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Children's exposure to odors in everyday contexts predicts their odor awareness

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Abstract
Introduction A great degree of interindividual variability has been reported in measures of psychophysical olfactory performance and odor awareness in both children and adults. Previous studies have suggested the possibility that one of the factors that might contribute to this variability could be the degree of odor exposure experienced in everyday contexts.
Aim In the present study, we hypothesized that children exposed to a greater variety of odors on a more frequent basis exhibit higher odor identification, discrimination, and odor awareness scores.
Results We have found an effect of odor exposure on one aspect of the children's olfactory knowledge as reflected in their reports of olfactory behavior, but not olfactory abilities. In so doing, we have replicated some of the previous findings in the literature of the female advantage in the olfactory domain. Namely, we report that girls showed a more profound metacognitive understanding of their sense of smell and a greater degree of olfaction-oriented behavior, which was not accounted for by a gender difference in verbal fluency. Nevertheless, girls did not outperform boys on any of the olfactory tests.
Conclusion Semi-longitudinal and longitudinal studies in verbally proficient children, employing both self- and parental reports of children's odor exposure and repeated olfactory testing, may provide insight into whether children exposed more frequently to a greater variety of odors over the longer term come to exhibit greater odor awareness and superior performance in olfactory tests.

Keywords Children · Odor awareness · Odor exposure · Olfactory abilities · Parental report · Self-report · Smell

Introduction

A great degree of variability has been established in the three most widely used measures of psychophysical olfactory performance, namely, odor identification, discrimination, and the olfactory threshold in both adults and children (e.g., Hummel et al. 2007b; Sorokowska et al. 2015). Also, considerable variability exists in self-reported odor awareness, which can be assessed with various metacognitive measures. These help researchers understand how individuals interact with their olfactory environments, which cannot be reproduced within laboratory settings. These measures include, for example, Odor Awareness Scale (OAS; Smeets et al. 2008) in adults and Children's Olfactory Behaviors in Everyday Life Questionnaire (COBEL; Ferdenzi et al. 2008a) in children. Studies in which these and similar measures have been employed reveal that while some people are readily aware of odors surrounding them in specific contexts and spontaneously point out to others their presence, others will only notice smells after they have been brought to their attention. Whereas some people let their attitudes and behaviors be affected by olfactory perceptions, others do not. Also, pleasant olfactory stimuli are sought more actively and unwanted, potentially disturbing odors are controlled more carefully by some individuals than by others. People exhibiting the former

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characteristics can be referred to as highly olfaction-oriented individuals.

Among the demographic factors which have been found to influence both olfactory performance and self-reported odor awareness, gender is the second most important one after age (for review, see Brand and Millot 2001). From an evolutionary point of view, it has been proposed that the female olfactory superiority has been selected specifically in the context of mate choice, but it appears that women also attach greater importance to olfactory cues than men in contexts unrelated to sexual behavior (e.g., Dematte et al. 2011). Furthermore, it seems to emerge relatively early in ontogeny, when the context of mate choice is far from relevant (Ferdenzi et al. 2008a, b; Monnery-Patris et al. 2009; Richman et al. 1992), although some studies have reported no gender differences in odor identification (Cameron and Doty 2013; Saxton et al. 2014; Schriever et al. 2014). Authors of these studies nevertheless concede that this might well be due to the relatively small sample size and thus insufficient statistical power. Females' greater odor awareness and use of odor cues has also been reported in both adults (Buron et al. 2011; Dematte et al. 2011; Sucker et al. 2010) and children (Ferdenzi et al. 2008a, b; Saxton et al. 2014). Specifically, girls seem to report greater awareness than boys to social and environmental odors, but not food odors (Ferdenzi et al. 2008a; Saxton et al. 2014).

Explanations for such variability in both olfactory abilities and odor awareness remain incomplete. One of the potential sources, originally proposed by Brand and Millot (2001), could be olfactory experience. In their review, the authors hypothesize that women may in general encounter olfactory stimuli more often than men, and thus they could have greater experience with a wider variety of odors. In western industrialized societies at least, this might result from women's long-term greater odor exposure within specific contexts, which possibly starts as early as during childhood. These contexts include cooking, use of cosmetic products, or housework (Bianchi et al. 2000; Coltrane 2000; Fuwa and Cohen 2007). Indeed, gender stereotyping of activities seems to be encouraged from very early in ontogeny. For instance, girls but not boys as young as 2 years of age show some knowledge of gender stereotyping of household chores (Poulin-Dubois et al. 2002).

