relatively poor. In comparing the overall identification performance of US children with that of German children, for whom the test was specifically developed, significant differences emerged, with higher scores obtained by the German sample. Analysis of errors indicated that a lack of semantic knowledge for the olfactory-presented objects may be at the root of poor identification skills in US children and therefore constitutes a problem in the development of an odor identification test for younger children valid across cultures.

Key words: children, cross-culture, odor identification, olfactory test, Sniffin' Sticks

Introduction

Potential etiologies associated with smell loss, such as head trauma and allergic rhinitis, are common diagnoses among children (Dalton

et al. 2009). However, until now, no suitable diagnostic instruments have been available to detect initial signs of olfactory loss in this population, consequently leading to early impairment, which might foster lifelong deficits (Laing et al. 2008).

A very common screening tool for detecting olfactory dysfunctions in adults is represented by identification tests (e.g., Sniffin' Sticks Test: Hummel et al. 1997). In light of their ease of application in clinical practice, many attempts have been made to adapt these tools for children (Cameron and Doty 2013; Dalton et al. 2013; Dżaman et al. 2013; van Spronsen et al. 2013; Schriever et al. 2014; Bastos et al. 2015). However, this approach carries certain disadvantages, including experience-related (Richardson and Zucco 1989; Goldman and Seamon 1992) and age-related confounders (e.g., Hummel, Kobal et al. 2007; Bastos et al. 2015; Sorokowska et al. 2015), which influence odor identification abilities. Experience, among other aspects, differs from culture to culture (e.g., Chrea et al. 2004). For example, in the United States, wintergreen is an odor commonly associated with sweet things, whereas in continental Europe, it is often considered as a medicinal odor, if it is known at all (Chrea et al. 2004). These cultural differences in olfactory experience raise the need for cross-cultural investigations of olfactory tests. Although the standardization of olfactory identification tests for adults has taken into account cultural differences (Shu et al. 2007; Konstantinidis et al. 2008; Tekeli et al. 2013; Sorokowska and Hummel 2014; Catana et al. 2014; Oleszkiewicz et al. 2015; Sorokowska et al. 2015), at present, no olfactory identification test suitable for children has been developed to be used across cultures. Beyond cultural aspects, olfactory identification scores are influenced by nonperceptual skills highly prone to developmental changes during infancy and childhood. Indeed, semantic knowledge, verbal fluency, and proficiency (Larsson et al. 2000, 2004; Hedner et al. 2010), as well as concentration abilities (Guinard 2001; Hugh et al. 2015), have an impact on odor identification abilities. As a result, older children tend to obtain higher scores when compared with younger children (e.g., Hummel, Bensafi et al. 2007; Dalton et al. 2011; Bastos et al. 2015).

A candidate as a potential "worldwide" olfactory test, besides the tools developed specifically for the US population (NIH Toolbox: Dalton et al. 2013; The Smell Wheel: Cameron and Doty 2013), is the Sniffin' Sticks Test (Burghart Messtechnik), which has been widely used in adults across cultures (e.g., Shu et al. 2007; Silveira-Moriyama et al. 2008; Sorokowska and Hummel 2014). Due to its low cost, easy administration, commercial availability, and acceptability for the participants, it constitutes a potential measure allowing for developmental and cross-cultural continuity of olfactory identification skills worldwide. For this reason, a number of groups have tried to develop a test based on the Sniffin' Sticks Test that would be suitable for testing children's olfactory performance (van Spronsen et al. 2013; Schriever et al. 2014; Sorokowska and Hummel 2014; Sorokowska et al. 2015; Bastos et al. 2015). However, the focus of the Sniffin' Sticks Test in childhood has thus far mostly addressed children above the age of 6, based on the observation that data collected in younger children were unreliable (44% of 3-to-5-year-old children were not able to complete the task) due to difficulties in understanding test instructions as well as lack of directed motivation (Hummel, Kobal et al. 2007; Hummel et al. 2011). Nevertheless, evidence shows that olfactory evaluation is accurate once testing is tailored to the skills of children as young as 3 years (Dalton et al. 2011; Dżaman et al. 2013; only 6% and 3.3% of children, respectively, were not able to finish the test). Studies adapting the Sniffin' Sticks Test to children younger than 3 years are very scant, showing low completion rates (Hummel, Bensafi et al. 2007; Bastos et al. 2015) and were never adopted for US children despite its benefits in the adult population. Therefore, the main aims of the study were to: (i) investigate US children's olfactory abilities assessed by using the identification part of the Sniffin' Sticks Test, when compared

with those of German children for whom the test was developed, (ii) evaluate the age effects of a test developed within a different culture with the broader aim of gaining knowledge to create future versions of the Sniffin' Sticks Test apt for children across cultures, and (iii) assess the effects of completion rates in younger children.

