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# Children's Personal Significance of Olfaction — the ChiPSO Questionnaire

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## Abstract

**Introduction** The human sense of smell has different functions which can be categorized as "food," "social," and "environment." Different questionnaires about the importance of olfaction in adults are available, but little attention has been paid to children and adolescents. Therefore, we aimed to develop a questionnaire about children's personal significance of olfaction (ChiPSO).

**Methods** The questionnaire was developed in two steps. The first questionnaire included 33 statements about the importance of olfactory information in daily life — covering three subscales "food," "environment," and "social" administered to 191 participants (mean age: 14.4 ± 1.7 years). The five best fitting items of each subscale were chosen for the final 15-item questionnaire. In the second part, we administered the developed questionnaire to 208 children and adolescents (mean age: 11.5 ± 3.5 years) who additionally underwent olfactory testing to investigate the association between olfactory function and questionnaire results. Participants were separated in two age groups: (i) 6–11 years (children), (ii) 12–17 years (adolescents).

**Results** A significant influence of age on the total ChiPSO score and all three subscales with adolescents scoring higher than children was found. Additionally, there was a significant influence of sex in adolescents on total ChiPSO score and subscales "social" and "food" with girls scoring higher than boys.

**Conclusion** We report an association between questionnaires results and olfactory performance. Additionally, olfactory information seems to be more important to adolescents compared to children and girls compared to boys.

**Implications** The ChiPSO questionnaire is a practical tool to evaluate the importance of olfactory information in children and adolescents aged 6–17 years.

**Keywords** Olfaction · Children · Questionnaire · Gender differences · Age differences

## Introduction

The human sense of smell has many different functions which were summarized in three categories by Stevenson (2010). The first one concerns ingestive behavior. The fact that mammals detect and identify potentially edible food by their sense of smell (e.g.Vander Wall et al. 2003; Schleich and Zenuto 2007; Hiramatsu et al. 2009)) is well known. Humans also are able to follow a scent trail (Porter et al. 2007), although this skill is less useful in our industrialized lifestyle. In addition, our food intake is regulated by olfaction, specifically retronasal olfaction. The "appetizer effect" describes the more palatable a food is, the more hunger it causes, and the more food is consumed (Yeomans 2000). Even the youngest, newborns, use their sense of smell to find the mothers nipple and start suckling (Varendi et al. 1994).

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Another important function of olfaction is hazard avoidance. Humans are able to learn that a perceived odor is dangerous when they have a somatic reaction to it (Van den Bergh et al. 1999). Potential microbial hazard is avoided by developing a disgust against, e.g., the smell of feces and vomit (Stevenson et al. 2010). The third function of olfaction is social communication (Stevenson 2010). For example, several studies suggest that the sense of smell plays a role in inbreeding avoidance (Wolf 1995; Weisfeld et al. 2003; Matchock and Susman 2006; Hochberg and Belsky 2013). In addition, women without contraceptive medication prefer the odor of men with dissimilar MHC constitution than their selves (Wedekind et al. 1995; Wedekind and Furi 1997) and olfaction in mate choice is more important to women compared to men (Herz and Inzlicht 2002; Havlicek et al. 2008). Different diseases have an individual odor (Liddell 1976; Brown 1995) and can hence be identified by humans (for review seePenn and Potts 1998; Penn and Potts 1998)). Next to the identification of illness (representing physical stress), also mental stress can be identified (Ackerl et al. 2002) and can activate brain structures associated with empathy (Prehn-Kristensen et al. 2009). Newborns change their behavior and become calm when smelling the odor of their mother's breastmilk (Nishitani et al. 2009; Cakirli and Acikgoz 2021).

There are different questionnaires about the importance of smell in adults (for a review see Han et al. 2021; Han et al. 2021)). In contrast, the importance of olfaction in children and adolescents has gained little attention. Questionnaires developed for adults cannot easily be applied to the pediatric cohort because of questions complexity, a shorter attention span, and different responsibilities and daily life activities in children (e.g., food purchase). Thus, we only know little about the importance of olfaction in children and adolescents. Croy et al. (2010) developed a questionnaire on the individual significance of olfaction in adults with three subscales: "association," "application," and "consequence." In this context, "association" implicates questions, which are unconscious processes triggered by the sense of smell (e.g., emotions). "Application" describes how often a person uses his sense of smell in daily life. Finally, "consequence" reflects, whether the sense of smell has an impact on daily life decisions (Croy et al. 2010). This questionnaire was slightly modified and used in older children and adolescents (aged 10 to 17 years) (Oleszkiewicz et al. 2016). A significant effect of age on the personal significance of olfaction, more precisely in subscale "application" but not on subscales "consequence" and "association," was observed and was higher in girls than in boys (Oleszkiewicz et al. 2016). These results may be explained by increasing interest in olfactory importance with rising claim to independence in older age groups according to pubertal status. According to human evolution, there are evolutionary and developmental changes in boys and girls in adolescence linked with an interest shift from parents to peer group (Hochberg and Belsky 2013). These findings might also be linked to processing of olfactory information, such as mate selection (Martinec Novakova et al. 2017).

