



Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Exploration of the relationship between olfaction, food Neophobia and fruit and vegetable acceptance in school-aged children

Linnea Apelman^{a,*}, Eva Roos^{a,b}, Jonas K Olofsson^c, Pernilla Sandvik^a^a Department of Food Studies, Nutrition and Dietetics, Uppsala University, Box 256, SE-751 05 Uppsala, Sweden^b Folkhälsan Research Center, PB 211, 002 51 Helsingfors, Finland^c Department of Psychology, Stockholm University, Frescativägen 8, SE-106 91 Stockholm, Sweden

ARTICLE INFO

Keywords:

Odor
Food exposure
Odor exposure
Sensory
Fruits
Vegetables

ABSTRACT

Rejection of food, including fruits and vegetables, is prevalent among children. In adolescents and adults, a link has been observed between food neophobia (the rejection of unfamiliar foods) and olfaction, which plays a key role in food acceptance. However, research on olfaction's role in food acceptance and rejection among children is limited. Utilizing the U-sniff test and the Italian Child Neophobia Scale, this study investigated associations between odor awareness, odor identification, food neophobia, and the acceptance of fruits and vegetables in Swedish children aged 9–12 years ($n = 126$). A Swedish version of the ChiPSO questionnaire on odor awareness (including subscales for food, social and environmental odors) was developed, and initial validation conducted through back translation, cognitive interviews, and exploratory factor analysis. Fruit and vegetable acceptance was assessed through a questionnaire and a tasting session. Findings indicated that food neophobia was associated with lower fruit and vegetable acceptance (questionnaire $\rho = -0.296$, $p = 0.002$; tasting session $\rho = -0.273$, $p = 0.004$) but no significant associations observed with odor awareness ($\rho = 0.159$, $p = 0.094$) or odor identification performance ($\rho = -0.141$, $p = 0.176$). However, odor awareness was negatively associated with vegetable acceptance ($\rho = -0.200$, $p = 0.034$), while odor identification performance showed no significant associations (questionnaire $\rho = -0.049$, $p = 0.638$; tasting session $\rho = -0.101$, $p = 0.316$). A negative association was found between odor identification performance and environmental odor awareness ($\rho = -0.269$, $p = 0.010$). This suggests that some children may struggle to identify odors due to emotional reactions and avoidant behaviors, reducing engagement and hindering identification. Further exploration of the relationship between olfaction and children's food acceptance or rejection is encouraged.

1. Introduction

Food neophobia, the reluctance to eat and/or avoidance of novel foods, are observed among children worldwide (Pliner, 1994). Like other fears, food neophobia serves the purpose of protecting us from danger (Cooke, Haworth, & Wardle, 2007) and is a common part of a child's developmental process. Although its persistency and intensity show individual variation (Birch, 1998), it was suggested that a child's most neophobic phase typically begins at 2–3 years of age (Dovey, Staples, Gibson, & Halford, 2008). This is when cognitive functions develop that enable grasping the concept of food and linking it to sensory experiences and the attributes of different foods (Fallon & Rozin, 1983). In a Swedish study with 6–11-year-olds, 30 % were categorized as picky eaters, which is a similar concept to food neophobia (Rydell,

Dahl, & Sundelin, 1995). In a European study, the degree of food neophobia was higher in Swedish children compared to Finnish, Spanish and Italian children (Proserpio et al., 2020). Further, Scandinavian studies confirm a decrease in food neophobia levels with increasing age; in a sample of Swedish children aged 7–17 years, younger children had higher food-related and general neophobia scores compared to older ones (Hursti & Sjöden, 1997). An age-related decline in food neophobia was also observed in Irish children, with 69 % exhibiting food-neophobic tendencies at age 6, and 60 % at age 9 (Hazley, Stack, Walton, McNulty, & Kearney, 2022).

Food neophobia has been associated with reduced dietary variety and quality, potentially influencing long-term health outcomes (Birch & Fisher, 1998), and is particularly associated with a low intake of fruits and vegetables (Fletcher, Wright, Jones, Parkinson, & Adamson, 2017;

* Corresponding author.

E-mail address: linnea.apelman@ikv.uu.se (L. Apelman).<https://doi.org/10.1016/j.foodqual.2024.105384>

Received 15 May 2024; Received in revised form 9 October 2024; Accepted 24 November 2024

Available online 28 November 2024

0950-3293/© 2024 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Perry et al., 2015; Proserpio et al., 2020). In a study with adolescents from Denmark, France, Italy and UK, higher acceptance of vegetables with less attractive sensory properties was observed among participants with lower levels of neophobia (Appleton et al., 2019). While genetics and heritage play a role in food neophobia (Knaapila et al., 2007), modifiable factors, such as social influence (Dovey et al., 2008) and increased exposure (Caton et al., 2012; Pliner, 1982; Pliner et al., 1993) has been associated with a decrease in food neophobia and increase in the acceptance of fruits and vegetables, providing hope for intervention. In addition, there appears to be a connection between food neophobia and sensory factors. High levels of food neophobia in children have been observed to be associated with high taste sensitivity (Cooke et al., 2007; Coulthard & Blissett, 2009), and the appearance of food seems to play an important role for children with food neophobia (Sandvik et al., 2021). Together with visual cues, olfaction is a pre-ingestive sense, that acts gatekeeper for food consumption as well as impacts our acceptance of foods by interacting with the other senses in the post-ingestive experience of eating (Stevenson, 2010). Yet, the scientific exploration of the role of olfaction in common eating behaviors in children, such as food neophobia, is still in an early stage (Demattè, Endrizzi, & Gasperi, 2014). Olfactory functions, such as the ability to detect and correctly identify odors, have been shown to change over a lifespan (Doty et al., 1984; Doty & Kamath, 2014). Older children show higher odor sensitivity and odor identification performances than younger ones (Monnery-Patris, Rouby, Nicklaus, & Issanchou, 2009; Schriever, Zscheile, Gellrich, & Hummel, 2021). These changes are believed to be influenced by increased linguistic abilities (Monnery-Patris et al., 2009; Stevenson, Mahmut, & Sundqvist, 2007), increased recognition memory (Frank, Brearton, Rybalsky, Cessna, & Howe, 2011), and increased exposure to diverse food-related odors (Cain et al., 1995; Martinec Nováková, Fialová, & Havlíček, 2018a). The ability to identify odors shows great inter-individual variation in children (Gellrich et al., 2019). Also varying among individuals is the role olfactory information plays in our everyday life, herein referred to as odor awareness, and a few tools have been developed to facilitate its assessment. In the present paper, the term odor awareness is used to compare high and low awareness of, and attention to, odor stimuli. In Sweden, odor awareness has been studied in an adult sample (Arshamian, Willander, & Larsson, 2011), but the role of olfaction in children's everyday lives has only begun to be explored. In Swedish adults, high odor awareness was positively associated with odor memory and the ability to identify odors (Arshamian et al., 2011). According to a study of adults, there was no relationship between odor awareness and odor identification (Demattè et al., 2011). In a study of German 6–17-year-olds, no association was observed between overall odor awareness and the ability to identify odors. Nonetheless, awareness of social odor cues specifically was positively associated with a greater odor identification ability. In addition, girls scored higher than boys in awareness of social- and food-related odor cues (Lohrer et al., 2022).