Methods

Participants

A total of 199 children participated in the study. Participants were recruited from visitors to the Please Touch Museum of Philadelphia; prior to testing, all parents or legal guardians provided written informed consent, and all children provided their verbal assent to participate. Participants were informed that they could discontinue participation at any time and upon completion of the test, each child received stickers as a token of appreciation for their effort. Demographic information (i.e., child's date of birth, sex and ethnicity), health status, and presence of known olfactory problems were obtained via caregiver's report. In the final analyses, 152 participants (98 females and 54 males) with an age range of 3–11 years (mean age in years: 6.13; SD: 1.79) were included. Reasons for exclusion were the following: (i) the measures were incomplete due to an obvious lack of motivation or comprehension of the task ($N = 12$); (ii) reported use of medication that affected olfactory or behavioral/cognitive performance ($N = 12$); (iii) reported diseases linked to olfactory dysfunction ($N = 14$); (iv) reported nonfluency in the English language ($N = 1$); (v) demographic information not provided by parent/caregiver ($N = 2$); and technical issues ($N = 6$). A Mann–Whitney U test indicated that the age distributions were not statistically different ($U = 2588$, $z = -0.22$, $P = 0.83$, $r = -0.02$) between male (mean age in years: 6.04; SD: 1.61) and female (mean age in years: 6.18; SD: 1.89) participants. As to investigate differences in identification rates between the German children and the US children above the age of 6, we selected the values from the previously published article by Schriever et al. (2014), allowing for direct comparisons with the group of US children included in the present study. In detail, the comparisons have been based on 205 German children (mean age in years: 8.59; SD: 1.12; range: 6–10; 105 females) and 71 age-matched US children (mean age in years: 7.67; SD: 1.3; range: 6–10; 47 females). All aspects of the study were approved by the local Institutional Review Board and were compliant with the Declaration of Helsinki.

Stimuli

Felt-tip pens filled with odors were used to deliver the olfactory stimuli. Eleven odors (Table 1) were selected from the Sniffin' Sticks Test "Identification" (Burghart Instruments), a standardized test used to evaluate adult and children olfactory performance (Hummel et al. 1997; Schriever et al. 2014). The selection of the specific odors was based on the selection made for the developmental German sample (Schriever et al. 2014). Considering the likelihood of US children having experienced some odors (e.g., turpentine), as well as the need for reducing the number of items to minimize fatigue effects in the youngest, a total number of 11 odors was presented.

Experimental setting and procedure

The study was run in a dedicated section of a large well-ventilated room. Following verbal assent, each child was seated at a kid's height table and was verbally presented with instructions by the experimenter. The level of understanding of these instructions, as well as the level of compliance and engagement, was evaluated by the

experimenter throughout the experimental session, which lasted about 5 min per child. By means of a multiple-choice task, the experimenter read out loud four descriptors at a time while pointing to each corresponding picture. For odor presentation, the cap of each odor pen was removed by the experimenter, and the pen's tip was placed approximately 2 cm in front of the child's nostrils for approximately 3 s. Eleven pens were presented separately, with an inter-stimulus interval of at least 30 s to limit olfactory adaptation. Participants were free to sample each odor as often as necessary (with an interval of 30 s between stimulations) in order to provide an identification response, which was made by pointing to the chosen image among four options (Figure 1).

Statistical analyses

All statistics were performed using SPSS software version 17.0 (SPSS Inc.). Descriptive statistics obtained for age and odor identification scores are presented as mean values, SDs and ranges. The performance data of the 11-item odor identification test was not

Table 1. List of target odors and distractors

Target	Distractor 1	Distractor 2	Distractor 3
Peppermint	Chives	Onion	Wood
Orange	Strawberry	Blackberry	Pineapple
Cinnamon	Honey	Chocolate	Vanilla
Coffee	Cigarette	Wine	Candle smoke
Banana	Coconut	Walnut	Cherry
Pineapple	Pear	Peach	Plum
Lemon	Peach	Apple	Grapefruit
Licorice	Mint	Cherry	Cracker
Rose	Camomile	Raspberry	Cherry
Garlic	Onion	Sauerkraut	Carrot
Cloves	Cinnamon	Pepper	Mustard

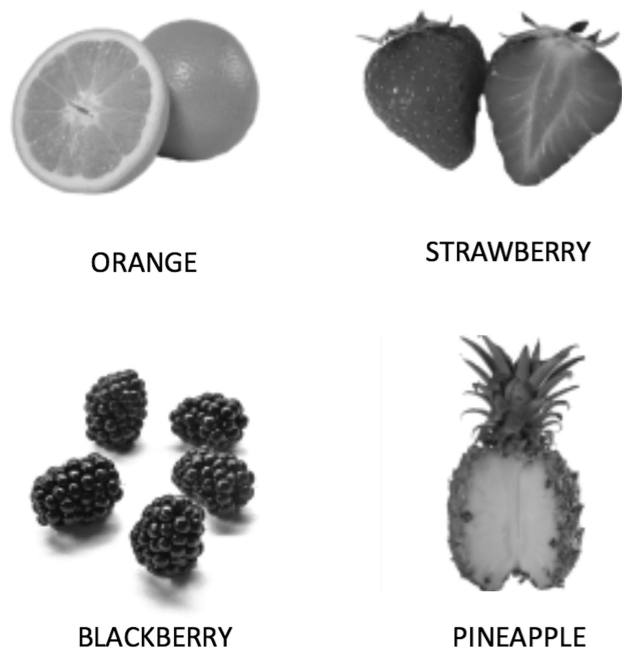


Figure 1. Example of visual stimuli. Sample layout of four response choices for the target odor (orange) and three distractors (strawberry, blackberry, and pineapple). Children were asked to point to the picture that best matched the odor they smelled.

normally distributed, as evaluated by a Kolmogorov–Smirnov test, $D(152) = 0.11$, $P < 0.001$). Therefore, Mann–Whitney U tests for independent samples were employed to analyze differences between the various age-groups. Simple linear regressions, Kruskal–Wallis tests and Spearman's correlations were performed to evaluate the effect of age on odor identification scores. The percentage of correct identifications for each odor was also calculated. In addition, accurate odor identification rates between the US and the German children (Schriever et al. 2014) were compared adopting a two-tailed Z -test for two proportions (Kirk 2007). For all tests, the level of significance was set at $\alpha < 0.05$.