Several studies have suggested a link between olfactory stimulation in everyday contexts, odor awareness, and olfactory performance. For example, in the study by Arshamian et al. (2011), adults exhibiting a high degree of odor awareness, assessed by means of self-reported presence of olfactory dreams, high olfactory imagery capacity, and olfactory interests, performed better than their lower-scoring counterparts on the test of free odor identification (also referred to as odor naming), but not cued odor identification. According to the authors, this was because the former had acquired a more elaborated olfactory knowledge base that supports spontaneous verbal retrieval of olfactory information. Recently, Nováková et al. (2014) have shown a positive association between odor identification and the composite olfactory score (comprised of odor identification, discrimination, and threshold) on the one hand and odor awareness on the other. More importantly, the authors have demonstrated that self-reported exposure to a greater variety of potentially intense or novel food odors and flavors in both childhood and adulthood was positively linked to both greater odor awareness and better odor identification. There was also a positive link between female-stereotyped activities in childhood and odor awareness. Hence, in adults there is some evidence that long-term everyday experience with odors may be linked to a better ability of odor identification and greater odor awareness. In children, the results have been mixed so far. Whereas in the original use of the COBEL instrument Ferdenzi et al. (2008b) have found no difference in odor identification performance between 7 to 10-year-olds scoring the highest and the lowest on COBEL, Saxton et al. (2014) have reported a positive correlation between COBEL scores and odor identification in the sample of Czech children aged 8–11 years, but not Namibian ones (9–15-year-olds). In the latter study, Namibian participants had also been interviewed about their olfactory environment, which, however, seemed to have no effect on the children's odor identification ability or COBEL scores.

Thus, the aim of the present study was to investigate whether children's olfactory abilities of odor identification and discrimination and COBEL scores could be predicted by parental reports of children's odor exposure in everyday contexts. We hypothesized that children exposed to a greater variety of odors on a more frequent basis would exhibit higher odor identification and COBEL scores.

Materials and Methods

Participants

The participants were 129 children of Czech origin (62 boys, mean age 6.84 ± 0.41 years, range 6.11–8.26 years), who were first-graders from six mixed-sex general education elementary schools in Prague and its suburbs. School principals had been contacted via telephone and e-mail to inform them about the planned study. Those who had provided permission to perform the study on the school's premises were asked to pass the information on to the teachers who distributed leaflets to children, who, in turn, handed them over to their parents. Girls and boys did not differ in terms of mean age or age distribution, boys = 6.89 ± 0.45 years, range 6.11–7.93 years, girls = 6.80 ± 0.38 years, range 6.28–8.26 years, respectively, Kolmogorov-Smirnov $Z = 0.93$, $p = 0.36$. According to parental reports, 12 children suffered from various allergies, chronic asthma, or other chronic conditions, and three have sustained

concussion with loss of consciousness. However, as the data obtained from these children did not manifest themselves as outliers, they have not been excluded from the analyses. Thus, the two identification tests and the discrimination one, the interview based on the Children's Olfactory Behaviors in Everyday Life Questionnaire (Ferdenzi et al. 2008a), and the verbal fluency task have been completed by 129 children. The complete descriptive data are given in Table 1.

Furthermore, 30 preschool children (15 boys, mean age 5.99 ± 0.43 years, range 5.25–6.75 years), all residents of Prague and its suburbs, have participated in a pilot study. It was conducted primarily in order to guide selection of pictures to be employed in the identification test and to verify they were understood correctly. Its other purpose was to assess children's understanding of the questions asked in the interview based on the COBEL (Ferdenzi et al. 2008a) and to compare performance on the three verbal fluency tests. The children have been recruited in the same manner as those participating in the main study.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). The study has been approved by the IRB of the Charles University (Approval Number 2015/11). Written informed consent has been obtained from the children's parents and oral informed consent has been provided by the children in the presence of a teacher employed by the school. The child-parent pairs each received 300 CZK (approx. 11 EUR or 12 USD) in compensation.

Questionnaires

Odor Exposure Inventory

Parents ($N = 134$, 124 mothers, mean age 37.30 ± 4.11 years, range 27–50 years) were asked to complete an inventory regarding their children's exposure to odors in various everyday contexts. It was based on the Olfactory Diversity Questionnaire (ODQ; Ferdenzi 2007), which provides parental reports of children's odor exposure and lists items involving activities potentially rich in olfactory stimulation. It has been reported to exhibit a moderate to strong association with children's both free and cued Sniffin' Sticks odor identification scores (Ferdenzi 2007). Items include, for instance, raising the child's awareness of the surrounding odors, child's exposure to exotic foods and a variety of herbs and spices, use of various scented products, presence of natural sources of odor (e.g., animals) in the household, smoking, or air pollution in the neighborhood. Response categories provided for items: Naming, Fragrance, Home fragrance, Car, Essential oils, Toys, Attention, Unusual and exotic foods, Seasoning, and Travel were "never" (1), "rarely" (2), "sometimes" (3), "often" (4), "very often" (5). For items: Scented cosmetic products, Scented household products, Odor impregnation, Breastfeeding, Smoking at home, and Smoking elsewhere, the response categories were a "yes" (2) or "no" (1). For items: Pets, Fragrant plants, and Environment, the original response format was a free answer. The complete list of the items is given in Table 2.