In adults, a connection between the sense of olfaction and food neophobia has been observed. Specifically, high levels of food neophobia has been related to low proficiency in tests of odor threshold and odor discrimination (Menghi et al., 2020) as well as odor identification (Demattè et al., 2013; Demattè et al., 2014; Raudenbush, Schroth, Reilly, & Frank, 1998). Further, neophobic adults have been observed to sniff their surroundings less extensively and rate odors as less pleasant (Raudenbush et al., 1998). In adolescents (15–17 years), high food neophobia was associated with a lower ability to identify odors and, lower self-assessed olfactory sensitivity, and low odor awareness (Sorokowska, Chabin, Hummel, & Karwowski, 2022). In children, research on olfaction and food neophobia is still limited.

Previous studies exhibit heterogeneous findings regarding gender disparities in olfactory functions, with some investigations demonstrating no discernible distinctions (Gellrich et al., 2019; Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997; Martinec Nováková, Vojtušová Mrzálková, & Kernerová, 2017) while others indicate variations (Ferdenzi, Mustonen, Tuorila, & Schaal, 2008; Martinec Nováková et al.,

2018a; Martinec Nováková, Fialová, & Havlíček, 2018b; Saxton et al., 2014).

Studies on olfactory awareness in Swedish children and adolescents are lacking.

Adult food neophobics are less accurate in naming odors (Demattè et al., 2013), it is yet unknown if this can be seen already in children. In addition, research on the role of odor awareness in food acceptance and food neophobia is scarce. To the best of our knowledge, this study is the first to investigate the interplay between odor awareness, odor identification, food neophobia, and food acceptance in children.

1.1. Aim

The study aimed to explore odor awareness, odor identification performance, and their potential relationships with food neophobia and fruit and vegetable acceptance in a sample of Swedish boys and girls 9–12 years. Specific research questions were:

1. What are the observed levels of odor awareness and odor identification within the sample?
2. What associations can be observed between the levels of odor awareness, odor identification performance, food neophobia, and the acceptance of fruits and vegetables among the sample?

2. Methods

2.1. Study design and participants

Between April and November 2023, 126 children aged 9–12 (69 girls and 45 boys, mean age 10.6 years (\pm 0.9)) participated in a cross-sectional study. They engaged in sensory tasks, including the hedonic rating of ten fruits and vegetables and identifying the sources of twelve odorants. They allocated 45 min to provide their answers to a survey. Gender and age were obtained via the survey, leaving 12 absent children with missing data. Children were recruited through grades 4 and 5 in Swedish primary schools. The age range of 9–12 years was chosen to focus on an age where A) neophobia has typically declined (Dovey et al., 2008) and B) cognitive skills have developed to enable participation in the sensory tests and reading skills are sufficient to complete the survey without assistance (Laureati, Pagliarini, Toschi, & Monteleone, 2015). All tests were conducted individually within the school premises. The survey was distributed by the school staff and the content and concepts were presented by a researcher, as were the sensory tasks and rating scales. The survey was completed via a web browser on tablets or computers in three schools, while in one school, it was completed using pen and paper. In the larger school classes, data collection was scheduled over several school days to ease the children's burden. In these cases, not all children were present in class all days, thus the dataset shows missing values. Children from four Swedish primary schools in three municipalities across two counties were recruited. Two school classes were included from each of three schools ($n = 31$, $n = 58$, $n = 26$), as well as a mixed group from various classes at the fourth school ($n = 11$). All schools were situated in the central part of the country, as refrigerated food samples served during sensory testing required proximity to the kitchen used for sample preparation. Contact was initiated via school staff through e-mail or phone. All pupils in the recruited classes, with a written confirmation of informed consent by their caregiver(s), were invited to participate. The study protocol was approved by the Swedish ethical review authority (2022–05433–01–317,056). The data that support the findings of this study are available from the corresponding author upon reasonable request.

2.2. Measures

Data were collected for the following variables: odor awareness, odor identification, level of food neophobia and acceptance of fruits and

vegetables. Data collection involved odor tests, tasting sessions and a questionnaire.

2.2.1. Odor awareness – The Swedish ChiPSO questionnaire

To assess participant's level of odor awareness, an adapted version of the Children's Personal Significance of Olfaction (ChiPSO) questionnaire by Lohrer et al. (2022) was developed: Swedish ChiPSO, consisting of 12 items. Each item consists of a statement, and the participants rate their level of agreement using a scale, ranging from 1 (I totally agree) to 5 (I totally disagree).

The original ChiPSO questionnaire comprises 15 items categorized into three dimensions: social, food, and environmental odor cues. These three dimensions are grounded in Stevenson's (2010) theories of the main functions of our sense of olfaction: to guide ingestive behavior, allow for communication with our social surroundings and avoid environmental hazards. When developing the original ChiPSO questionnaire, 33 items were suggested for inclusion. Based on the findings of an exploratory factor analysis (EFA) with a predetermined 3-factor structure, the 5 items with the highest factor loadings for each of the 3 factors were selected for inclusion. In the Swedish adaption, Swedish ChiPSO, all 33 original items were analyzed. To ensure accuracy, the items were back-translated from Swedish to English by 2 independent bilinguals (1 male and 1 female). All 33 analyzed questionnaire items are displayed in Appendix 1. Appendix 2 presents the adjustments made during the adaptation process based on cognitive interviews with children aged 8–13 ($n = 5$).

To investigate the factor structure of the 33-item questionnaire in the present sample, an exploratory factor analysis (EFA) was conducted. The number of factors was determined using a cut-off of Eigenvalues of 1 or higher. Factors were extracted through maximum likelihood orthogonally rotated (Varimax method), unless factors were correlated. Factors with a correlation coefficient between 0.30 and 0.85 were rotated obliquely (Oblimin method). Model fit measures were calculated and reliability was explored. The latter focused on internal consistency (Cronbach's alpha) and consistent validity by comparing factor loadings, factor correlations, and convergent and discriminant validity linked to the results of the study by Lohrer et al. (2022). The EFA analysis suggested a 4-factor structure (Appendix 1), with 3 factors aligning with the theoretical dimensions (food, social and environmental odor cues). The fourth factor lacked a clear theoretical interpretation and, therefore, the items associated with it were excluded. Twelve out of the 33 items showed high correspondence (factor loadings >0.4) to one of the remaining three factors and were included, resulting in a concise 12-item instrument (Table 1). To test this 3-factor structure, a confirmatory factor analysis (CFA) was conducted on the same dataset, and model fit and reliability measures were calculated. In the CFA, the factor structure showed a good fit, $\chi^2(65.9) = 51, p = 0.078$; TLI = 0.934; CFI = 0.949; RMSEA = 0.04–2 (90 % CI 0.00–0.0805), SRMR = 0.071. The included items are presented together with factor loadings in Table 1. The questionnaire showed good internal reliability (Cronbach's alpha = 0.72) and good or acceptable internal reliability of the 3 subscales: environment ($\alpha = 0.82$), social ($\alpha = 0.73$) and food odor cues ($\alpha = 0.64$).