Only one questionnaire was exclusively conducted to investigate the smell-importance in children (Ferdenzi et al. 2008b, a). Ferdenzi et al. conducted the Children's Olfactory Behavior in Everyday Life (COBEL) questionnaire with 16 items. It uses different answer formats, such as multiple choice, alternative format, and open questions, and therefore, its result calculation can be complicated. In accordance with the present work, items were separated into the subscales "food," "social," and "environment." In the first COBEL study, children's age ranged from 6 to 10 years. Only in a subsequent study was the COBEL questionnaire applied to older age groups (Saxton et al. 2014). Ferdenzi et al. found an influence of age on the COBEL questionnaire with higher scores in older children. When adjusted for verbal fluency, the influence of age on COBEL scores lost its significance (Ferdenzi et al. 2008b, a). However, the age range in their study was small with children ranging from 6 to 10 years. A wider age range including adolescents would yield more information about the importance of olfaction. The findings by Ferdenzi et al. (2008b, a) were replicated in a consecutive study by the same group, observing higher scores in older children compared to younger ones. Furthermore, a few studies using the COBEL questionnaire showed significantly higher scores in girls compared to boys (Ferdenzi et al. 2008b, a; Ferdenzi et al. 2008b, a; Saxton et al. 2014, Novakova et al. 2018). No association between questionnaire results and olfactory function was found (Novakova and Mrzilkova 2016).

We aimed to develop another questionnaire investigating the Children's personal significance of olfaction (ChiPSO) which (a) is based on the COBEL and on the functions of olfaction according to Stevenson (2010), (b) is applicable to a broad age spectrum in children and adolescents, and (c) has a high practicability because of low time requirement and simple application. Additionally, olfactory testing was performed to evaluate the association between importance of olfaction and performance in odor identification and olfactory threshold testing. Furthermore, we analyzed the influence of age and sex on questionnaire results. The study was divided in two Parts. Part I: Development of the questionnaire; Part II: Influence of age, sex, and smell performance on personal significance of olfaction.

Based on the results of previous studies, we hypothesize that older participants would have higher questionnaire score. Furthermore, we expect girls to have higher questionnaire

scores compared to boys. Lastly, we hypothesize that those with a higher olfactory testing score would have a higher questionnaire score than those with a low olfactory testing score.

## Part I

### Material and Methods

**Participants** A total of 191 children and adolescents (boys: 97 and girls: 94, mean age: 14.4 ± 1.7 years; range: 11–18 years) participated. All participants were recruited from 7 to 12th class in a secondary school in Germany. The task was explained in detail to the participants by the examiner. No time limitation was enforced on answering the questionnaire. Participants and their parents were informed about the study and provided informed consent for study participation. All aspects of the study were compliant with the Declaration of Helsinki. The ethics committee of the technical university Dresden approved the study (EK 284072017). The authors declare no conflicts of interest.

**Questionnaire** The development of the questionnaire was done in two steps. Based on the questionnaire "Individual significance of olfaction" (Croy et al. 2010) and the questionnaire "Children's Olfactory Behavior in Everyday Life" (COBEL) (Ferdenzi et al. 2008b, a; Bjorklund et al. 2018), a first questionnaire including 33 questions about the importance of olfactory information in daily life was designed to assess for comprehensibility, redundancy, and coherence with the main score and the subscales. The questionnaire includes three subscales (I) "food," (II) "environment," and (III) "social" aspects. Each item was formulated as a personal statement and had a four-scaled answer format (4, "I totally agree"; 3,"I mostly agree"; 2, "I mostly disagree"; and 1, "I totally disagree"). The total score ranged between 33 and 132 points. The five best fitting items of each subscale were chosen for the final 15-item version of the questionnaire.

**Statistical Analyses** SPSS Statistics 28.0 (IBM SPSS statistics, Armonk, NY, USA: IBM Corp) was used for statistical analysis. A principal component analysis was conducted to select the five best fitting items with the highest loading for each of the three subscales. The principal component analysis was performed for the 33 items with a fixed number of factors (number of factors = 3) using Oblim with Kaiser-Normalization as rotation method. Factor loadings < 0.3 were suppressed for display. Further analyses with the selected items were conducted in view of age corrected partial correlation between subscales and total score as well as a principal component analysis with the above-mentioned settings for the final 15-item questionnaire. For testing internal reliability in 15-item questionnaire, Cronbach's alpha test was used.

### Results

A total of 191 children and adolescents answered the 33-item questionnaire. The Kaiser–Meyer–Olkin test (KMO) was 0.74 and the Bartlett's test of sphericity was highly significant with $p < 0.001$. Using a principal component analysis, the loading for each item in the three categories was calculated (Table 1). After checking for redundancy, the five items with the highest loading in each subscale were used to develop a final 15 item questionnaire (Tables 2 and 3). A loading of 0.3 was set as the lower cutoff for acceptance of an item. Some items with a loading higher than 0.3 were discarded because of redundancy.