Results

Odor identification performance increases with age

The overall mean score for the 11-item odor identification test was 6.18 points (SD: 2.11; range 2–10), corresponding to approximately 56% identification accuracy. For the whole sample, a Mann–Whitney U test was run to determine whether there were differences in odor identification performance between male and female participants. Distributions of the odor identification scores for males and females were similar, as assessed by visual inspection. Odor identification scores for females (mean rank = 78) were not significantly different from those obtained by males (mean rank = 73), $U = 2456.50$, $z = -0.737$, $P = 0.46$, $r = 0.06$. There was a significant relationship between age of the children and odor identification score, $\rho(152) = 0.5$, $P < 0.001$. A linear regression indicated that age could statistically significantly predict odor identification scores, $F(1, 150) = 43.549$, $P < 0.001$, and age accounted for 22.5% of the explained variability in odor identification scores. Participants' average odor identification score increased by 0.56 points for each year increment in age. Figure 2 visualizes the distribution of odor identification scores by age. Given the significant effect of age in predicting odor identification performance, we divided the sample into three subgroups: Group I (3–4.99 years; $N = 46$, 31 females), Group II (5–7.99 years; $N = 77$, 46 females), and Group III (8–11 years; $N = 29$, 21 females), in line with Dalton et al. (2011). In light of the

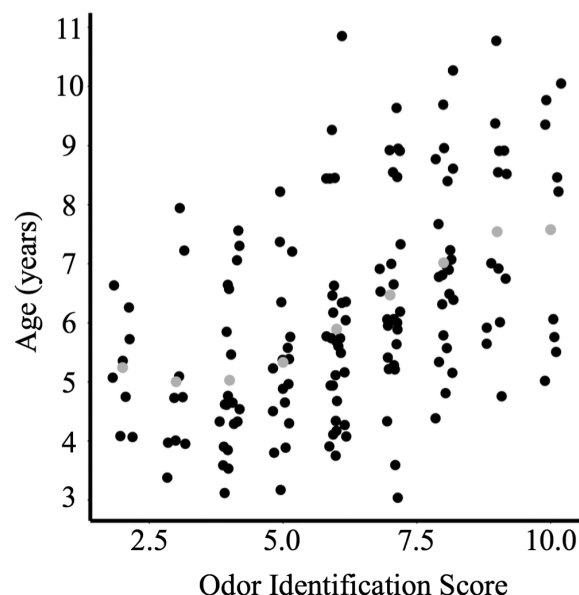


Figure 2. Scatterplot representing the distribution of odor identification scores by age. The grey dots depict the average identification score for each age-group.

paucity of the data in literature—especially when considering the youngest children—the present subdivision will lead to (i) identify the odors that children of different ages are most sensitive to, in order to make a reliable screening and (ii) suggest age-dependent norms for the detection of possible olfactory impairment. In order to compare the odor identification scores among the three groups, a Kruskal–Wallis test was run. Results showed that odor identification scores were statistically significantly different between the three different age-groups, $\chi^2(2) = 40.639$, $P < 0.001$, $\eta^2 = 0.52$, with a mean rank odor identification score of 47.20 for Group I, 80.66 for Group II, and 111.93 for Group III. Performances of the three age-groups on the 11-item odor identification test are reported in Table 2. No sex difference was revealed in the odor identification test for any of the three age-groups (Table 2).

Percentages of correct identifications and age-dependent hyposmia cutoff suggestions

Finally, to evaluate performance for each individual odor, we determined the percentage of correct identification for each odor separately, as well as identification rate for their respective distractor. Please refer to Table 3 for absolute values of percent identification of each odor and Figure 3 for proportions of identification of the individual images (odors and distractors). Please note that the percentage of identification of each target odor was significantly greater when compared with each of the respective distractors (all P s < 0.007). A detailed description of odor identification for the three age-groups can be found in Table 3.

Although we did not include in the US sample a group of anosmic children, we identified cutoff values to separate normosmia from hyposmia. Based on the previously applied <10th percentile rule (Hummel et al. 2007; Schriever et al. 2014), an odor identification score of <3 in both Group I (3–4.99 years) and II (5–7.99 years) and a score of <6 in Group III (8–11 years) may be considered reflecting hyposmia. According to this definition, three children in Group I (6.52%), five children in Group II (6.49%), and one child in Group III (3.44%) showed reduced odor identification skills below the 10th percentile cutoff.

Completion rates are >88% across groups

The percentage of success in performing the Sniffin' Sticks was of 88.46% for Group I, 93.9% for Group II, and 96.7% for Group III (six, five, and one children were not able to complete the task, respectively).

