# Maturation of odour identification ability and related factors in children*

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## Abstract

**Background**: Olfaction plays an important role in our daily and social lives, both as adults and as children. This study assessed whether the ability to identify odours increases with age, as well as the ability in various age groups and the factors involved.

**Methods**: The survey was performed in 2017 on 697 Japanese children (366 girls and 331 boys) aged 6–18 years who lived in Tsunan, Niigata Prefecture, Japan by using the 'Open Essence', a card-type odour identification test. We collected information regarding age, sex, and physical characteristic. We also inquired whether participants had siblings or if members of the family smoked, and whether they had conversations about odour at home. Statistical analysis was performed to evaluate the factors affecting odour identification abilities.

**Results**: The results showed that the odour identification abilities of children increase with age, and children who have daily conversations about odours at home have better odour identification abilities.

**Conclusions**: Odour identification ability increases with age. In addition, our findings suggest that conversation may positively affect odour identification. Hence, it is important for children to be exposed to an environment where they develop an interest in smells for better growth of their olfactory identification ability.

**Key words**: conversation, odour identification, odorant, olfaction

## Introduction

The ability of individuals to identify odours changes throughout their lifetime(1-3). Several odour identification tests have been developed, and it is known that odour identification ability increases through childhood(1-9). Olfaction can affect important aspects of life, including brain function, the choice of a future partner(10, 11), and other social activities(10-12); hence, the identification of factors affecting olfaction is important and of significant interest.

Additionally, cultural differences are known to affect the results(8, 12). In adults, it is known that sex(1-5, 7-9, 11-12), height(2), weight(2), body mass index (BMI)(2, 4, 13), and sex hormones(2, 12) affect odour identification. However, the factors that positively or negatively affect odour identification in childhood are still under discussion. Moreover, daily life environmental factors in children are particularly underexplored.

There have been several reports on odour identification and environmental factors in children. Studies suggest that smoking or passive smoking may affect olfaction in children(4, 12), and those children who help with cooking, are exposed to domestic animals, or have siblings tend to be aware of and are able to recognise related odours(11). Furthermore, children with more exposure to odours(11) and those whose parents show a higher interest in odour demonstrate better odour identification abilities(12). Therefore, we hypothesise that certain environmental factors at home can affect olfactory development and odour identification in children.

In the present study, we performed a survey with an odour-related questionnaire and assessed odour identification with the Open Essence test[14-16] (OE) to evaluate the factors affecting odour identification abilities in children. OE is the major odour identification screening test for adults in Japan and was selected because of its simplicity and ease of adaptation for use in children. However, its effectiveness or the score which distinguishes normosmia from olfactory dysfunction in children is unknown, and this test is different from other odour identification tests because it does not involve forced choices. We believe that this may change the results with respect to odour identification. We incorporated the 10th percentile OE score for each age from this study into our findings to establish the score that distinguishes normosmia from olfactory dysfunction, thereby adapting this screening test for use in children following the method used in earlier studies by Schriever et al.[5, 8].

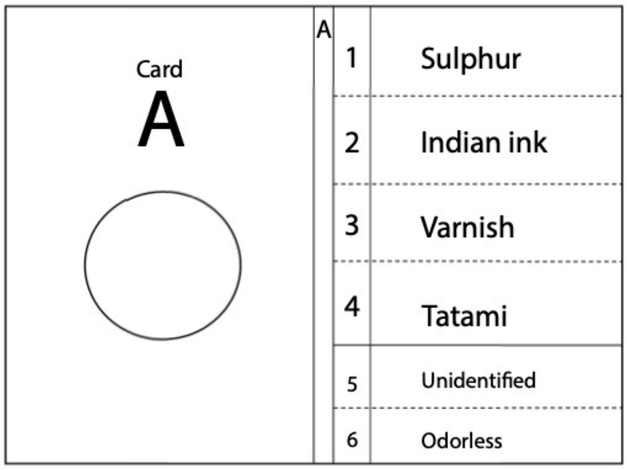


Figure 1. Sample of Open Essence test card translated in English. Name of choices are actually written in Japanese.