Further analyses of the questionnaire were conducted using the final 15-item version (Table 2). As was done previously, a Kaiser–Meyer–Olkin test was performed and yielded a KMO of 0.71. The Bartlett's test of sphericity was highly significant with $p < 0.001$. The principal component analysis gave loadings for each item in the corresponding subscale between 0.424 and 0.855. Factor loadings below 0.3 are not displayed. No overlap between factor loadings greater than 0.3 was observed. The three factors and thus associated subscales were clearly separable from each other.

Partial correlation analysis showed a significant positive correlation between all three subscales, ranging between $r = 0.46$ and 0.53 ($p < 0.001$). Additionally, a high positive correlation between the three subscales and the total score was observed, ranging from $r = 0.78$ to 0.83 ($p < 0.001$) (Table 4).

The questionnaire showed a good internal reliability in total (Cronbach's alpha = 0.79) and in each subscale: "food" (Cronbach's alpha = 0.69), "environment" (Cronbach's alpha = 0.69), and "social" (Cronbach's alpha = 0.77).

## Part II

### Material and Methods

**Participants** The second part of the study aimed to examine the influence of age, sex, and olfactory performance on the ChiPSO. A total of 208 children and adolescents (boys: 104 and girls: 104; mean age: 11.5 ± 3.5 years; range: 6–17 years) participated. All participants were recruited via posters. Children and their parents/legal guardians were informed about the procedure and aim of the study in written and verbal form. Children younger than 8 years only received a verbal explanation about the procedure. Written informed consent was obtained from the parents/legal

**Table 1** Factor loadings for each statement of the 33-item questionnaire. Factor loadings < 0.3 are not displayed. The selected items for the final questionnaire are highlighted in bold

| Item number | Statement | Environment | Social | Food |
|---|---|---|---|---|
| Item 32 | **It would bother me if there were no odors anymore** | **0.699** | | |
| Item 9 | **When I walk on the street, I normally smell something of the surrounding** | **0.687** | | |
| Item 21 | It would bother me, if I could not smell anymore | 0.635 | | |
| Item 27 | **I normally try to find out where an odor comes from** | **0.607** | | |
| Item 22 | **When I smell an odor around me, I try to guess what it is** | **0.584** | | |
| Item 24 | **I like to smell the odors around me when I walk in nature** | **0.564** | | |
| Item 18 | If I smell something, I try to find out where it comes from | 0.526 | | |
| Item 17 | I know the smell of my bedroom | 0.515 | | |
| Item 29 | I do know how my blankets/stuffed animals smell/have smelled | 0.436 | | |
| Item 6 | Certain smells immediately activate memories | 0.316 | | |
| Item 28 | I smell on food to find out whether it is spoiled or not | | | |
| Item 26 | I think that people smell of something, even without perfume or deodorant | | | |
| Item 14 | The smell of a person plays a role in the decision weather I like him/her | | | |
| Item 25 | When I smell delicious food, I get hungry | | | |
| Item 31 | **I smell myself to check whether I have a bad odor** | | **−0.761** | |
| Item 2 | **It happens that I smell my clothes** | | **−0.755** | |
| Item 20 | **It happens that I smell parts of my body** | | **−0.738** | |
| Item 33 | **I smell my cloth to check whether it has to be washed** | | **−0.586** | |
| Item 8 | **I find that my parents smell of something** | 0.307 | **−0.474** | |
| Item 11 | When I am sweating, I can smell it | | −0.449 | |
| Item 12 | If someone is smoking next to me, it bothers me | | | |
| Item 16 | I smell my breakfast before eating it | | | 0.740 |
| Item 10 | **I sniff on food before eating** | | | **0.736** |
| Item 7 | **If there is a dish on the table that I don't know I would smell it before eating** | | | **0.603** |
| Item 4 | I smell tea/lemonade before drinking it | | | 0.573 |
| Item 19 | **When I don't like the smell of a food I don't eat it** | | | **0.549** |
| Item 13 | **Smelling nasty odors while eating usually make me lose my appetite** | | | **0.530** |
| Item 1 | **The smell of a food plays a role in the decision whether I like it or not** | | | **0.512** |
| Item 30 | I feel rather quickly disturbed by odors in my environment | | | 0.391 |
| Item 5 | If my parents have a nasty smell, I don't hug them | | | 0.368 |
| Item 15 | It happens that I smell school tools | | | 0.320 |
| Item 3 | When there is a nasty smell in a room, I leave the room as soon as possible | | | 0.312 |
| Item 23 | If a schoolmate has a nasty smell, I try to stay away | | | |

guardians prior to the study. All children and adolescents gave their assent to participate in the study. All aspects of the study were compliant with the Declaration of Helsinki. The local ethics committee approved the study (EK 318082017). The authors declare no conflict of interest.

**Procedure** After explaining the study procedure in detail, olfactory testing using the "Sniffin' Sticks" was assessed. This was followed by performing the questionnaire that was developed in the "Part I" section.