2.2.2. Odor identification – The universal sniff test (U-sniff)

Odor identification performance was assessed using the Universal Sniff test (U-sniff), a test for children validated by Schriever et al. (2018). The test includes 12 Sniffin' sticks facilitating exposure to the odors of foods (apple, banana, butter, coffee, fish, lemon, onion, orange, peach and strawberry) and non-food items (cut grass and flower). The task was performed individually in a calm separate room, where the researcher held the stick in front of the child's nose. According to the U-Sniff protocol, participants were exposed to each odor stimulus for three seconds and could sniff again if needed. Thereafter, the child was asked to identify the smell by choosing between 4 alternative pictures, the odds of guessing correctly were thus 25 %. The maximum score was 12

Table 1

Factor loadings of the Swedish ChiPSO questionnaire items (Confirmatory factor analysis) $n = 98$.

Factor	Item	Factor loadings
Food	The smell of a food plays a role in the decision whether I like it or not (1)	0.454
	Smelling nasty odors while eating usually make me lose my appetite (13)	0.491
	When I don't like the smell of a food I don't eat it (19)	0.571
	I smell on food to find out whether it is spoiled or not (28) *	0.585
Social	It happens that I smell my clothes (2)	0.589
	When I am sweating, I can smell it (11) *	0.452
	It happens that I smell parts of my body (20)	0.643
	I smell myself to check whether I have a bad odor (31)	0.835
	I smell my clothes to check whether it has to be washed (33)	0.490
Environmental	If I smell something, I try to find out where it comes from (18) *	0.790
	When I smell an odor around me, I try to guess what it is (22)	0.694
	I normally try to find out where an odor comes from (27)	0.773

() Brackets indicate item numbers (1–33) suggested in the original ChiPSO study by Lohrer et al. (2022).

* Asterisks denote items not included in the 15-item original ChiPSO questionnaire by Lohrer et al. (2022).

correct answers. The test has demonstrated high internal consistency ($\alpha = 0.90$) and test-retest reliability ($r = 0.88$) in a previous study (Schriever et al., 2018).

2.2.3. Food neophobia – The Italian child food Neophobia scale (ICFNS)

Participants' levels of food neophobia were assessed using the Italian Child Food Neophobia Scale (ICFNS) by Laureati, Bergamaschi, and Pagliarini (2015) adapted for use with Swedish children by Proserpio et al. (2020). The questionnaire consists of 8 items, statements rated for their level of agreement using a 5-point Likert scale displayed together with emoticons (visual representations of facial expressions, see Laureati, Pagliarini, et al., 2015). The statements are:

- 1) Almost every day I eat new and unusual foods.
- 2) I don't trust new foods.
- 3) If a food is new, I don't try it.
- 4) I like to try weird tastes and foods, which are unusual and coming from different countries (R).
- 5) When I am at a friend's party, I like to try new foods (R).
- 6) I am afraid to eat food I have never had before.
- 7) I am very fussy when it's a matter of food.
- 8) I really eat everything! (R).

Reversed items (R) were recalculated and a total score ranging from 8 to 40 was calculated, a higher score indicating a higher degree of food neophobia. Internal reliability in the current sample was slightly below the conventional threshold of 0.70 (Cronbach's $\alpha = 0.64$).

2.2.4. Fruit and vegetable acceptance – Questionnaire and tasting sessions

Fruit and vegetable acceptance was assessed in two ways: through a questionnaire and in a tasting session including food samples. In the questionnaire, the assessment was conducted using a section of the Pro Greens questionnaire (Lynch et al., 2014), allowing participants to rate their acceptance on a 4-point hedonic scale, ranging from *Dislike a lot* to *Like a lot*, displayed together with the option *Have not tried*. The

questionnaire comprises 12 fruit items (apple, banana, pear, orange, plum, peach, tangerine/clementine, melon, strawberry, grapes, cherries and kiwi) and 12 vegetable items (tomato, cucumber, lettuce, cabbage, spinach, leek, green beans, onion, carrot, broccoli, cauliflower, green peas). The list was expanded with 2 more fruits (pineapple and grapefruit) and 3 more vegetables (celery, green asparagus and fennel), to include all items offered in the tasting sessions. Scores were calculated separately for fruits and vegetables, as well as combined.

In addition, the participants rated their acceptance of 10 food samples, 5 fruits (red apple, banana, orange, pineapple, pink grapefruit) and 5 vegetables (cucumber, cabbage, celery, green asparagus, and fennel), in tasting sessions. Items were selected for their documented consumption in the target group (Enghardt Barbieri, 2003), low cost, and diverse sensory profiles. Tastings were conducted in the morning (between breakfast and lunch) or in the afternoon, with no sessions occurring immediately after lunch. Hedonic ratings were collected using a 7-point Likert Scale ranging from *I like a lot* to *I dislike a lot* and displayed together with emoticons, advised by Guinard (2000). Food samples were cut into pieces of 2–4 cm and weighing 10–15 g, depending on the fruit or vegetable type, and served in individual lid-covered containers marked with 3-digit codes. FIZZ (Biosystems) was used to set up the rating questionnaires and a randomized serving order. The participants used computers, tablets, or pen and paper to rate their acceptance. Scores were calculated for fruits collectively, vegetables collectively, and for fruits and vegetables combined.

2.3. Statistical analyses

Correlation analyses were conducted in Jamovi software to explore possible associations between children's odor awareness, odor identification abilities, their levels of food neophobia and acceptance of fruits and vegetables. Guided by Shapiro-Wilk tests for normality, the non-parametric Spearman's rank correlation coefficient (ρ) was applied for all correlation analyses, since several variables showed to be non-normally distributed. Comparisons of mean values between groups of individuals within the sample, for example boys and girls, were conducted using comparative tests. Independent samples *t*-tests were conducted for variables observed to be normally distributed, while non-parametric Mann-Whitney *U* tests were used for variables not normally distributed. Mean differences among age groups (9, 10, 11, or 12 years) were measured by conducting an analysis of variance (ANOVA).

Missing data points were handled as advised by Allison (2001). After list-wise deletion, single missing questionnaire item responses were imputed. Imputations were performed using the calculated mean of the other participant's responses of the specific item. Since less than 0.026 % of the dataset was imputed, this should have little impact on the findings.

3. Results

The study was conducted over multiple days and school attendance varied daily, resulting in fluctuations in participant numbers. Specifically, 114 participants completed the questionnaire, 106 participated in odor identification testing, and 117 took part in tasting sessions. In total, 91 of the participants completed all tests. The mean age of the sample was 10.6 years (SD 0.91) showing no significant difference between girls and boys ($U = 1350, p = 0.22$). At the time of data collection, 11.4 % of the children reported being 9 years old, 36.0 % being 10 years old, 34.2 % being 11 years old and 18.4 % being 12 years old.