## Materials and methods

### Study population and sampling

The subjects were selected from elementary, junior, and high school students in Tsunan, a town in Niigata Prefecture, Japan, in 2017. We excluded immigrants and students requiring special care. The selected area is rural, with a rich natural landscape and a population of under 10,000 people. We selected this area to minimise cultural bias. The survey was performed in seasons other than winter to avoid the period when the common cold can be contracted. Before the survey, assent and informed consent were obtained from the children and their parents or guardian, respectively. The OE test kits and questionnaires were distributed to the children at school by the teachers; the children were asked to provide answers to the OE test by themselves and respond to the questionnaire with their parent or guardian at home. The answers were collected from the school approximately 1 month later.

### Sensory testing

The OE test is a 12-card odour identification test for adults. It was published in 2008 by the Japanese National Institute of Advanced Industrial Science and Technology. The odorants included Indian ink, wood perfume, menthol, Japanese orange, curry, household gas, rose, hinoki cypress, sweaty socks, condensed milk and roasted garlic. Each odour is enclosed in a microcapsule and sprayed on each card. When subjects open and fold the card in half and rub the halves together, the microcapsule pops and the odour is released. The subject sniffs the odour and selects 1 of the 6 given descriptors (answers 1 to 4 refer to the specific odour emitting object, 5 is 'Unidentified', and 6 is 'Odourless') (Figure 1). The normative score for adults is 8 or greater[16]. All participants performed the test.

### Questionnaire

In addition to the OE test, we collected information regarding age, sex, and physical characteristics, i.e., weight (kg) and height (cm), and calculated the BMI. We also inquired whether participants had siblings or if members of the family smoked, and whether they had conversations about odour (Supplementary Data 1). Parents or guardians were allowed to help the children to read and understand the available answers. However, they were informed not to disclose the correct answers to their children to ensure proper evaluation. We used the BMI percentile to define overweight and obese children. A BMI from percentile 85 to below 95 was defined as overweight, and that above 95 as obese.

### Statistical analysis

All statistical analyses were conducted using the program "SPSS" version 24 (IBM Corp., Armonk, NY, USA). P values <0.05 were considered statistically significant. The correlation between the OE score and age, height, weight, and BMI was analysed based on the R-value and the p-value using Pearson's test. The difference of OE score between sex and the presence of siblings, passive smoking in the home, and conversation about odours at home was analysed using Student's t test. And to establish the score that distinguishes normosmia from olfactory dysfunction, the children were classified into the following 3 groups based on age: 6–9 years, 10–14 years, and 15–18 years. Each group was assessed using the mean test scores, standard deviations, minimum scores, maximum scores, 10th percentile scores.

### Ethics

This study was performed in accordance with the guidelines of the Declaration of Helsinki on Research Involving Human Subjects and was approved by the local ethical committee of The Jikei University Hospital (26-126 [7631]).

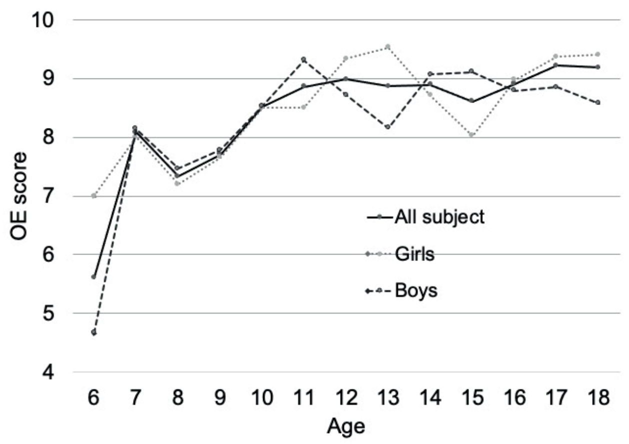


Figure 2. Age-related differences in OE scores from 6 to 18 years of age.

