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Review Article

Olfactory perception in children

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Abstract The ability to smell is important for protection from danger and quality of life, even in children. Although smell loss is rare in children, it can be indicative of some childhood disorders and may be useful for understanding some disorders. This paper reviews the methods and results of behavioral testing olfaction in children, with an emphasis on odor identification, the most common method of assessing the sense of smell in both children and adults. The Pediatric Smell Wheel® is described as a relatively new and powerful tool for testing olfaction in children as young as 4 years of age. An example of its use in testing children with a childhood disorders (autism spectrum disorder, ASD) is provided in addition to a review of the literature on smell function in ASD. It is possible to reliably test sense of smell in children as young as 4 years old and many studies have shown that performance improves with age and can be impacted by childhood disorders. Sex differences in children are briefly discussed. Finally, the paper suggests other methods of testing olfaction in children, such as odor discrimination, that depend less on cognitive factors, which may enhance our understanding of the olfactory capabilities of young children.

Importance of olfaction in daily life

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, compared to adults, smell loss is relatively uncommon in children.[4] A recent analysis of over 1200 consecutive

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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 reported that only 4% of that patient population had smell loss deriving from childhood.[5] 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 medical conditions that children face, such as CHARGE[1],[8] obesity,[9] head trauma,[10,11] cleft palate,[12,13] and cancer.[14] Moreover, olfactory testing may shed light on neurodevelopmental disorders, including attention-deficit/hyperactivity disorder[15,16] and autism spectrum disorder[17] and as will be discussed below.

The negative effect of aging in adults on olfactory function is clear,[18,19] but less is known about olfactory function in child development, at least in part because there are special challenges in the testing of olfaction in children. For example, at the same time that changes in olfactory function may be occurring, children are developing cognitively—improving their memory, linguistic skills and attention span as well as expanding their experience of the world. Thus, tests of olfaction must take care not to conflate perceptual and cognitive development. Given these potential clinical applications, there is clearly a need for a standardized, reliable, and child-friendly test of olfactory function.

Objective methods of testing olfaction in children

There are several methods of assessing human olfactory function (for further details, see the Measurement of Chemosensory Function article in this volume). The two most common tests are *odor detection threshold* and *odor identification* tests, although numerous other tests are sometimes employed, including tests of *odor discrimination, odor memory*, and *assessments of suprathreshold intensity changes as a function of odorant concentration*. Stimuli (odorants) can be presented in one of several ways, including in opaque jars or squeeze bottles, in microencapsulated Scratch and Sniff® labels,[20] or in convenient wands or pen-like dispensers ("Snap & Sniff®" wands[21] and Sniffin' Sticks[22]).

Threshold Detection tasks typically use a "staircase" procedure (in which odor concentration is increased or decreased depending upon the participant's response on a previous trial) and determine the minimum concentration of an odor that can be detected. *Tests of Odor Identification* involve selecting a verbal label or picture associated with several (usually four) multiple choice response alternatives that best matches an odor. Odor identification is the most popular since it is reliable, practical, rapid and commercially available. Several tests of odor identification have been developed to test adults, including 40-, 12-, 8-, 4-, and 3-item versions of the University of Pennsylvania Smell Identification Test (UPSIT), a microencapsulated odorant test that presents odors in booklet form,[20] the "Sniffin' Sticks Test", a 16-item test that uses pen-like devices,[22] the 13-item Japanese "Odor Stick ID Test"[23] and the 16-item "Scandinavian Odor ID Test".[24]

Odor Discrimination involves, in its simplest form, the presentation of two stimuli in rapid succession and asking the participant to indicate whether the two stimuli are the same or different. A "triangle" version of this task involves presenting three stimuli and asking the participant to indicate which one differs from the other two. *Odor Memory* typically invokes recognition memory. A common paradigm is to have a participant smell and remember one or more odors and then to select, from a set of odors, the odor(s) that were previously smelled. Performance on tests of odor detection, discrimination, identification, and memory are highly correlated, suggesting that they measure the same underlying neural processes.[25]

Changes in olfactory performance in childhood

Odor detection threshold

While odor detection threshold measures do not require knowledge of the identity of odors, results from such tests have been variable, reflecting, in part, attention and reliability issues, as well as the influences of repeated testing. Moreover, many fewer studies have measured odor detection threshold (compared to odor identification) in children (Table 1). Toulouse and Vaschide[26] found that children between the ages of 3 and 12 improved in their ability to detect camphor as they aged. Dorries et al[27] 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[28] 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[29] found no decrease in thresholds with age across the age span of 4—12 years 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.[8,30—32] Solbu et al[33] have even found enhanced smell function in children relative to adults for trimethylamine (a fishy odor).

Odor identification

Odor identification, as measured using tests designed for adults, varies as a function of age-poorer performance is seen in both young children[34](Fig. 1) and in the elderly

[1] "CHARGE is an abbreviation for several of the features common in the disorder: coloboma, heart defects, atresia choanae (also known as choanal atresia), growth retardation, genital abnormalities, and ear abnormalities." https://ghr.nlm.nih.gov/condition/charge-syndrome.

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