3.1. Odor awareness, odor identification, food neophobia and fruit and vegetable acceptance

The mean odor awareness score (sum of all 12 Swedish ChiPSO item ratings) was 31.24 (SD 6.36, scale 12–48). The mean values for the scale's three dimensions were 2.71 (SD = 0.60) for food, 2.48 (SD =

0.74) for social and 2.82 (SD = 0.83) for environmental odor cues. The mean U-sniff test score was 9.82 (SD 1.53) out of a maximum of 12 correctly identified odors, with no significant difference seen between boys and girls ($U = 850, p = 0.11$) or different ages ($F(3, 31.7) = 0.815, p = 0.495$). Food neophobia scores ranged from 8 to 34 on a scale of 8–40, with a mean value of 20.6. The mean questionnaire-rated acceptance of the 14 fruits and 15 vegetables was 3.56 (SD 0.57) on a 6-point scale, with 4.09 (SD 0.738) for fruits and 2.91 (SD 0.762) for vegetables. In the tasting sessions, the overall liking of the 5 fruits and the 5 vegetables was rated at 4.47 (SD 0.75) on a 7-point scale. The mean rating for fruits were 5.39 (SD 1.04) and 3.55 (SD 1.07) for vegetables. In the present sample, no significant differences were found between boys and girls concerning the measured variables; see Table 2.

3.2. Associations between odor awareness, odor identification, food neophobia and the acceptance of fruits and vegetables

The results of the analyses of associations between variables are presented in Table 3. No association was observed between the mean

Table 2

Mean values and differences between groups (boys/girls) in Odor Awareness, Odor Identification Ability, Food Neophobia and Acceptance of Fruits and Vegetables, as explored through Swedish ChiPSO, U-sniff test, Italian Childhood Food Neophobia Scale (ICFNS), Pro Greens questionnaire and tasting sessions ($n = 106$ –117).

	All	Girls	Boys	Difference
Odor awareness - Swedish ChiPSO¹				
Mean rating (scale 1–4)	2.71 (0.61)	2.73 (0.59)	2.70 (0.60)	
Food	2.71 (0.60)	2.69 (0.62)	2.75 (0.56)	$U = 1348, p = 0.620$
Social	2.48 (0.74)	2.48 (0.75)	2.48 (0.70)	$U = 153, p = 0.880$
Environment	2.82 (0.83)	2.85 (0.83)	2.76 (0.85)	$U = 1325, p = 0.610$
Mean Score (scale 12–48)	31.24 (6.36)	31.10 (6.61)	31.40 (6.02)	$U = 1544, p = 0.96$
Odor identification - U-sniff test²				
Mean score (scale 0–12)	9.82 (1.53)	10.0 (1.51)	9.54 (1.52)	$U = 850, p = 0.110$
Food neophobia - ICFNS³				
Mean score (range 8–40)	20.60 (4.74)	20.70 (4.61)	20.30 (4.97)	$t = -0.381, p = 0.700$
Acceptance of fruits and vegetables Questionnaire⁴				
Mean rating (scale 1–5)	3.56 (0.57)	3.61 (0.49)	3.49 (0.68)	$U = 1430, p = 0.559$
Fruits	4.09 (0.74)	4.21 (0.54)	3.91 (0.94)	$U = 1349, p = 0.288$
Vegetables	2.91 (0.76)	2.97 (0.76)	2.83 (0.77)	$t = 1.540, p = 0.130$
Tasting sessions⁵				
Mean rating (scale 1–7)	4.47 (0.75)	4.49 (0.68)	4.49 (0.86)	$U = 0.003, p = 0.974$
Fruits	5.39 (1.04)	5.51 (0.96)	5.18 (1.16)	$U = 1430, p = 0.559$
Vegetables	3.55 (1.07)	3.47 (1.11)	3.79 (0.99)	$U = 1430, p = 0.974$

¹ $n = 114$.

² $n = 106$.

³ $n = 114$.

⁴ $n = 114$.

⁵ $n = 117$.

Table 3
Correlations (Spearman's rho, ρ) between Odor Awareness, Odor Identification, Food Neophobia, and Fruit and vegetable (FV) Acceptance.

	Odor awareness ¹				Odor identification ²
	Overall	Food	Social	Environment	
Odor identification²	-0.182 $p = 0.066$	-0.143 $p = 0.177$	0.037 $p = 0.714$	-0.269* $p = 0.010$	
Food neophobia³	0.159 $p = 0.094$	0.169 $p = 0.078$	-0.005 $p = 0.957$	0.113 $p = 0.240$	-0.141 $p = 0.176$
FV Acceptance⁴					
Questionnaire	-0.169 $p = 0.074$	-0.192* $p = 0.045$	-0.108 $p = 0.256$	-0.101 $p = 0.295$	-0.049 $p = 0.638$
Fruits	-0.025 $p = 0.793$	-0.053 $p = 0.581$	0.028 $p = 0.766$	-0.002 $p = 0.983$	0.002 $p = 0.983$
Vegetables	-0.200* $p = 0.034$	-0.248** $p = 0.009$	-0.106 $p = 0.263$	-0.098 $p = 0.309$	-0.091 $p = 0.384$
Tasting session	-0.202* $p = 0.031$	-0.148 $p = 0.131$	-0.008 $p = 0.929$	-0.192 $p = 0.051$	-0.101 $p = 0.316$
Fruits	-0.046 $p = 0.626$	-0.015 $p = 0.880$	-0.064 $p = 0.500$	-0.010 $p = 0.917$	-0.023 $p = 0.818$
Vegetables	-0.196* $p = 0.036$	-0.155 $p = 0.115$	0.037 $p = 0.693$	-0.186 $p = 0.058$	-0.086 $p = 0.394$

¹ Swedish ChiPSO questionnaire data.

² U-sniff test data.

³ Italian Childhood Food Neophobia Scale data.

⁴ Pro Greens questionnaire and tasting session data.

* Significant correlation $p < 0.05$.

** Significant correlation $p < 0.01$.

overall odor awareness (sum of all 12 Swedish ChiPSO items) and the level of food neophobia. Nor was any correlation discovered between the overall odor awareness and the questionnaire-rated acceptance of fruits. Concerning vegetables, however, a negative correlation was observed with both the overall odor awareness and food odor awareness. Food odor awareness also showed a negative connection to the mean acceptance of all fruits and vegetables combined. Similar connections were observed in the data from the food sample tastings: negative correlations between overall odor awareness and the mean acceptance of all fruits and vegetables combined, as well as the vegetables analyzed separately. No similar connections were observed in the data related to the acceptance of fruits.

In the present sample, no correlations were observed between the participants' odor identification performances and their overall odor awareness, however, a negative correlation was observed between odor identification performances and the level of environmental odor awareness. No associations were observed between participants' odor identification performances and their level of food neophobia or acceptance of fruit and vegetables.

Finally, food neophobia was negatively associated with the mean questionnaire-rated acceptance of fruits and vegetables (fruits: $\rho = -0.256$, $p = 0.006$; vegetables $\rho = -0.260$, $p = 0.006$; fruits and vegetables combined: $\rho = -0.296$, $p = 0.002$; not shown in Table 3). Similar connections were observed in the data from the food sample tastings although the association to liking of fruits was not significant (fruits: $\rho = -0.161$, $p = 0.098$; vegetables $\rho = -0.242$, $p = 0.012$; fruits and vegetables combined: $\rho = -0.273$, $p = 0.004$; not shown in Table 3).