Comparison with the German sample

A significant difference in the overall identification performance was observed ($U = 3993$, $z = -5.76$, $P < 0.001$), with German children scoring higher (with a mean of 8.55 points; SD 1.66; range 1–11 points) when compared with the US children (mean of 7.03; SD 1.94; range 2–10 points). The percentage of correct identifications for each item was also calculated and compared between the two groups. No differences have been detected regarding peppermint (92.6% vs. 94.3%, German and US sample, respectively), lemon (74.6% vs. 63.4%), licorice (66.3% vs. 56.3%), and pineapple (72.2% vs. 66.2%; all P s > 0.05). On the contrary, we observed significant differences between the two samples regarding orange ($z = -2.3$, $P = 0.02$; 79.5% vs. 91.5%), better identified by the US children and cinnamon ($z = 3.15$, $P = 0.001$; 89.7% vs. 74.6%), banana ($z = 5.15$, $P < 0.001$; 90.7% vs. 64.7%), garlic ($z = 3.24$, $P = 0.001$; 66.8% vs. 45%), coffee ($z = 2.19$, $P = 0.03$; 81.4% vs. 69%), cloves ($z = 4.74$, $P < 0.001$, 72.2% vs. 40.8%), and rose ($z = 4.69$, $P < 0.001$; 68.3% vs. 36.6%), better identified by the German children. Figure 4 provides an overview of the data.

Discussion

In the current study, we investigated how US children performed on a shortened version of the odor identification subtest of the Sniffin' Sticks Test. In line with previous studies, no sex differences were evident in odor identification performance (Hummel, Bensafi et al. 2007; Cameron and Doty, 2013; Džaman et al. 2013; Schriever et al. 2014) and an age effect was evident: the older the children are, the better at identifying odors they become (Hummel, Bensafi et al. 2007; Dalton et al. 2011; Cameron and Doty 2013; Schriever et al. 2014;

Table 2. Odor identification performance results per age-group

Group	N	F/M	Age	ID score	Range	Mann–Whitney U test	P value
I (3–4)	46	31/15	4.22 (0.51)	4.83 (1.62)	2–9	$U = 182.5$	0.23
II (5–7)	77	46/31	6.16 (0.73)	6.35 (2.06)	2–10	$U = 564$	0.12
III (8–10)	29	21/8	9.06 (0.73)	7.90 (1.47)	5–10	$U = 65$	0.35

F = females; M = males. Displayed are means and standard deviations for age and identification score (ID score).

Table 3. Percentages of correct odor identifications for each individual odor, presented for overall and each age-group separately

Odor	Overall (%)	Group I (3–4) (%)	Group II (5–7) (%)	Group III (8–10) (%)
Peppermint	79.61	56.52	87.01	96.55
Orange	78.95	56.52	85.71	96.55
Cinnamon	71.71	63.04	68.83	93.10
Coffee	68.42	63.04	68.83	75.86
Banana	64.47	60.87	66.23	65.52
Pineapple	60.53	45.65	63.64	75.86
Lemon	48.03	23.91	51.95	75.86
Licorice	41.45	26.09	38.96	72.41
Rose	36.84	36.96	38.96	31.03
Garlic	36.18	32.61	29.87	58.62
Cloves	32.24	17.39	35.06	48.28

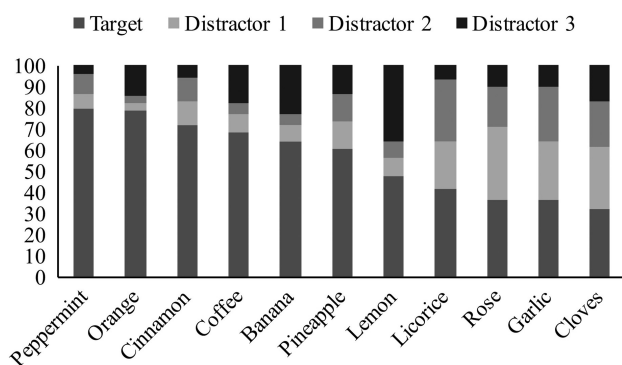


Figure 3. Percentage of identification of the target odor (in black) and each distractor (in gray scale).

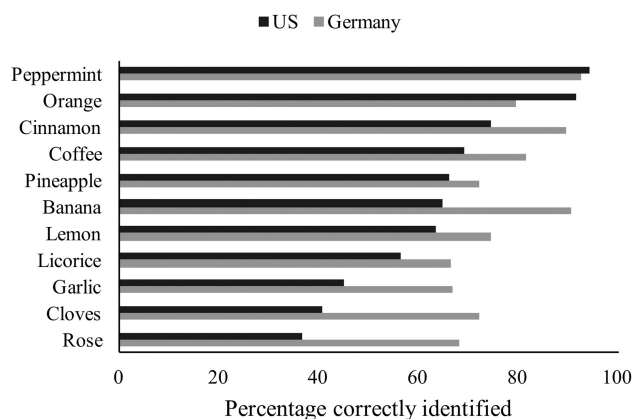


Figure 4. Percentage of correctly identified odors by the US and German samples.

Sorokowska et al. 2015). As predicted, we can here confirm the presence of age-related differences in odor identification within a US population, akin to what has been previously reported. It is well-documented that correct identification of odors is possible only if the subject had previous experience with the smell and the underlying odor object (Goldman and Seamon 1992). Therefore, as children get older, they acquire more familiarity and become more confident with their olfactory environment, as we did find in the present study.