## Results

### Subjects

The subjects of this study were 697 children (366 girls and 331 boys) aged 6–18 years. The OE test scores from all subjects had a mean value of 8.68 and ranged from 1 to 12.

### Age and sex

The lowest (5.60) and highest (9.22) mean OE test scores were observed among children aged 6 and 17 years, respectively. Among girls, the mean test score was lowest (7.00) in 6-year-olds and highest (9.53) in 13-year-olds. Among boys, the mean test score was lowest (4.67) in 6-year-olds and highest (9.31) in 11-year-olds (Figure 2). Age and test score was positively correlated (R = 0.183, P < 0.001 (Table 1). However, the scores of girls and boys did not differ significantly (t=1.210, P = 0.227) (Table 2).

Table 1. The correlation between age, height, weight, BMI, and OE score[a].

| Correlation (Pearson) | R-value | P-value |
|---|---|---|
| Score-age | 0.183 | < 0.001 |
| Score-height | –0.066 | 0.148 |
| Score-weight | –0.044 | 0.338 |
| Score-BMI | –0.018 | 0.699 |

[a]All factors are analysed with the R-value and p-value using Pearson's test. A p-value < 0.05 indicates significance. Abbreviations: BMI, Body Mass Index.

### Physical condition

Twelve children (9 girls and 3 boys) were overweight, and 13 children (6 girls and 7 boys) were obese. The mean test score was not correlated with either height (R = –0.066; P = 0.148), weight (R = –0.044; P = 0.338), or BMI (R = –0.018 P = –0.699) (Table 1).

### Home environment

The mean OE test scores of children who had siblings (8.92 ± 2.06) and those who did not (8.62 ± 1.82) were not significantly different (t = –1.023, P = 0.307). Furthermore, the mean OE test scores of children who had family members who smoke (8.92 ± 2.04) and those who did not (8.74 ± 2.06) were not significantly different (t = –0.256, P = 0.798). However, the mean test score of children who had a conversation about odours at home (9.16 ± 1.95) was significantly higher than that of those who did not (8.74 ± 2.06, t = –2.216, P = 0.027) (Table 2). To investigate the relationship between age and having had a conversation about odours at home, we additionally compared these groups; howe-

Table 2. Difference between sex, siblings, family smoking, and conversations about smell at home[†].

| Characteristic | | No. of subjects | Mean | SE | t-value | P-value |
|---|---|---|---|---|---|---|
| Sex | | 697 | | | 1.210 | 0.227 |
| | Boy | 331 | 8.58 | 2.06 | | |
| | Girl | 366 | 8.77 | 2.36 | | |
| Siblings | | 491 | | | –1.023 | 0.307 |
| | Yes | 438 | 8.92 | 2.06 | | |
| | No | 53 | 8.62 | 1.82 | | |
| Family smoking | | 492 | | | –0.256 | 0.798 |
| | Yes | 214 | 8.92 | 2.04 | | |
| | No | 278 | 8.74 | 2.06 | | |
| Talk about smell at home | | 463 | | | –2.216 | 0.027 |
| | Yes | 184 | 9.16 | 1.95 | | |
| | No | 279 | 8.74 | 2.06 | | |

[†]All factors are analysed with the t-value and p-value using t-test. A p-value < 0.05 indicates statistical significance. Abbreviations: Mean, mean Open Essence test score; SE, standard error.

Table 3. Number of subjects and the Open Essence score for 3 different age groups†.

| Characteristic | Age group 1 | Age group 2 | Age group 3 |
|---|---|---|---|
| Age, years | 6 to 9 | 10 to 14 | 15 to 18 |
| All subjects | 101 | 360 | 236 |
| Boys | 51 | 183 | 98 |
| Girls | 50 | 177 | 138 |
| Mean score ± SE | 7.58 ± 2.29 | 8.86 ± 2.02 | 8.87 ± 1.99 |
| Median score | 8 | 9 | 9 |
| Minimum score | 2 | 2 | 1 |
| Maximum score | 12 | 12 | 12 |
| 10th percentile score | 5 | 6 | 7 |
| Lower than 10th percentile score (n) | 9 | 24 | 21 |
| Lower than 10th percentile score (%) | 8.91 | 6.66 | 8.89 |

†All factors are analysed with the p-value using Pearson's test. A p-value < 0.05 indicates statistical significance. Abbreviation: SE, standard error.

ver, no relationship was observed (t = 0.544, P = 0.587).