4. Discussion

This is, to the best of our knowledge, the first study exploring possible associations between food neophobia and odor identification performance in children. In the present sample, high food neophobia was associated with a lower acceptance of fruits and vegetables. No associations were observed between food neophobia and odor awareness or the ability to identify odors, however, the children scoring higher on odor awareness rated a lower acceptance of vegetables. No such

correlation was observed with their acceptance of fruits.

The findings indicating a negative correlation between childhood food neophobia and fruit and vegetable acceptance align with the findings of previous studies (Fletcher et al., 2017; Perry et al., 2015; Proserpio et al., 2020). Considering that previous findings indicate that food familiarity (Mustonen, Oerlemans, & Tuorila, 2012) and odor identification performance (Monnery-Patris et al., 2009; Schriever et al., 2021) among children increase with age and that this development is influenced by the increased exposure to odors (Cain et al., 1995; Martinec Nováková et al., 2018a), it would be reasonable to expect food neophobia to be negatively associated with the ability to identify odors. However, previous studies have shown mixed results; a study including adolescents and another one on adults has confirmed this hypothesis (Demattè et al., 2013; Sorokowska et al., 2022), while no associations were observed in another study including adults (Menghi et al., 2020). In the present sample including children, no association was observed. One could hypothesize that the potential effects of food neophobia on olfactory identification skills in children might not be detected at such an early stage. It is also important to note that the Universal Sniff test was developed to determine children's olfactory function for clinical purposes and has, in the present study and by Menghi and co-authors (Menghi et al., 2020), been applied in research. As previously suggested (Menghi et al., 2020), the sensitivity of the measurement may not be intricate enough to capture a potential effect, explaining why potential associations could exist despite non-significant test results from an analysis of this kind. The children in the present study were 9–12 years old and indeed, odor identification increased with age, we did however not see any floor effect on the contrary, were the children overall scored quite high. The odor identification score of the present sample was moderately lower than the mean score (10.8 ± 1.32) of children 9–11 years in a healthy German sample (Gellrich et al., 2019). The median score in the present sample was 10, indicating normosmia (normal olfactory function); however, the scores ranged from 3 to 12, indicating cases of a reduced sense of smell within the sample. In addition, odor identification ability was not associated with the acceptance of fruits and vegetables and it's thus unclear if this might be related to the measurement tool or not.

A Swedish tool to measure children's importance of olfactory cues in everyday life was developed. The Swedish ChiPSO questionnaire exhibited good to acceptable internal reliability, aligning with the original ChiPSO (Lohrer et al., 2022) and similar instruments (Dematté et al., 2011; Smeets, Schifferstein, Boelema, & Lensvelt-Mulders, 2008). Differences in factor structure between the original and Swedish ChiPSO suggest potential cultural variations in the measured constructs, emphasizing the need for cultural context consideration (Caprara, Barbaranelli, Bermúdez, Maslach, & Ruch, 2000). The overall levels of odor awareness in the present sample aligned with findings from a German sample of children aged 6–11 (Lohrer et al., 2022). In Polish adolescents, higher odor awareness was associated with a lower degree of food neophobia. In the present study of 9–12-year-old Swedish children, no connection was observed between food neophobia and odor awareness, though $\rho = 0.159$, $p = 0.094$ suggests a potential trend. While the association is only marginally significant, its direction is noteworthy, contrasting with previous findings in adolescents (Sorokowska et al., 2022) by indicating higher odor awareness in children with food neophobia. One could argue however that a positive association does not need to be counterintuitive. Although, neophobic adults have been shown to sniff their surroundings less extensively and rate odors as less pleasant (Raudenbush et al., 1998), olfaction is a distal sense acting as a gatekeeper for food consumption (Stevenson, 2010) and might thus be of higher importance for individuals with food neophobia. Indeed, a study of 20–22-month-old toddlers showed food-neophobic children to be more responsive to olfactory cues than less neophobic children (Monnery-Patris et al., 2015). These ideas also resonate with the findings showing higher levels of odor awareness to be associated with a decreased acceptance of fruit and vegetables (combined ratings), and vegetables separately. This could be attributed to children with lower odor awareness being less sensitive to, or less influenced by, the odors of vegetables, leading to their higher acceptance. Indeed, the flavor profile generally differs between fruits and vegetables, with less attractive odor components being more common in vegetables, e.g. sulfurous notes in brassica vegetables such as cabbage (Marcinkowska & Jeleń, 2020). In vegetables, the perceived intensities of basic tastes are observed to be low (Poelman, Delahunty, & De Graaf, 2017; Van Stokkom, Blok, Van Kooten, De Graaf, & Stieger, 2018), suggesting that the sensory modalities of vision, tactile perception and olfaction may play an even more significant role in the acceptance (Van Stokkom et al., 2018). Thus, introducing individuals who are highly odor-aware to playful familiarization with vegetable odors might foster positive experiences and contribute to enhancing acceptance. Technologies, where odors are integrated with digital games, might be one innovative way to enable increased engagement (Niedenthal, Fredborg, Lundén, Ehrndal, & Olofsson, 2023).

Finally, a negative association was found between children's environmental odor awareness and their odor identification abilities. This would suggest that children who are less attuned to odors in their environment may perform better in identifying specific odors, a finding noteworthy given that the questionnaire items used to assess environmental odor awareness focus on exploration and active efforts to identify odors (e.g., trying to find out where a smell comes from or guessing the source of an odor). The negative association between children's environmental odor awareness and identification abilities may reflect negative emotional reactions or avoidant behaviors, as several items on the scale measuring odor awareness may capture such responses in addition to actual awareness. Children who score higher on the scale might be exhibiting avoidance, limiting their opportunities to engage with and learn to identify specific odors. Further highlighting the complexity of the relationship between odor awareness and identification abilities, previous findings (Lohrer et al., 2022) contradict the current results by showing a positive relationship between awareness of social odor cues and odor identification abilities. It may be reasonable to suggest that children with lower odor identification ability resonate with statements related to attempting to identify odors, as they likely

encounter a greater number of challenges to identify odors. While a link between odor awareness and odor identification abilities seem to exist, further investigation is required to clarify the direction and underlying mechanisms of this relationship. It is also important to note that diverse assessment tools are employed among the existing studies in the field.

4.1. Strengths and limitations of the study

Testing procedures were standardized to reduce biases yet conducted in non-laboratory settings to maintain familiarity for participants. Olfactory assessments occurred in various school settings, selected to best allow for ventilation and minimal disruptions. Questionnaire data were collected using both tablets or computers and pen and paper, no significant differences in mean scores were, however, found between these methods of data collection. During the analysis, variations in test results across different schools were observed. While these differences could reflect genuine variations in the sample, they may also indicate potential inconsistencies in the data collection process. To enhance the participants' understanding, researchers and school staff collaborated in discussing the concepts and procedures with the children, a process that might benefit from an even more standardized approach to ensure a consistent understanding of concepts and assessment scales across participant groups.