In order to make a reliable evaluation and avoid confounders related to the lack of knowledge of certain odors, we assessed odor identification skills separately in three age subgroups that were homogenous by age and showing significantly different odor identification scores. Considering Group I (3–4.99 years), only five odors (i.e., peppermint, orange, cinnamon, coffee, and banana) were identified with a frequency of >50%. In particular, the odors of “orange,” “cinnamon,” and “banana” seem to be the most commonly identified odors within this age range (and within this specific constellation of odor descriptors, see Gudziol and Hummel 2009); this is in line with other studies (e.g., Dżaman et al. 2013; Bastos et al. 2015). Interestingly, “cinnamon” and “banana” have also been recently proven to be the best suited odors for a short olfactory test aimed at establishing normosmia in adults (Lötsch et al. 2016). To our knowledge, only two studies investigated olfactory abilities in children starting from 3 year using the identification part of the Sniffin’ Sticks Test (Hummel, Bensafi et al. 2007; Bastos et al. 2015). Hummel, Bensafi et al. (2007) reported that 44% of children between 3 and 5 years failed to perform the test, whereas Bastos

et al. (2015) tested only 9 children within this age range, reporting that only 5 of 16 the items were highly identified in more than 75%. However, interpretation of the data reported in this latter study may be difficult in light of the limited number of participants. Although the completion rates in the present study are higher when compared with Hummel, Bensafi et al. (2007), suggesting that even the youngest children might be able to perform the Sniffin’ Sticks Test, the average percentage of odors correctly identified by Group I was only 43.9%, with a completion rate of 88%. One possible explanation for this lack of olfactory identification in Group I may be related to the fact that such an ability is significantly correlated with the level of cognitive functions (Hedner et al. 2010), including difficulties in task comprehension and low concentration abilities (Guinard 2001). In particular, the limited span of attention may interfere with testing procedures (Strickland et al. 1988), given that visual selective attention abilities develop at about 5 to 6 years of age (for a review, see Garon et al. 2008). Indeed, one might argue that children aged below 5 years (i.e., belonging to Group I) may not be able to identify the correct picture among four images because the visual scanning task is too complex for their age (Fabes and Filsinger 1986) and attention to the target is degraded by the presence of surrounding objects (Casco et al. 1998). However, this seems unlikely, given that numerous cognitive and language assessment tools include tasks that require correct response selection from a field of four choices (e.g., Peabody Picture Vocabulary Test: Dunn and Dunn 2007; Wechsler Preschool Primary Scale of Intelligence: Wechsler 1967). These tests are normalized and validly used as early as 2 years of age, suggesting that the visual scanning component of the Sniffin’ Sticks test should be manageable for our group of children.

An alternative, and more likely, explanation of our results could be linked to the maturity of integration abilities, where information from one sensory channel (e.g., olfaction) needs to be integrated with another (e.g., vision). As cross-modal integration is still developing between the ages of 3 and 6 (Sarafino and Armstrong 1986), where children younger than 5 years of age may perform poorly in visually guided cued odor identification because of a still immature capacity of integrating multimodal sensory information. This seems to be reflected by our findings, depicting the gradual, age-related increase of the Sniffin’ Sticks Test identification score in children.

As expected, the number of correctly identified odors increased with age, especially between 5 and 10 years old (Lehrner et al. 1999; Monnery-Patris et al. 2009). More specifically, Group II was able to correctly identify 57.7% of the odors and the percentage higher still for Group III (71.8%). However, the item-by-item results indicated that some odors, such as “rose,” “garlic,” and “cloves” were overall identified at a low rate (<40%). The analysis of identification errors provides useful insights on the process of characterizing odor identification in children.

The task of identifying an odor using verbal labels can be conceptually divided into at least three processes: (i) the encoding of the odor, (ii) the activation of the odor in semantic memory, and (iii) the selection of the most appropriate labels in order to identify the odor (e.g., Schab 1991), as previously suggested for the identification of odors via verbal labels in adults. The low identification rate in children may be due to limitations in one or more of the processes presented within the model. Regarding the encoding of the odor, it is unlikely that children might have had problems with the elaboration of the perceptual features of the odors, because the experimenter visually ensured that the presence of the odors elicited a reaction and, whenever unclear, the experimenter asked the child to smell the odor again. Therefore, the low identification rate might

be better explained by a lack of semantic knowledge of the odor smelled. It is well-known that in adults, olfactory information activates semantic knowledge to different degrees depending upon the person's familiarity with a particular smell (Dalton 2002). Based on this, as the level of olfactory semantic knowledge is low during childhood (as demonstrated by an independent US sample by Doty et al. 1984), it is plausible that children were not able to form an olfactory image based on the odor provided because they are not familiar with that smell (Larsson 1997). However, this explanation seems unlikely because rose and garlic are common odors that children have most probably already encountered in their daily lives and for which they verbally express familiarity. The smell of rose and garlic is indeed reported as familiar by US children as young as age 5 in approximately 70% of cases (unpublished data). As a consequence, as the first two processes seem to be intact in children, the most likely explanation for this lack of identification may be linked to the third process. Accordingly, children might have had difficulties in identifying part of the odors because of issues related to the semantic categorization of the pictures presented during the task. This is in line with the results obtained both in adults (Engen 1987) and in children of different cultures (Valentin and Chanquoy 2012; Goubet et al. 2014). For example, Engen (1987) showed that when the distractors and the correct label belonged to different semantic categories (e.g., pizza, turpentine, and clove for the target grape), performance in adults reached 93% of correct identification. If, however, the correct name and the distractors were highly similar, correct identification dropped to about 50% correct (e.g., melon, strawberry, and plum; see also Gudziol and Hummel 2009). The same effect was also found in children. Indeed, a recent study conducted by Goubet et al. (2014) showed that identification of odors in preschoolers was better when the picture of the target odor was semantically unrelated to the distractor pictures. In our specific case, with respect to the "rose" odor, children seem to have been confused by the distractor camomile, which belongs to the same semantic category "flower." The same hypothesis applies to explain the low rate of identification of "garlic" and "cloves." We hypothesize that children had difficulties in correctly identifying these odors because of the distractors (e.g., onion for garlic and cinnamon for cloves). This seems to be further strengthened by the fact that the same errors have been witnessed for "garlic" and "onion," which belong to the same semantic category (i.e., food), to "cloves" and "cinnamon" (i.e., spices), as well as "lemon" (identified in <50% of cases) and "grapefruit", both part of the citrus category.