**The 10th percentile OE test scores of children from each age group**

The 10th percentile score was calculated; the scores were 5, 6 and 7 in children aged 6–9 years, 10–14 years, and 15–18 years, respectively (Table 3).

**Selection of 'unidentified' and 'odourless'**

The OE test contained two unforced choices, which were 'unidentified' and 'odourless' (Figure 1). 'Unidentified' was most commonly selected for 'Japanese orange' by 81 children (11.6%), followed by 'Indian ink' by 49 (7.0%) and 'condensed milk' by 47 (6.7%). 'Unidentified' was least commonly selected for 'curry' by 2 children (0.3%), followed by 'sweaty socks' by 13 (1.9%). 'Odourless' was most selected for 'roasted garlic' by 22 children (3.2%), followed by 'condensed milk' by 14 (2.0%) and 'Japanese orange' by 12 (1.7%). Only two children selected 'unidentified', and none of the children selected 'odourless' for 'curry'.

## Discussion

In the present study, the OE test and the questionnaire survey performed in children aged 6–18 years showed that the mean OE test score increased with age. Among the factors examined, talking about odours at home was the only factor that was positively associated with the OE test score. Finally, we calculated the 10th percentile OE value in each age group of children based on the study findings.

An olfactory measurement has three major elements as follows: odour detection, identification, and discrimination. Each element has a different maturation period during development in a child. Olfactory ability has been reported in the late trimester of pregnancy[17, 18], and detection[17-20] and discriminatory abilities are noted in infants and children[17, 21]. However, odour identification is supposedly less pronounced in younger children[1-5, 7].

Among the factors examined for their involvement in odour identification in the present study, the age of the child was found to be positively associated with the OE test score; this is consistent with the findings of previous studies[1-9]. Although these studies used different odour identification tools, they all demonstrated that odour identification ability increased with age. Furthermore, the studies differed across countries, regions, and residential environments. Nevertheless, the odour identification ability generally reached a plateau when children were approximately 11 years of age[1-4].

Although sex-specific differences in odour identification abilities have been documented for several decades[1-5, 7-9, 11-12], there was no sex difference in the present study; this issue remains highly debated because of the differences in the tests performed. In addition, odour identification is affected by subjects' language abilities and daily experiences[10-12, 22]. Social perceptions of gender have changed significantly during the last several decades, as have opportunities linked to education and work. Differences in historical backgrounds or cultures may cause sex-specific differences in odour identification abilities.

Among the variables examined in the present study, three showed no relation with the OE test score. First, we found no relation between the OE test score and physical variables, such as height, weight, and BMI. However, several other studies have also found no relation between odour identification ability and height[2], weight[2], or BMI[2,4,13]. On the contrary, obesity had been found to decrease odour identification abilities[13]. As only 25 children were overweight or obese, whether these variables are correlated with the OE test score remains unclear from our data.

A second variable with no relation with the OE test score in this study was the presence of siblings when participants lived in a similar environment; few reports have mentioned this variable in relation with odour identification, stating that awareness of odour in daily life might affect olfaction[11-12, 22]. However, odour identification abilities differ among people from different countries, even within the same age group[8]. Moreover, the geographical region within a country can also affect odour identification capacities[8]. Therefore, a more detailed questionnaire is needed for evaluating this issue.