It is important to consider that the non-significant correlation analysis results do not exclude the possibility of existing associations. Given the application of a non-parametric test, less sensitive compared to parametric tests applied to normally distributed data, there is a likelihood of Type II errors (false negatives) affecting the results. In addition, it should be noted that the observed gender discrepancies may have been skewed by the disproportionate distribution of boys and girls in the sample.

A notable strength lies in the introduction of the Swedish ChiPSO questionnaire, an adaptation of the ChiPSO questionnaire by Lohrer et al. (2022). This marks the first effort, to our knowledge, to assess olfactory awareness in Swedish children. However, certain limitations should be acknowledged, including a small sample size and non-standardized testing environments. A single dataset was used for both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). While this approach allowed for a cohesive analysis, it may have introduced overfitting and affected the generalizability of the results.

We encourage further evaluation of the questionnaire tool within the target group and cultural context, in addition to validation by examining test-retest reliability and construct validity.

4.2. Practical implications

These findings contribute to the body of knowledge on odor identification and awareness, as well as possible relationships with food neophobia and the acceptance of fruits and vegetables. Further exploration of the relationship between food neophobia and olfaction could help identify possibilities for finding ways to assist neophobic individuals and their families. Understanding a child's relationship with odors may facilitate the design of personalized prevention and intervention strategies, which could be more efficient in reducing neophobia and minimizing the risk of negative experiences and aversions.

5. Conclusion

In this study, a questionnaire to quantify odor awareness in children was developed. Utilizing this measure, we explored possible associations between concepts related to olfaction and food neophobia. In this sample, food neophobia was associated with a lower acceptance of fruits and vegetables but not to odor awareness or odor identification performances. Interestingly, children with higher odor awareness showed a lower acceptance of vegetables, while no such relationship was found for fruits. These findings suggest that children's sensitivity to odors may

reduce their willingness to accept vegetables. Future studies could explore whether playful exposure to vegetable odors might help increase acceptance.

Ethical statement

School classes from four primary schools were recruited via school staff through e-mail or phone. All pupils in the recruited classes, with a written confirmation of informed consent by their caregiver(s), were invited to participate. The study protocol was approved by the ethical committee of Sweden (2022–05433–01-317,056). The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution

LA collected the data, with the help and supervision of PS. LA designed the statistical approach with the supervised coordination of PS and ER. PS, ER and JO also supervised LA in the interpretation of the data and PS, ER and JO supervised the manuscript process. All authors have reviewed and approved the final manuscript and take full responsibility for ensuring any questions concerning its accuracy and integrity are promptly investigated and addressed.

Appendix A. Factor loadings (exploratory factor analysis) of the current sample for the 33 items suggested in the original ChiPSO questionnaire by Lohrer et al. (2022). Factor loadings <0.3 are not displayed and items selected for inclusion in the final Swedish ChiPSO questionnaire are highlighted in bold

Item	Statement	Factor 1	Factor 2	Factor 3	Factor 4
31	I smell myself to check whether I have a bad odor	0.672			
2	It happens that I smell my clothes	0.634			
20	It happens that I smell parts of my body	0.602			
11	When I am sweating, I can smell it	0.581			
10	I sniff on food before eating	0.511	0.499		0.341
33	I smell my clothes to check whether it has to be washed	0.493			
16	I smell my breakfast before eating it	0.422			
6	Certain smells immediately activate memories	0.410			
30	I feel rather quickly disturbed by odors in my environment	0.398		0.313	0.356
21	It would bother me, if I could not smell anymore	0.331			
32	It would bother me if there were no odors anymore				
12	If someone is smoking next to me, it bothers me				
17	I know the smell of my bedroom		0.604		
4	I smell tea/lemonade before drinking it		0.577		
3	When there is a nasty smell in a room, I leave the room as soon as possible		0.471		
29	I do know how my blankets/stuffed animals smell/have smelled	0.429	0.440		
7	If there is a dish on the table that I don't know I would smell it before eating	0.342	0.434		0.410
24	I like to smell the odors around me when I walk in nature		0.415		
23	If a schoolmate has a nasty smell, I try to stay away		0.396		
25	When I smell delicious food, I get hungry		0.367		
15	It happens that I smell school tools	0.321	0.348		
14	The smell of a person plays a role in the decision whether I like him/her				
8	I find that my parents smell of something				
26	I think that people smell of something, even without perfume or deodorant				
22	When I smell an odor around me, I try to guess what it is			0.756	
18	If I smell something, I try to find out where it comes from		0.440	0.650	
27	I normally try to find out where an odor comes from		0.502	0.614	
5	If my parents have a nasty smell, I don't hug them			-0.415	
9	When I walk on the street, I normally smell something of the surrounding			-0.347	
13	Smelling nasty odors while eating usually make me lose my appetite				0.682
1	The smell of a food plays a role in the decision whether I like it or not				0.657
19	When I don't like the smell of a food I don't eat it				0.448
28	I smell on food to find out whether it is spoiled or not				0.411

Appendix B. Adaptions of the Children's Personal Significance of Olfaction (ChiPSO) Questionnaire to a Swedish Context

The adjusted translation was pre-tested on a small sample (3 boys and 2 girls, aged 8–13) in verbally probed cognitive interviews using the think-aloud technique. Two main discrepancies were discussed during the interviews and adjustments made accordingly. Firstly, the Swedish words used to describe the concepts of *blankets* and *stuffed animals* (item 29), and secondly the concept of *lemonade* (item 4). The words chosen for the final version of

the questionnaire in Swedish were advised by the cognitive interviews with children, probed to explain their interpretation of different words suggested to replace the unclear concepts. Other adaptations made, advised by the interviews, were changing the use of the sign forward slash to the words *and* (item 4) and *or* (item 29), as well as adding examples of school tools (item 15). In item 6, the personification of the non-living object *certain smells* was not clear to some of the Swedish children. Instead of attributing the action to *activate memories* to this abstract concept, a first-person perspective was introduced to increase understanding. In item 10, the Swedish pronoun *den* (in English *it*) was added as a direct object to increase clarity. Several children reported not having experienced anyone smoking close to them, as mentioned in item 12, but no changes were made to the item based on this knowledge.

Data availability

Data will be made available on request.