Therefore, our data are in line with this semantic categorization hypothesis. In fact, the images chosen as distractors, belonging to the same semantic category of the target image, might have been the cause of the low odor identification performance. Limitations in this third process may contribute to poor odor identification performance, supporting the idea that deficits in odor identification may result from weak associations between the olfactory percept and semantic memory rather than from poor olfactory perception per se.

The low rate of identification may also depend on the level of experience that a particular cultural group has toward the visual image (e.g., licorice; Dubois 2000). For example, the visual prototype of "licorice" refers to black licorice for Europeans, whereas in the United States, licorice is associated with a red color. This culturally driven mismatch in the visualization of an odor concept has likely biased the choices of children who did not recognize the picture associated with the odor, because it does not specifically represent the image of the same odor in the United States. US children could therefore have found it more challenging to identify the odor

because of the different representation (e.g., color) of the target image. This is in line with the results presented by Gottfried and Dolan (2003) and Jadaui et al. (2012) who showed that in adults, the presentation of visual stimuli can influence olfactory information processing. In addition, licorice may be an example of an odor that acts as a possible confounder in cross-cultural comparisons and might be dropped based on the fact that it does not represent some children's olfactory experience, rather than because it is misinterpreted based on semantic knowledge.

To specifically address the usability of an odor identification test cross-cultures, we directly compared the performance of the US children older than 6 years of age with that of the German children, for whom the test was originally developed (Schriever et al. 2014). The mean total odor identification score was significantly higher in the German children when compared with the US children, indicating that on average, the German children were able to correctly identify more odors. The analysis of errors showed no differences in the odor identification proportion of peppermint, lemon, licorice, and pineapple across cultures. On the contrary, we observed that cinnamon, banana, garlic, coffee, cloves, and rose odors were poorly identified by US children when compared with German children, whereas orange identification scores revealed greater accurate identification for the US children. Although the reasons behind these cultural differences are unclear, we advance three hypotheses, which should be taken into account when developing odor identification cross-cultural tests. First, the olfactory representation for the poorly identified odors may not be well formed in the US children, perhaps due to familiarity issues. This emerges prominently for odors such as garlic and cloves, which the US children correctly identified in less than 50% of cases. Second, the olfactory representation may be present, but the choice may reflect more consistently the visual information. Therefore, this might have rendered some distractors more attention-grabbing than others. The case of the rose might be an example of this second hypothesis. Rose was indeed often misinterpreted by children as camomile, which is an object part of the same category (i.e., flowers) but showing a more prototypical representation of flowers (e.g., daisy-like appearance) when compared with the rose. This reassignment may also apply cross-culturally, for which some objects more than others are considered prototypical (rose, for instance, may be considered as a prototypical flower in Germany, but not in the United States). Third, assuming that the olfactory representation of an object is present and that the distractors are not visually misleading, the failure in not selecting the correct choice may depend on the inability to associate the correct verbal label to the olfactory representation. Although this is unlikely, given that the labels were mostly known to the participants, we cannot exclude that familiarity effects have occurred for some children (e.g., choosing carrot over garlic, only based on the familiarity of the word). This aspect is translated across cultures, for instance, in the greater familiarity that the German children have with "sauerkraut" when compared with the US children. Therefore, when using the current version of the Sniffin' Kids in populations other than the German, it is important to keep in mind that low performances in the identification of odors like cinnamon, banana, garlic, coffee, cloves, and rose may be due to cultural differences and may not necessarily reflect an olfactory impairment. Future studies are needed to carefully select the proper test items to be used cross-culturally as well as target/distractors combinations and their visual representations.

Taken together, the present study confirms that the use of a shortened version of the German Sniffin' Kids can be used in US children, though only from age 5. Applying the 10th percentile rule to our

sample (Hummel et al. 2007; Schriever et al. 2014), a score of 3 and 6 might represent the cutoff values in order to discriminate between normosmia and hyposmia in 3- to 7-year-old and 8- to 10-year-old children, respectively. This result, especially for Group I (age range 3–4.99) requires further investigation, given the limited completion rate (88%) when compared with the other groups, and future studies should include a group of US anosmic children in order to confirm these preliminary results. The careful analysis of errors highlights that a lack of semantic knowledge for the olfactory objects as well as the reduced exposure to some odors typical of a specific culture may be at the root of poor identification skills.