**Olfactory Assessment** Standardized smell tests were used for assessing olfactory function. The olfactory threshold subtest of the validated "Sniffin' Sticks" (Kobal et al. 1996; Hummel et al. 2007) and the "U-Sniff" odor identification test for children (Schriever et al. 2018) were used to measure the olfactory function of the participants. The odorants were presented in felt tip pens ("Sniffin' Sticks", Burkhardt GmbH, Wedel, Germany).

For the olfactory threshold test, the n-butanol and phenyl ethyl alcohol (PEA) olfactory threshold test was used in the wide step method, described by Croy et al. (2009). The tests were executed in a staircase procedure starting with the highest dilution of n-butanol and PEA. The tests consisted of 8 triplets of "Sniffin' Sticks." One felt tip pen of each triplet contained n-butanol or PEA dilution while the other two pens were odorless. The possibility of visual identification of the odor-containing pen was eliminated by blindfolding the

**Table 2** Factor loadings for each item of the 15-item questionnaire. Factor loadings < 0.3 are not displayed

| New item number | Statement | Social | Environment | Food |
|---|---|---|---|---|
| Item 15 | I smell myself to check whether I have a bad odor | 0.855 | | |
| Item 2 | It happens that I smell my clothes | 0.810 | | |
| Item 8 | It happens that I smell parts of my body | 0.805 | | |
| Item 13 | I smell my cloth to check whether it has to be washed | 0.656 | | |
| Item 5 | I find that my parents smell of something | 0.424 | | |
| Item 3 | When I walk on the street, I normally smell something of the surrounding | | 0.753 | |
| Item 9 | When I smell an odor around me, I try to guess what it is | | 0.679 | |
| Item 11 | I normally try to find out where an odor comes from | | 0.667 | |
| Item 6 | It would bother me if there were no odors anymore | | 0.649 | |
| Item 14 | I like to smell the odors around me when I walk in nature | | 0.583 | |
| Item 4 | When I don't like the smell of a food I don't eat it | | | 0.712 |
| Item 12 | The smell of a food plays a role in the decision whether I like it or not | | | 0.672 |
| Item 10 | Smelling nasty odors while eating usually make me lose my appetite | | | 0.645 |
| Item 1 | I sniff on food before eating | | | 0.623 |
| Item 7 | If there is a dish on the table that I don't know I would smell it before eating | | | 0.604 |

**Table 3** Final 15-item questionnaire

| | | I totally agree | I mostly agree | I mostly disagree | I totally disagree |
|---|---|---|---|---|---|
| 1 | I sniff on food before eating | | | | |
| 2 | It happens that I smell my clothes | | | | |
| 3 | When I walk on the street, I normally smell something of the surrounding | | | | |
| 4 | When I don't like the smell of a food I don't eat it | | | | |
| 5 | I find that my parents smell of something | | | | |
| 6 | It would bother me if there were no odors anymore | | | | |
| 7 | If there is a dish on the table that I don't know I would smell it before eating | | | | |
| 8 | It happens that I smell parts of my body | | | | |
| 9 | When I smell an odor around me, I try to guess what it is | | | | |
| 10 | Smelling nasty odors while eating usually make me lose my appetite | | | | |
| 11 | I normally try to find out where an odor comes from | | | | |
| 12 | The smell of a food plays a role in the decision whether I like it or not | | | | |
| 13 | I smell my cloth to check whether it has to be washed | | | | |
| 14 | I like to smell the odors around me when I walk in nature | | | | |
| 15 | I smell myself to check whether I have a bad odor | | | | |

**Table 4** Age controlled partial correlation between subscales and total score

| | | Social | Food | Environment |
|---|---|---|---|---|
| Food | Correlation (r) | 0.46 | | |
| Environment | Correlation (r) | 0.46 | 0.53 | |
| Total score | Correlation (r) | 0.83 | 0.81 | 0.78 |

subjects. Applying a 3-alternative forced-choice paradigm, the children had to identify the odor-containing pen out of the triplet. After two successful or one false pen-identification, the next higher or lower concentration was induced. The staircase-procedure was repeated until seven reversal points were obtained. The average of the last four reversal points yielded the individual olfactory threshold. Sixteen points were the maximum score, which could be achieved in each olfactory threshold test (Hummel et al. 1997). Because subjectively normosmic children were examined, two olfactory threshold tests were used to achieve a wider dispersion of olfactory test scores. In addition, a suprathreshold test for children, the "U-Sniff" odor identification test, was applied (Schriever et al. 2018). Each of the twelve odorants including apple, banana, butter, coffee, cut grass, fish, flower, lemon, onion, orange, peach, and strawberry was administered separately to the participant. The task was to identify

the odorant with the help of four descriptors given in picture and writing. The examiner always read out the displayed cards and showed the labeled pictures. The interval between the odorant presentations was approximately 20 s. The number of correctly identified odors was summed to determine the odor identification score. The participants' scores could range from 0 to 12 points (Schriever et al. 2018).

**ChiPSO Questionnaire** The questionnaire was answered by paper and pencil. The statements and answer options were read to participants aged 6 to 11 years. Participants aged 12 to 17 years answered the questionnaire by themselves with no help from the parents being allowed. The statements of the questionnaire are displayed in Table 3.