Table 1 Mean ± SD, their respective 95 % bias corrected and accelerated bootstrap confidence intervals (in brackets), and range for age, verbal fluency, olfactory measures, COBEL scores (total and food, social, and environmental component), and the three components of odor exposure in boys and girls

	Boys ($N = 62$)			Girls ($N = 67$)		
	Mean	SD	Range	Mean	SD	Range
Age (months)	82.21	5.03	73.30–95.00	81.78	4.55	75.30–99.10
Verbal fluency	12.76 [11.68; 13.94]	4.37 [3.49; 5.20]	5.00–27.00	13.90 [13.00; 14.87]	4.02 [3.24; 4.66]	7.00–27.00
Identification "blue"	7.82 [7.43; 8.24]	1.63 [1.38; 1.82]	4.00–11.00	7.81 [7.42; 8.20]	1.53 [1.34; 1.70]	4.00–10.00
Identification "purple"	7.53 [6.97; 8.05]	2.15 [1.80; 2.52]	1.00–12.00	7.94 [7.54; 8.35]	1.72 [1.51; 1.90]	4.00–11.00
Identification total	15.35 [14.58; 16.13]	3.19 [2.76; 3.56]	8.00–22.00	15.75 [15.08; 16.40]	2.57 [2.17; 2.95]	9.00–20.00
Discrimination	8.19 [7.36; 9.03]	3.36 [2.81; 3.84]	2.00–16.00	9.07 [8.46; 9.67]	2.66 [2.24; 3.01]	4.00–15.00
COBEL total	5.60 [5.08; 6.12]	2.45 [2.11; 2.71]	1.50–11.00	6.75 [6.27; 7.25]	2.02 [1.88; 2.46]	2.50–11.50
COBEL food	1.27 [1.08; 1.46]	0.79 [0.69; 0.87]	0–3.00	1.47 [1.30; 1.64]	0.68 [0.59; 0.75]	0–3.00
COBEL social	1.25 [1.03; 1.47]	0.97 [0.86; 1.05]	0–3.50	1.70 [1.47; 1.92]	0.97 [0.85; 1.06]	0–3.50
COBEL environmental	3.07 [2.78; 3.38]	1.32 [1.13; 1.49]	0.50–6.50	3.58 [3.31; 3.84]	1.27 [1.08; 1.43]	1.00–6.00
Odor control and naming	−0.13 [−0.39; 0.12]	1.01 [.85; 1.13]	−2.14–2.44	0.12 [−0.10; 0.33]	0.99 [0.87; 1.07]	−1.86–2.48
Food	0.01 [−0.23; 0.24]	1.02 [0.88; 1.14]	−1.95–2.16	−0.01 [−0.23; 0.24]	0.99 [0.86; 1.10]	−2.20–2.44
Environmental odors	−0.08 [−0.29; 0.15]	0.90 [0.76; 1.02]	−2.52–1.76	0.07 [−0.21; 0.33]	1.10 [0.95; 1.20]	−2.49–1.89

Please note that Item 3 (comprising the environmental component) has been removed from the COBEL-based interview. Also, both identification tests were only comprised of 12 instead of the original 16 items

Table 2 An overview of the components (percentage of total variance), items, their wording, response format, and loadings