Funding

Support for this research has been provided by the National Science Foundation (1113648), awarded to the Please Touch Museum and the Monell Chemical Senses Center, the RISE Worldwide fellowship to C.W., the Knut and Alice Wallenberg Foundation (KAW 2012.0141) awarded to J.N.L., the Louise Slade Fellowship to V.P., and The Deutsche Forschungsgemeinschaft to T.H. (DFG HU441/18-1).

Acknowledgements

We greatly thank Ms Kristen Gregory and Ms Smiljana Mutic for assistance with data collection and Ms Georgette Argiris for comments.

References

- Bastos LO, Guerreiro MM, Lees AJ, Warner TT, Silveira-Moriyama L. 2015. Effects of age and cognition on a cross-cultural paediatric adaptation of the Sniffin' Sticks Identification Test. *PLoS One*. 10(8):e0131641.
- Cameron EL, Doty RL. 2013. Odor identification testing in children and young adults using the smell wheel. *Int J Pediatr Otorhinolaryngol*. 77(3):346–350.
- Casco C, Tressoldi PE, Dellantonio A. 1998. Visual selective attention and reading efficiency are related in children. *Cortex*. 34(4):531–546.
- Catana I, Negoiaş S, Maniu A, Porojan M, Cosgarea M. 2014. A modified version of “Sniffin’Sticks” odor identification test: The Romanian cultural adaptation. *Clujul Medical*. 85:218–223.
- Chrea C, Valentin D, Sulmont-Rossé C, Mai HL, Nguyen DH, Abdi H. 2004. Culture and odor categorization: agreement between cultures depends upon the odors. *Food Qual Prefer*. 15:669–679.
- Dalton P. 2002. Olfaction. In: Yantis S, Pashler H, editors. *Steven's handbook of experimental psychology*, 3rd ed. New York: John Wiley. 691–746.
- Dalton P, Doty RL, Murphy C, Frank R, Hoffman HJ, Maute C, Slotkin J. 2013. Olfactory assessment using the NIH Toolbox. *Neurology*. 80:S32–S36.
- Dalton P, Mennella JA, Cowart BJ, Maute C, Pribitkin EA, Reilly JS. 2009. Evaluating the prevalence of olfactory dysfunction in a pediatric population. *Ann N Y Acad Sci*. 1170:537–542.
- Dalton P, Mennella JA, Maute C, Castor SM, Silva-Garcia A, Slotkin J, Christopher R, Parkes W, Pribitkin EA, Reilly JS. 2011. Development of a test to evaluate olfactory function in a pediatric population. *Laryngoscope*. 121:1843–1850.
- Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, Rosenberg L. 1984. Smell identification ability: changes with age. *Science*. 226(4681):1441–1443.
- Dubois D. 2000. Categories as acts of meaning: the case of categories in olfaction and audition. *Cog Sci Quarterly*. 1(1):35–68.
- Dunn DM, Dunn, LM. (2007). *Peabody picture vocabulary test: manual*. New York: Pearson.
- Dżaman K, Zieliński-Jurkiewicz B, Jurkiewicz D, Molińska-Glura M. 2013. Test for screening olfactory function in children. *Int J Pediatr Otorhinolaryngol*. 77(3):418–423.
- Engen T. 1987. Remembering odors and their names. *Am Sci*. 75(5):497–503.
- Fabes RA, Filsinger EE. 1986. Olfaction and young children's preferences: a comparison of odor and visual cues. *Percept Psychophys*. 40(3):171–176.
- Garon N, Bryson SE, Smith IM. 2008. Executive function in preschoolers: a review using an integrative framework. *Psychol Bull*. 134(1):31–60.
- Goldman WP, Seamon JG. 1992. Very long-term memory for odors: retention of odor-name associations. *Am J Psychol*. 105(4):549–563.
- Gottfried JA, Dolan RJ. 2003. The nose smells what the eye sees: crossmodal visual facilitation of human olfactory perception. *Neuron*. 39(2):375–386.
- Goubet N, McCall DD, Ducz JK, Bingham ML. 2014. Semantic context facilitates odor identification in children and adults. *Dev Psychobiol*. 56(3):592–598.
- Gudziol V, Hummel T. 2009. The influence of distractors on odor identification. *Arch Otolaryngol Head Neck Surg*. 135(2):143–145.
- Guinard J-X. 2001. Sensory and consumer testing with children. *Trends Food Sci Tech*. 11:273–283.
- Hedner M, Larsson M, Arnold N, Zucco GM, Hummel T. 2010. Cognitive factors in odor detection, odor discrimination, and odor identification tasks. *J Clin Exp Neuropsychol*. 32(10):1062–1067.
- Hugh SC, Siu J, Hummel T, Forte V, Campisi P, Papsin BC, Propst EJ. 2015. Olfactory testing in children using objective tools: comparison of Sniffin' Sticks and University of Pennsylvania Smell Identification Test (UPSIT). *J Otolaryngol Head Neck Surg*. 44:10.
- Hummel T, Bensafi M, Nikolaus J, Knecht M, Laing DG, Schaal B. 2007. Olfactory function in children assessed with psychophysical and electrophysiological techniques. *Behav Brain Res*. 180(2):133–138.
- Hummel T, Kobal G, Gudziol H, Mackay-Sim A. 2007. Normative data for the “Sniffin’ Sticks” including tests of odor identification, odor discrimination, and olfactory thresholds: an upgrade based on a group of more than 3,000 subjects. *Eur Arch Otorhinolaryngol*. 264(3):237–243.
- Hummel T, Sekinger B, Wolf SR, Pauli E, Kobal G. 1997. ‘Sniffin’ Sticks’: olfactory performance assessed by the combined testing of odor identification, odor discrimination and olfactory threshold. *Chem Senses*. 22(1):39–52.
- Hummel T, Smitka M, Puschmann S, Gerber JC, Schaal B, Buschhütter D. 2011. Correlation between olfactory bulb volume and olfactory function in children and adolescents. *Exp Brain Res*. 214(2):285–291.
- Jadaui JB, Djordjevic J, Lundström JN, Pack CC. 2012. Modulation of olfactory perception by visual cortex stimulation. *J Neurosci*. 32(9):3095–3100.
- Kirk RE. 2007. *Statistics: an introduction*, 5th ed. Belmont (CA): Wadsworth Publishing.
- Konstantinidis I, Printza A, Genetzaki S, Mamali K, Kekes G, Constantinidis J. 2008. Cultural adaptation of an olfactory identification test: the Greek version of Sniffin' Sticks. *Rhinology*. 46(4):292–296.
- Laing DG, Segovia C, Fark T, Laing ON, Jinks AL, Nikolaus J, Hummel T. 2008. Tests for screening olfactory and gustatory function in school-age children. *Otolaryngol Head Neck Surg*. 139(1):74–82.
- Larsson M. 1997. Semantic factors in episodic recognition of common odors in early and late adulthood: a review. *Chem Senses*. 22(6):623–633.
- Larsson M, Finkel D, Pedersen NL. 2000. Odor identification: influences of age, gender, cognition, and personality. *J Gerontol B Psychol Sci Soc Sci*. 55(5):P304–P310.
- Larsson M, Nilsson LG, Olofsson JK, Nordin S. 2004. Demographic and cognitive predictors of cued odor identification: evidence from a population-based study. *Chem Senses*. 29(6):547–554.
- Lehrner JP, Glück J, Laska M. 1999. Odor identification, consistency of label use, olfactory threshold and their relationships to odor memory over the human lifespan. *Chem Senses*. 24(3):337–346.
- Lötsch J, Ullrich A, Hummel T. 2016. How many and which odor identification items are needed to establish normal olfactory functions? *Chem Senses*. 41(4):1–6.
- Monnery-Patris S, Rouby C, Nicklaus S, Issanchou S. 2009. Development of olfactory ability in children: sensitivity and identification. *Dev Psychobiol*. 51:268–276.
- Oleszkiewicz A, Taut M, Sorokowska A, Radwan A, Kamel R, Hummel T. 2015. Development of the Arabic version of the “Sniffin’Sticks” odor identification test. *Eur Arch Otorhinolaryngol*. 273(5):1–6.