**Statistical analyses** Descriptive analysis including mean and standard error was used to describe characteristics of the study population. Testing for normal distribution was performed using histograms, QQ-Plot, and Shapiro–Wilk test. Data were not normally distributed. Because of known differences in odor identification test between age groups, the study population was separated in two age groups (Gellrich et al. 2019, Gellrich et al. 2021). The first group ranged between 6 and 11 years (children); the second one included participants between 12 and 17 years (adolescents) with 104 participants in each group. Four generalized linear mixed models with Bonferroni post-hoc tests were applied to analyze the influence of sex (boys, girls), age group (6–11 years, 12–17 years), and their interaction on the dependent variables of total ChiPSO score as well as each subscale. A Man-Whitney-*U* test was conducted between age group/sex and olfactory performance. Spearman correlation analysis was used, analyzing correlations between age and subscales/total score of the questionnaire. An age-controlled partial correlation was conducted between olfactory performance and questionnaire score/subscale scores.

## Results

**Olfactory Performance** Considering the whole study population, the mean odor identification test score was 10.4 ± 0.1 points (range 5–12 points), 7.3 ± 0.2 points (range 1–14.5 points) in olfactory threshold test with n-butanol and 10.2 ± 0.2 points (range 1.5–15 points) in olfactory threshold test with PEA. Adolescents had a significantly better odor identification performance (children: 10.1 ± 0.2 points vs. adolescents: 10.7 ± 0.1 points; $U = 4230$; $p < 0.01$) and n-butanol detection threshold (children: 7.0 ± 0.3 points vs. adolescents: 7.6 ± 0.2 points; $U = 4413$; $p = 0.021$)). No differences in PEA olfactory threshold test between age groups (children: 9.9 ± 0.3 points vs. adolescents: 10.6 ± 0.3 points; $U = 4768$; $p = 0.14$) were observed. There was no main effect of sex in olfactory performance.

**Influence of Age and Sex on ChiPSO Questionnaire** The mean total score of the questionnaire was 42.2 ± 0.5 points (range: 20–55 points), 16.2 ± 0.2 points (range: 7–20 points) in subscale "environment," 13.3 ± 0.3 points (range: 5–20 points) in subscale "social" and in subscale "food" the observed mean was 12.8 ± 0.2 points (range: 5–20 points). A significant positive correlation between age and total score as well as age and all three subscales (total score: $r = 0.47$, $p < 0.001$; "food": $r = 0.15$, $p = 0.033$; "social": $r = 0.57$, $p < 0.001$; "environment": $r = 0.24$, $p < 0.001$) was observed.

Generalized linear mixed models were used to analyze the influence of age and sex on the total score of the questionnaire and its subscales. Findings of these analyses are summarized in Table 5.

**Total Score** There was a significant influence of age on total score ($F = 49.18$, $p < 0.001$), with adolescents scoring higher than children (children: 39.0 ± 0.7; adolescents: 45.4 ± 0.7;

**Table 5** Points, *F*- and *p*-values for age group, sex, and interaction (age group*sex) for total ChiPSO score and each subscale

| | | Children vs. adolescents | Boys vs. girls | Interaction (age group*sex) |
|---|---|---|---|---|
| " Food" | *F*-value: | **5.79;** | 4.20; | 3.84; |
| | *p*-value: | **0.017;** | 0.42; | 0.051 |
| | points: | **12.23 ± 0.31 vs. 13.27 ± 0.31** | 12.31 ± 0.31 vs. 13.19 ± 0.31 | |
| " Environment" | *F*-value: | **15.16;** | 0.57; | 0.57; |
| | *p*-value: | **< 0.001;** | 0.45 | 0.45 |
| | points: | **15.49 ± 0.243 vs. 16.83 ± 0.243** | | |
| "Social" | *F*-value: | **93.96;** | 2.5; | **4.348;** |
| | *p*-value: | **< 0.001;** | 0.12 | **0.038** |
| | points: | **11.28 ± 0.30 vs. 15.35 ± 0.30** | | |
| Total score | *F*-value: | **49.18;** | **3.87;** | 2.53; |
| | *p*-value: | **< 0.001;** | **0.05;** | 0.11 |
| | points: | **39.00 ± 0.65 vs. 45.44 ± 0.65** | **41.32 ± 0.65 vs. 43.13 ± 0.65** | |

$p < 0.001$). In addition, the effect of sex on the total ChiPSO score was significant ($F = 3.87$, $p = 0.05$). Girls showed higher scores than boys (boys: $41.3 \pm 0.7$; girls: $43.1 \pm 0.7$; $p = 0.05$). No interaction between sex and age group was observed ($F = 2.53$, $p = 0.11$). Further analysis showed that the difference in ChiPSO score between boys and girls was driven by adolescents (boys: $43.8 \pm 0.9$, girls: $47.1 \pm 0.9$, $F = 6.33$, $p = 0.013$). There was no difference between girls and boys on ChiPSO scores in children (boys: $38.8 \pm 0.9$, girls: $39.2 \pm 0.9$, $F = 0.71$, $p = 0.79$) (Fig. 1a).