References

- Allison, P. D. (2001). *Missing data*. Sage.
- Appleton, K., Dinnella, C., Spinelli, S., Morizet, D., Saulais, L., Hemingway, A., Monteleone, E., Depezay, L., Perez-Cueto, F., & Hartwell, H. (2019). Liking and consumption of vegetables with more appealing and less appealing sensory properties: Associations with attitudes, food neophobia and food choice motivations in European adolescents. *Food Quality and Preference*, *75*, 179–186. <https://doi.org/10.1016/j.foodqual.2019.02.007>
- Arshamian, A., Willander, J., & Larsson, M. (2011). Olfactory awareness is positively associated to odour memory. *Journal of Cognitive Psychology*, *23*(2), 220–226. <https://doi.org/10.1080/20445911.2011.483226>
- Birch, L. L. (1998). Development of food acceptance patterns in the first years of life. *Proceedings of the Nutrition Society*, *57*(4), 617–624. <https://doi.org/10.1079/PNS19980090>
- Birch, L. L., & Fisher, J. O. (1998). Development of eating behaviors among children and adolescents. *Pediatrics (Evanston)*, *101*(3 Pt 2), 539–549. <https://doi.org/10.1542/peds.101.S2.539>
- Cain, W. S., Stevens, J. C., Nickow, C. M., Giles, A., Johnston, I., & Garcia-Medina, M. R. (1995). Life-span development of odor identification, learning, and olfactory sensitivity. *Perception*, *24*(12), 1457–1472. <https://doi.org/10.1068/p241457>
- Caprara, G. V., Barbaranelli, C., Bermúdez, J., Maslach, C., & Ruch, W. (2000). Multivariate methods for the comparison of factor structures in cross-cultural research: An illustration with the big five questionnaire. *Journal of Cross-Cultural Psychology*, *31*(4), 437–464. <https://doi.org/10.1177/0022022100031004002>
- Cooke, L. J., Haworth, C. M., & Wardle, J. (2007). Genetic and environmental influences on children's food neophobia. *The American Journal of Clinical Nutrition*, *86*(2), 428–433. <https://doi.org/10.1093/ajcn/86.2.428>
- Coulthard, H., & Blissett, J. (2009). Fruit and vegetable consumption in children and their mothers. Moderating effects of child sensory sensitivity. *Appetite*, *52*(2), 410–415. <https://doi.org/10.1016/j.appet.2008.11.015>
- Demattè, M. L., Endrizzi, I., Biasioli, F., Corollaro, M. L., Pojer, N., Zampini, M., ... Gasperi, F. (2013). Food neophobia and its relation with olfactory ability in common odour identification. *Appetite*, *68*, 112–117. <https://doi.org/10.1016/j.appet.2013.04.021>
- Demattè, M. L., Endrizzi, I., Biasioli, F., Corollaro, M. L., Zampini, M., & Gasperi, F. (2011). Individual variability in the awareness of odors: Demographic parameters and odor identification ability. *Chemosensory Perception*, *4*(4), 175–185. <https://doi.org/10.1007/s12078-011-9103-7>
- Demattè, M. L., Endrizzi, I., & Gasperi, F. (2014). Food neophobia and its relation with olfaction. *Frontiers in Psychology*, *5*, 127. <https://doi.org/10.3389/fpsyg.2014.00127>
- Doty, R. L., & Kamath, V. (2014). The influences of age on olfaction: A review. *Frontiers in Psychology*, *5*. <https://doi.org/10.3389/fpsyg.2014.00020>
- Doty, R. L., Shaman, P., Applebaum, S. L., Giberson, R., Siksorski, L., & Rosenberg, L. (1984). Smell identification ability: Changes with age. *Science*, *226*(4681), 1441–1443. <https://doi.org/10.1126/science.6505700>
- Dovey, T. M., Staples, P. A., Gibson, E. L., & Halford, J. C. G. (2008). Food neophobia and 'picky/fussy' eating in children: A review. *Appetite*, *50*(2), 181–193. <https://doi.org/10.1016/j.appet.2007.09.009>
- Enghardt Barbieri, H. (2003). *Riksmaten - barn 2003: Livsmedels- och n??ringsintag bland barn i Sverige*.
- Fallon, A. E., & Rozin, P. (1983). The psychological bases of food rejections by humans. *Ecology of Food and Nutrition*, *13*(1), 15–26. <https://doi.org/10.1080/03670244.1983.9990728>
- Ferdenzi, C., Mustonen, S., Tuorila, H., & Schaal, B. (2008). Children's Awareness and Uses of Odor Cues in Everyday Life: A Finland–France Comparison. *Chemosensory Perception*, *1*(3), 190–198. <https://doi.org/10.1007/s12078-008-9020-6>
- Fletcher, S., Wright, C., Jones, A., Parkinson, K., & Adamson, A. (2017). Tracking of toddler fruit and vegetable preferences to intake and adiposity later in childhood: Tracking of fruit and vegetable preferences. *Maternal & Child Nutrition*, *13*(2), Article e12290. <https://doi.org/10.1111/mcn.12290>
- Frank, R. A., Brearton, M., Rybalsky, K., Cessna, T., & Howe, S. (2011). Consistent flavor naming predicts recognition memory in children and young adults. *Food Quality and Preference*, *22*(1), 173–178. <https://doi.org/10.1016/j.foodqual.2010.09.009>
- Gellrich, J., Sparing-Paschke, L.-M., Thieme, T., Schwabe, K., Dworschak, A., Hummel, T., & Schriever, V. A. (2019). Normative data for olfactory threshold and odor identification in children and adolescents. *International Journal of Pediatric Otorhinolaryngology*, *123*(Journal Article), 5–9. <https://doi.org/10.1016/j.ijporl.2019.01.009>
- Guinard, J.-X. (2000). Sensory and consumer testing with children. *Trends in Food Science & Technology*, *11*(8), 273–283. [https://doi.org/10.1016/S0924-2244\(01\)00015-2](https://doi.org/10.1016/S0924-2244(01)00015-2)
- Hazley, D., Stack, M., Walton, J., McNulty, B. A., & Kearney, J. M. (2022). Food neophobia across the life course: Pooling data from five national cross-sectional surveys in Ireland. *Appetite*, *171*, Article 105941. <https://doi.org/10.1016/j.appet.2022.105941>
- Hummel, T., Sekinger, B., Wolf, S. R., Pauli, E., & Kobal, G. (1997). 'Sniffin' Sticks': Olfactory performance assessed by the combined testing of odor identification. *Odor Discrimination and Olfactory Threshold*, *14*. <https://doi.org/10.1093/chemse/22.1.39>
- Hurst, U.-K. K., & Sjöden, P.-O. (1997). Food and general Neophobia and their relationship with self-reported food choice: Familial resemblance in Swedish families with children of ages 7–17 years. *Appetite*, *29*(1), 89–103. <https://doi.org/10.1006/appe.1997.0108>
- Laureati, M., Bergamaschi, V., & Pagliarini, E. (2015). Assessing childhood food neophobia: Validation of a scale in Italian primary school children. *Food Quality and Preference*, *40*, 8–15. <https://doi.org/10.1016/j.foodqual.2014.08.003>
- Laureati, M., Pagliarini, E., Toschi, T. G., & Monteleone, E. (2015). Research challenges and methods to study food preferences in school-aged children: A review of the last 15 years. *Food Quality and Preference*, *46*, 92–102. <https://doi.org/10.1016/j.foodqual.2015.07.010>
- Lohrer, E. C., Dworschak, A., Croy, I., Gellrich, J., Sabha, M., Parisato, L., & Schriever, V. A. (2022). Children's personal significance of olfaction—The ChiPSO questionnaire. *Chemosensory Perception*, *15*(2), 154–164. <https://doi.org/10.1007/s12078-022-09303-z>
- Lynch, C., Kristjansdottir, A. G., te Velde, S. J., Lien, N., Roos, E., Thorsdottir, I., ... Yngve, A. (2014). Fruit and vegetable consumption in a sample of 11-year-old children in ten European countries – The PRO GREENS cross-sectional survey. *Public Health Nutrition*, *17*(11), 2436–2444. <https://doi.org/10.1017/S1368980014001347>
- Marcinkowska, M., & Jelen, H. H. (2020). Determination of the odor threshold concentrations and partition coefficients of isothiocyanates from Brassica vegetables in aqueous solution. *LWT*, *131*, Article 109793. <https://doi.org/10.1016/j.lwt.2020.109793>
- Martínez Nováková, L., Fialová, J., & Havlíček, J. (2018a). Development of Children's olfactory abilities and odor awareness is not predicted by temperament: A longitudinal study. *Chemosensory Perception*, *11*(2), 59–71. <https://doi.org/10.1007/s12078-017-9240-8>
- Martínez Nováková, L., Fialová, J., & Havlíček, J. (2018b). Effects of diversity in olfactory environment on children's sense of smell. *Scientific Reports*, *8*(1), 2937. <https://doi.org/10.1038/s41598-018-20236-0>
- Martínez Nováková, L., Vojtušová Mrzilková, R., & Kermerová, A. (2017). Gender differences in influences of temperament on olfactory reactivity and awareness. *Scientific Reports*, *7*(1), 8920. <https://doi.org/10.1038/s41598-017-09231-z>
- Menghi, L., Khomenko, L., Pedrotti, M., Clicerì, D., Aprea, E., Endrizzi, I., Cavazzana, A., Biasioli, F., Giacalone, D., & Gasperi, F. (2020). Arousal influences olfactory abilities in adults with different degree of food neophobia. *Scientific Reports*, *10*(1), 20538. <https://doi.org/10.1038/s41598-020-77428-w>
- Monnery-Patris, S., Rouby, C., Nicklaus, S., & Issanchou, S. (2009). Development of olfactory ability in children: Sensitivity and identification. *Developmental Psychobiology*, *51*(3), 268–276. <https://doi.org/10.1002/dev.20363>
- Monnery-Patris, S., Wagner, S., Rigal, N., Schwartz, C., Chabanet, C., Issanchou, S., & Nicklaus, S. (2015). Smell differential reactivity, but not taste differential reactivity, is related to food neophobia in toddlers. *Appetite*, *95*, 303–309. <https://doi.org/10.1016/j.appet.2015.07.021>
- Mustonen, S., Oerlemans, P., & Tuorila, H. (2012). Familiarity with and affective responses to foods in 8–11-year-old children. The role of food neophobia and parental education. *Appetite*, *58*(3), 777–780. <https://doi.org/10.1016/j.appet.2012.01.027>
- Niedenthal, S., Fredborg, W., Lundén, P., Ehrndal, M., & Olofsson, J. K. (2023). A graspable olfactory display for virtual reality. *International Journal of Human-Computer Studies*, *169*, Article 102928. <https://doi.org/10.1016/j.ijhcs.2022.102928>
- Perry, R. A., Mallan, K. M., Koo, J., Mauch, C. E., Daniels, L. A., & Magarey, A. M. (2015). Food neophobia and its association with diet quality and weight in children aged 24 months: A cross sectional study. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 13. <https://doi.org/10.1186/s12966-015-0184-6>
- Pliner, P. (1994). Development of measures of food Neophobia in children. *Appetite*, *23*(2), 147–163. <https://doi.org/10.1006/appe.1994.1043>
- Poelman, A. A. M., Delahunty, C. M., & De Graaf, C. (2017). Vegetables and other core food groups: A comparison of key flavour and texture properties. *Food Quality and Preference*, *56*, 1–7. <https://doi.org/10.1016/j.foodqual.2016.09.004>
- Proserpio, C., Almlí, V. L., Sandvik, P., Sandell, M., Methven, L., Wallner, M., ... Laureati, M. (2020). Cross-national differences in child food neophobia: A