- Richardson JT, Zucco GM. 1989. Cognition and olfaction: a review. *Psychol Bull.* 105(3):352–360.
- Sarafino EP, Armstrong JW. 1986. *Child and adolescent development*. St. Paul (MN): West Pub. Co.
- Schab FR. 1991. Odor memory: taking stock. *Psychol Bull.* 109:242.
- Schriever VA, Mori E, Petters W, Boerner C, Smitka M, Hummel T. 2014. The “Sniffin’Kids” Test-A 14-Item Odor Identification Test for Children. *Plos One.* 9:e101086.
- Shu CH, Yuan BC, Lin SH, Lin CZ. 2007. Cross-cultural application of the “Sniffin’Sticks” odor identification test. *Am J Rhinol.* 21:570–573.
- Silveira-Moriyama L, Carvalho MDJ, Katzenschlager R, Petrie A, Ranaivaud R, Barbosa ER, Lees AJ. 2008. The use of smell identification tests in the diagnosis of Parkinson’s disease in Brazil. *Mov Disord.* 23:2328–2334.
- Sorokowska A, Hummel T. 2014. Polish version of the Sniffin’ Sticks Test—adaptation and normalization. *Otolaryngol Pol.* 68(6):308–314.
- Sorokowska A, Schriever VA, Gudziol V, Hummel C, Hähner A, Iannilli E, Sinding C, Aziz M, Seo HS, Negoias S, *et al.* (2015). Changes of olfactory abilities in relation to age: odor identification in more than 1400 people aged 4 to 80 years. *Eur Arch Otorhinolaryngol.* 272:1937–1944.
- van Spronsen E, Ebbens FA, Fokkens WJ. 2013. Olfactory function in healthy children: normative data for odor identification. *Am J Rhinol Allergy.* 27(3):197–201.
- Strickland M, Jessee PO, Filsinger EE. 1988. A procedure for obtaining young children’s reports of olfactory stimuli. *Percept Psychophys.* 44(4):379–382.
- Tekeli H, Altundağ A, Salihoğlu M, Cayönü M, Kendirli MT. 2013. The applicability of the “Sniffin’ Sticks” olfactory test in a Turkish population. *Med Sci Monit.* 19:1221–1226.
- Valentin D, Chanquoy L. 2012. Olfactory categorization: a developmental study. *J Exp Child Psychol.* 113(3):337–352.
- Wechsler, D. (1967). *Wechsler preschool and primary scale of intelligence*. New York: Psychological Corporation.