**"Environment"** A significant effect of age ($F = 15.16$, $p < 0.001$) was observed; adolescents scored higher than children (children: $15.5 \pm 0.2$; adolescents: $16.8 \pm 0.2$; $p < 0.001$). There was no difference between boys and girls ($F = 0.57$, $p = 0.45$) and no interaction between age group and sex ($F = 0.57$, $p = 0.45$) on the subscale score "environment" (Fig. 1b).

**"Social"** There was a significant influence of age on the subscale "social" ($F = 93.96$, $p < 0.001$); adolescents scored higher than children (children: $11.3 \pm 0.3$; adolescents: $15.4 \pm 0.3$; $p < 0.001$). There was no significant influence of sex on the score ($F = 2.5$, $p = 0.12$). There was a significant interaction between age and sex ($F = 4.348$, $p = 0.038$). Adolescent girls scored significantly higher than adolescent boys ($F = 6.72$, $p = 0.01$). These observations were not made in children ($F = 0.13$, $p = 0.72$) (Fig. 1c).

**"Food"** There was a significant influence of age on the scores of the subscale "food" ($F = 5.79$, $p = 0.017$), adolescents scored higher than children (children: $12.2 \pm 0.3$; adolescents: $13.3 \pm 0.3$; $p = 0.017$). In addition, a main effect of sex was observed on this subscale ($F = 4.20$, $p = 0.042$); girls scored higher than boys (boys: $12.3 \pm 0.3$; girls: $13.2 \pm 0.31$; $p = 0.042$). A missed significance was observed in interaction between sex and age group ($F = 3.84$, $p = 0.051$). In line