The third variable with no relation with the OE test score in the present study was the presence of a smoker in the child's family. The health hazards linked to active and passive smoking are well known. Passive smoking is a risk factor for airway diseases[23] that can impair intellectual development[24]. In addition, active[1, 4, 25-27] and passive[25] smoking are risk factors for olfactory disorders in adults. Since both active and passive smoking negatively affects odour identification abilities in adults[25], we expected passive smoking to be associated with lower OE test scores in the present study. However, our results did not support this hypothesis because our questionnaire only asked whether there are smokers in the house and did not investigate other details such as smoking quantity. Therefore, our findings do not prove whether passive smoking is involved in the development of odour identification in children.

The most important finding of our study is that we observed a positive influence on the OE test score by children's opportunity to talk about odours with their families at home. We selected this factor because we assumed that if children live with families who regularly talk about odour, they are likely to be more conscious of odours than other children. One study showed that children of parents who are more aware of odours have better olfaction than other children[12]. The ability of children to identify and discriminate odours may be related to their families[12] and awareness of odours[11-12, 22]. Furthermore, the olfactory abilities of healthy children[28] and adults who have olfactory dysfunction[29] can be improved through olfactory training. Awareness and repeated exposure to odour may positively affect olfaction in children. Our result supported that it is important for children to be exposed to an environment where they develop an interest in smells for better growth of their olfactory identification ability, but further evidence is required to confirm a causal link between exposure and olfactory development.

The results show that a certain percentage (0.3–12.1%) of the children answered that they did not recognise the odour, or that there was none (0–3.3%). Since the test was conducted in a wide range of age groups, from 6 to 18 years, it is possible that some children had only guessed the answer if they could not comprehend the odour; however, only 2 children selected the 'unidentified' response, and none selected 'odourless' for 'curry'. We believe that most of the children could answer with help from their parent/guardian.

The present study found that the OE test scores of children were lower than those of adults but improved with age. The 10th percentile score of OE was 5 for children aged 6–9 years, 6 for children aged 10–14 years, and 7 for children aged 15–18 years. This finding may be useful to distinguish olfactory dysfunction from normosmia. However, we need to compare these for use in clinical practice.

Our study had several limitations. The questionnaire for parents was filled out at home, and we were not able to examine whether they answered honestly. The OE test was also performed at the children's homes; we could not verify whether the participants completed the tests by themselves. This may bias result in younger children and explain the slight dip at 7-9 years old. In addition, the descriptors in the OE test were based on letters written on cards without drawings; the absence of drawings suggests that younger participants may not have understood some of the words and may have received higher scores if pictures were shown[6,30]. There were missing values for physical conditions including weight, height, and BMI, as well as environmental factors including passive smoking, siblings, and talking about odours.

## Conclusion

The opportunity to talk about odours with families at home improves olfactory identification abilities in children. Our result indicates that it is important for children to be exposed to an environment where they develop an interest in smells for better growth of their olfactory identification ability, but further evidence is required to confirm a causal link between exposure and olfactory development.

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## Authorship contribution

EM: conceptualisation, data collection and analysis, funding acquisition, investigation, methodology, resources, and total project administration and supervision. RSe: data analysis and writing of the original draft. YT: data analysis. RSa: data analysis. MT: writing, review, and editing of the manuscript. HK and NO: supervision and writing, review, and editing of the final manuscript.

## Conflict of interest

None of the authors declare any conflict of interest.

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**This manuscript contains online supplementary material**

## SUPPLEMENTARY MATERIAL

Supp Data 1. The questionnaire administered to children's parent/guardian. [Translated from Japanese]

CONSENT AND QUESTIONNAIRE FORM

Q1. Do you agree to participate in this study and answer the questions below?
YES / NO (If the answer is NO, you do not have to answer the questions below.)

Q2. Do you have any siblings?
YES / NO

Q3. Is there anyone who smokes at home?
YES / NO

Q4. Please write the height and weight.
(      cm) / (      kg)

Q5. Do you have any conversations about 'odour' at home?
YES / NO

Name of children / Age of children          /          years old
Name of guardian / parent

Date of answer