- comparison of five European countries. *Food Quality and Preference*, 81, Article 103861. <https://doi.org/10.1016/j.foodqual.2019.103861>
- Raudenbush, B., Schroth, F., Reilley, S., & Frank, R. A. (1998). Food Neophobia, odor evaluation and exploratory sniffing behavior. *Appetite*, 31(2), 171–183. <https://doi.org/10.1006/appe.1998.0161>
- Rydell, A.-M., Dahl, M., & Sundelin, C. (1995). Characteristics of school children who are choosy eaters. *The Journal of Genetic Psychology*, 156(2), 217–229. <https://doi.org/10.1080/00221325.1995.9914818>
- Sandvik, P., Laureati, M., Jilani, H., Methven, L., Sandell, M., Hörmann-Wallner, M., ... Almlí, V. L. (2021). Yuck, this biscuit looks lumpy! Neophobic levels and cultural differences drive Children's check-all-that-apply (CATA) descriptions and preferences for high-fibre biscuits. *Foods*, 10(1), Article 1. <https://doi.org/10.3390/foods10010021>
- Saxton, T. K., Martinec Nováková, L., Jash, R., Šandová, A., Plotěná, D., & Havlíček, J. (2014). Sex differences in olfactory behavior in Namibian and Czech children. *Chemosensory Perception*, 7(3–4), 117–125. <https://doi.org/10.1007/s12078-014-9172-5>
- Schriever, V. A., Agosin, E., Altundag, A., Avni, H., Cao Van, H., Cornejo, C., & de los Santos, G., Fishman, G., Fragola, C., Guarneros, M., Gupta, N., Hudson, R., Kamel, R., Knaapila, A., Konstantinidis, I., Landis, B. N., Larsson, M., Lundström, J. N., Macchi, A., ... Hummel, T.. (2018). Development of an international odor identification test for children: The universal sniff test. *The Journal of Pediatrics*, 198(Journal Article), 265–272.e3. <https://doi.org/10.1016/j.jpeds.2018.03.011>
- Schriever, V. A., Zscheile, L., Gellrich, J., & Hummel, T. (2021). Odor identification performance in children aged 3–6 years. *Pediatric Research*, 89(5), 1304–1309. <https://doi.org/10.1038/s41390-020-1083-3>
- Smeets, M. A. M., Schifferstein, H. N. J., Boelema, S. R., & Lensvelt-Mulders, G. (2008). The odor awareness scale: A new scale for measuring positive and negative odor awareness. *Chemical Senses*, 33(8), 725–734. <https://doi.org/10.1093/chemse/bjn038>
- Sorokowska, A., Chabin, D., Hummel, T., & Karwowski, M. (2022). Olfactory perception relates to food neophobia in adolescence. *Nutrition*, 98, Article 111618. <https://doi.org/10.1016/j.nut.2022.111618>
- Stevenson, R. J. (2010). An initial evaluation of the functions of human olfaction. *Chemical Senses*, 35(1), 3–20. <https://doi.org/10.1093/chemse/bjp083>
- Stevenson, R. J., Mahmut, M., & Sundqvist, N. (2007). Age-related changes in odor discrimination. *Developmental Psychology*, 43(1), 253–260. <https://doi.org/10.1037/0012-1649.43.1.253>
- Van Stokkom, V. L., Blok, A. E., Van Kooten, O., De Graaf, C., & Stieger, M. (2018). The role of smell, taste, flavour and texture cues in the identification of vegetables. *Appetite*, 121, 69–76. <https://doi.org/10.1016/j.appet.2017.10.039>