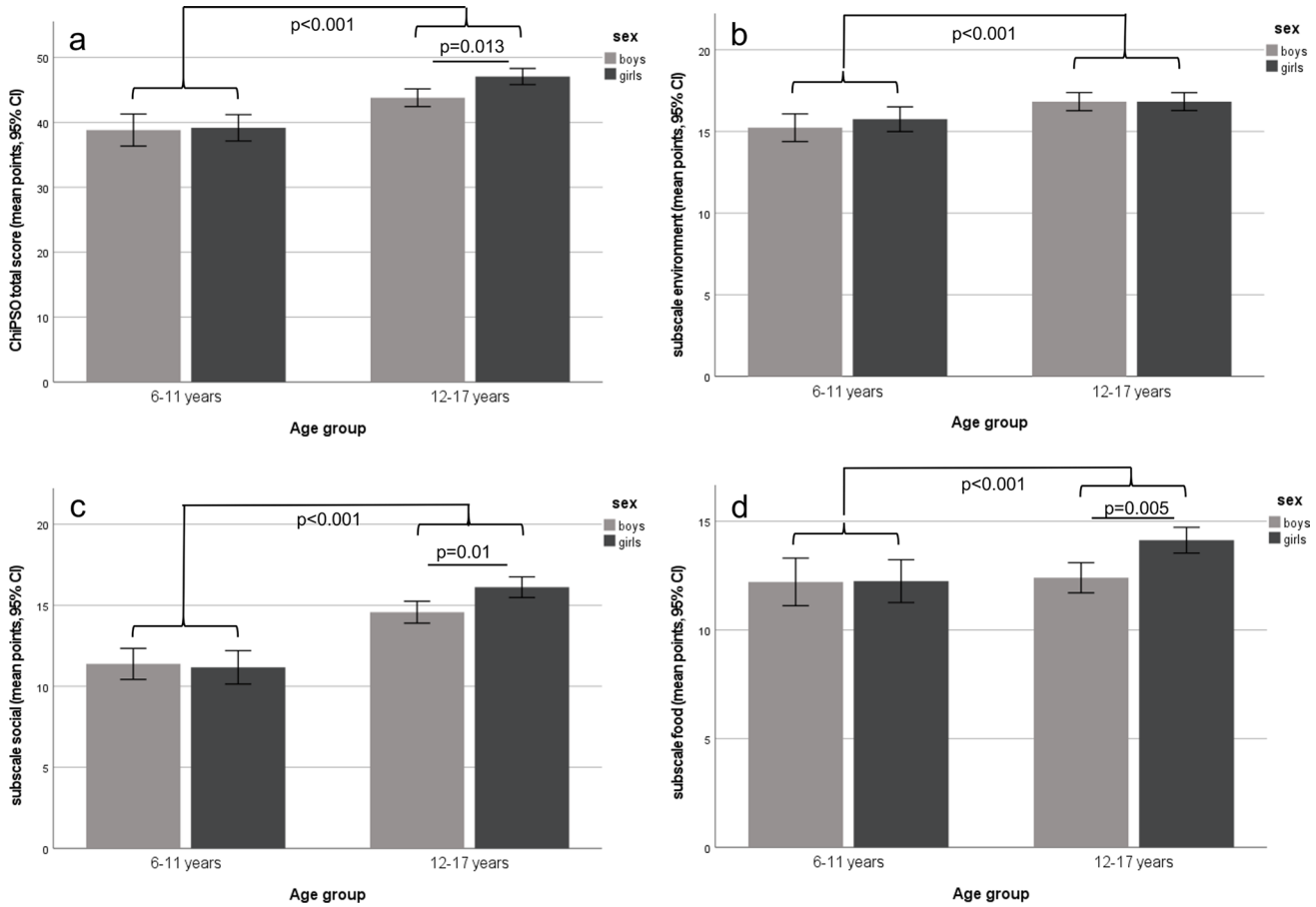


**Fig. 1** Influence of sex and age on ChiPSO total scores and subscales including standard error. **a** In ChiPSO total score a significant difference between children and adolescents was observed with adolescents scoring higher. In adolescents there was a significant difference between boys and girls with girls scoring higher than boys. **b** A significant difference between children and adolescents was observed with adolescents scoring higher in subscale "environment." No significant sex differences were observed. **c, d** adolescents scored higher than children and girls scored higher than boys in adolescents in subscale "social" (**c**) and subscale "food" (**d**)

with the subscale "social," adolescent girls scored higher on the subscale "food" than boys (girls: $14.1 \pm 0.4$; boys: $12.4 \pm 0.4$; $p = 0.005$). There was no difference between boys and girls in children on the subscale "food" ($F = 0.004$, $p = 0.95$) (Fig. 1d).

**Influence of Odor Identification and Olfactory Threshold Scores on ChiPSO Questionnaire** When analyzing both age groups together, there was no observed correlation between olfactory test results and total ChiPSO scores, nor between olfactory test results and the subscale "food" or "environment." A positive correlation between odor identification test and the subscale "social" was observed ($r = 0.14$, $p = 0.049$). Further analyses were conducted for each age group separately. No correlations between olfactory test performance and questionnaire scores in children were found. The above observed significant positive correlation between odor identification score and subscale "social" lost the significance in the subgroup analysis ($r = 0.11$, $0 = 0.28$). A significant correlation was observed between odor identification score and total questionnaires score ($r = 0.20$, $p = 0.042$) in adolescents.

## Discussion

The aim of the study was the development of a questionnaire (ChiPSO) to assess the importance of olfactory information for children and adolescents with three categories, including "food," "social," and "environmental" aspects and to evaluate the association with olfactory abilities. Fifteen items (five for each subscale) were selected for the final questionnaire. The influence of olfactory performance as well as sex and age on ChiPSO was investigated. Adolescents scored higher on the ChiPSO and all three subscales. Girls outperformed boys in total ChiPSO questionnaire and subscale "food" as well as "social." A positive correlation between odor identification performance and ChiPSO questionnaire was found in adolescents.

### Part I: Development of a Questionnaire

In the "Part I" section of the study, a questionnaire about the importance of olfactory information in everyday life was developed. All subscales showed psychometric items with good internal reliability and correlation between subscales and total questionnaires score. The range of Cronbach's alpha for the 15-item ChiPSO questionnaire (0.68 and 0.78) was comparable to Cronbach's alpha of questionnaires reported in previous studies targeting the importance of olfactory information: COBEL questionnaire (0.78) (Ferdenzi et al. 2008b, a) and the questionnaire developed by Croy et al. (2010) (0.77).

### Part II: Influence of Age, Sex, and Olfactory Performance on the Importance of Olfactory Information in Daily Life

In the second part of the study, the influence of age, sex, and olfactory performance on ChiPSO questionnaire score and its subscales was examined.

#### Influence of Age and Sex on ChiPSO Questionnaire

A positive correlation between age and total ChiPSO score, as well as all three subscales, was observed. These results are complementary to other studies observing higher scores in older participants in other questionnaires (Ferdenzi et al. 2008b, a; Ferdenzi et al. 2008b, a; Oleszkiewicz et al. 2016).

Adolescent female participants scored higher in the total ChiPSO score as well as on the subscales of "social" and "food" compared to boys in this age group. These findings were also partly observed in COBEL questionnaire. In this study, girls scored significantly higher than boys in total score, as well as the subscales "social" and "environment," but not in the subscale "food." These results were not influenced by verbal abilities (Ferdenzi et al. 2008b, a). Another study from the same group also showed significantly higher scores in girls than in boys in total COBEL, and subscales "environment" and "social" (Ferdenzi et al. 2008b, a). This effect of sex on questionnaire results in older children and adolescents was also shown in a study using the modified questionnaire by Croy et al. from 2010. Therein, girls scored significantly higher than boys in subscales "application," "consequence," and "association" (Oleszkiewicz et al. 2016). Stevenson formulated three main functions of human olfaction including social communication ingestion and "avoiding environmental hazards" (Stevenson 2010). In this context, it is discussed whether olfactory information is important to avoid inbreeding (Wolf 1995; Weisfeld et al. 2003; Matchock and Susman 2006), finding an immunological compatible partner (Wedekind et al. 1995; Wedekind and Furi 1997), and bypassing acute or chronical sick people (Penn and Potts 1998). Another study suggests that olfactory cues from peer-groups gain more interest from childhood to adolescents, rather than avoidance of relatives, by means of olfactory information (Novakova et al. 2017). In and after puberty, gaining independence from their parents and mate selection are getting more important to adolescents (Hochberg and Belsky 2013; Novakova et al. 2017). The findings in the previous studies might explain higher questionnaire scores of the older age group in subscale "social," reflecting a greater importance. In context of girls scoring higher in subscale "food," one study from 2014 found a significant

positive correlation between odor identification and female stereotyped activities in heterosexual women, but not in homosexual women nor either homosexual or heterosexual men (Novakova et al. 2014). Nevertheless, it only can be hypothesized that food may play a more important role to girls in traditionally encultured tasks.

### Influence of Olfactory Performance on ChiPSO Score

Regarding the influence of olfactory performance on ChiPSO questionnaire and its subscales, a significant positive correlation between odor identification performance and the subscale "social" was seen. In "U-Sniff" odor identification test, most odors are food-associated. Therefore, the odors of the "U-Sniff" test could not be assigned to the subscales "social," "food," and "environment." Furthermore, there was a positive correlation between odor identification scores and total ChiPSO score in adolescents. There was no correlation in the children between olfactory testing and ChiPSO results. This may be in part a result of the lower responsibility and decision-making ability in younger children compared to adolescents. Younger children do not prepare their own meals and do not have to decide whether food is rotten or not and whether their clothes need to be washed. That changes in adolescence with their responsibility increased in food preparation and self-hygiene (Hochberg and Belsky 2013). That maybe explain the correlation between olfactory performance and ChiPSO results in this age group. In contrast to our findings, no significant association between odor identification performance and COBEL scores was found by Ferdenzi et al. (2008b, a). This difference might be explained by the difference in the age of the study populations. Ferdenzi et al. (2008b, a) only included children younger than 12 years in their study. Here, the most prominent influence of olfactory performance on ChiPSO questionnaire results was in adolescents.

### Olfactory Performance

In line with previous publications, there was an increase in performance in the odor identification test with age (Ferdenzi et al. 2008b, a; Ferdenzi et al. 2008b, a; Cameron 2018). However, despite statistical significance, there is less than a 1-point difference between the two age groups. A study from 2006 in an adult population determined that a perceived improvement in olfactory abilities is reached only if there is an increase of at least 3 points in the odor identification test (Gudziol et al. 2006). Therefore, the clinical relevance of this result is questionable. The performance on the n-butanol olfactory threshold test also increased with age, while scores in the PEA olfactory threshold test did not differ significantly between the two age groups. We did not observe significant differences in olfactory performance between boys and girls. While some studies observed higher scores in odor identification testing in girls compared to boys (Ferdenzi et al. 2008b, a; Saxton et al. 2014, Novakova et al. 2018), other studies declare no difference between girls and boys in the context of odor identification performance (Novakova and Mrzilkova 2016, Gellrich et al. 2021).

### Limitations

This study contains a large sample size and the full dataset, resulting in a robust dataset. In addition, participant sex and age group was evenly distributed. The testing procedure was standardized to minimize a potential bias of test condition. However, the study was based on voluntary participation, which could lead to a bias towards participants that were more interested in olfactory information than other children. While testing itself was standardized, the surrounding was not. Most measurements were performed in participants' homes, resulting in variability in the experimental setting. Nevertheless, testing always was performed in a well-ventilated room and a quiet setting. When testing young children, the shorter attention span of the young participants has to be considered (Gellrich et al. 2021). Especially, olfactory threshold testing is rather long and strenuous. Therefore, the wide-step method for olfactory threshold testing was used to shorten test duration (Croy et al. 2009). Because of closed questioning, the influence of verbal abilities on questionnaire results is debatable. Unfortunately, it was not possible to completely exclude problems in understanding the questionnaire in younger age children. Children were told to ask, whenever they did not understand an item and/or answer. Nevertheless, possible uncertainty introduces a bias in direction to lower or higher endpoints, as also described in a previous study about pleasantness of odors (Brothankova et al. 2021).

## Conclusion

The ChiPSO questionnaire is a practical tool to evaluate the importance of olfaction in children and adolescents aged 6 to 17 years. We report an association between the importance of olfaction by means of the ChiPSO questionnaire and olfactory abilities. In addition, olfactory information seems to be more important to adolescents compared to younger children and girls compared to boys.

**Author Contribution** Conveyed and designed the study: VAS, IC, MS, LP, and AD Performed the study: MS, LP, and AD Analyzed the data: ECU and VAS. Wrote the paper: ECU, IC, JG, and VAS.

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## Declarations

**Ethical Approval** All aspects of the study were compliant with the Declaration of Helsinki. The ethics committee of the technical university Dresden approved the study (EK 284072017, EK 318082017). The authors declare no conflicts of interest.

**Informed Consent** Participants and their parents were informed about the study and provided informed consent for study participation.

**Conflict of Interest** The authors declare no competing interests.



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