Component	Item	Wording	Response format	Loading
Odor control and naming (21.88 %)	Home fragrance	Please rate how often you odorize your home with scented candles, sticks, diffusers, air fresheners, Papier d'Arménie, Potpourri, etc.	Never (1) to very often (5)	0.654
	Essential oils	Please rate how often you use essential oils or products containing essential oils.	Never (1) to very often (5)	0.630
	Car	Please rate how often you use air freshener in your car.	Never (1) to very often (5)	0.577
	Fragrance	Please rate how often you wear cologne, eau de toilette, eau de parfum, or perfume.	Never (1) to very often (5); recoded to three categories	0.570
	Naming	Please rate how often you teach your child to recognize and name various odors and their sources.	Never (1) to very often (5); recoded to three categories	0.568
	Scented cosmetic products/ Scented household products (merged into Fragrant purchases)	*Do you prefer to purchase (1) cosmetic and (2) household products which are richly scented? (merged variable)*	*Yes/no; recoded to both (3), either (2), neither (1)*	*0.426*
Food (11.54 %)	Unusual and exotic foods	Please rate how often you let your child try unusual or exotic foods or dishes.	Never (1) to very often (5); recoded to three categories	0.615
	Seasoning	Please rate how often you use various spices and herbs to season your home-cooked meals.	Never (1) to very often (5); recoded to three categories	0.514
	Attention	*Please rate how often you draw your child's attention to odors, pleasant or otherwise, of people, things, or places.*	*Never (1) to very often (5); recoded to three categories*	*0.430*
Environmental odors (9.93 %)	Environment	Are there any objects in the vicinity of your home which are, even occasionally, a source of strong odor, whether pleasant or not (busy road, industrial or agricultural facility, dumping ground, restaurant, etc.)?	List all that apply; recoded to yes (2)/no (1)	0.560
	Travel	Please rate how often you take your child on trips outside Europe.	Never (1) to very often (5); recoded to yes (2)/no (1)	−0.533
	Pets	*Do you keep any pets at home?*	*List all that apply; recoded to yes (2)/no (1)*	*0.434*
	Toys	*Please rate how often your child plays with toys which have an odor.*	*Never (1) to very often (5); recoded to yes (2)/no (1)*	*0.221*
Items with low variability (not used)	Odor impregnation	Do you sometimes come home impregnated with odor, whether due to your profession or leisure activities?	Yes (2)/no (1)	N/A
	Breastfeeding	Has your child been breastfed (for a minimum of 2 months)?	Yes (2)/no (1)	N/A
	Smoking at home	Do you or a family member smoke at home?	Yes (2)/no (1)	N/A
	Smoking elsewhere	Are there any places your child visits often where he or she becomes exposed to cigarette smoke?	Yes (2)/no (1)	N/A
	Fragrant plants	Do you grow fragrant plants or herbs at home?	List all that apply	N/A

Items with weak loadings (<0.512) are given in italics at the component on which their loadings have been the highest. Items with low variability and, therefore, not used in categorical PCA are given at the bottom

N/A not available

Visual exploration of bar charts showed that responses to items Odor impregnation, Smoking at home, Smoking elsewhere, Breastfeeding, and Fragrant plants exhibited very small variability, with the most frequent response being never/no or no answer given in over 85 % of cases, with the exception of Breastfeeding, to which 88 % of the parents responded in the affirmative. Therefore, responses to these questions have been excluded from the analysis. Furthermore, due to low frequencies of responses ($N<5$) in the "never" and "very often" categories, the 5-category

response format had to be recoded to a 3-category format, merging the "never" and "rarely" categories on the one hand and "often" and "very often" on the other for some frequency questions. Specifically, this recoding pertained to Attention, Fragrance, Naming, Seasoning, and Unusual and exotic foods. Toys and Travel, due to their low frequencies in both the "often" and "very often" categories, still resulting in $N \leq 5$ in the merged category, were recoded to a "yes/no" response format ("never" = "no", other responses = "yes"). Also, since the items Scented cosmetic products and Scented household products were highly correlated, $\lambda = 0.633$, $p < 0.001$, they have been merged into a single variable (Fragrant purchases) and coded so that a 3 denoted a preference for fragrance in both cosmetic and household products, 2 in either and 1 in neither. Finally, since 75 % of the 64 % of families who had pets reported keeping multiple animal species, responses have been recoded as "yes/no". The same applied to item Environment, with the answer "busy road" given in over 75 % of responses.

To identify the components underlying the reports of odor exposure and to obtain component scores to be used in the subsequent analyses, we performed a categorical principal component analysis (PCA) using the IBM SPSS categorical PCA (CATPCA) Optimal Scaling option. Given the low variability in some items as mentioned above, of the original 19 items, 13 variables including one merged were entered in the analysis. The assumptions of the analysis were met, since an exploration of correlations between the variables showed that extreme multicollinearity (>0.9) or singularity (=0.0) were not a problem, and all the data were positive integer. The CATPCA settings involved discretizing the ordinal variables by means of ranking and the nominal ones by grouping, and selecting variable principal as the normalization method. Dimensions in solution were determined upon several trials in order to obtain the most interpretable structure of loadings. Specifically, eigenvalues were used as an indication of how many dimensions were needed, following the general rule which states that the eigenvalue for a dimension should be larger than 1 when all variables are either single nominal, ordinal, or numerical. Joint plots of the category points showed that the categories of variables were separated by the categorical principal components analysis clearly enough as could be expected when the level is truly ordinal. The plot of the object scores revealed no outliers. The recommendation of Stevens (2009:332) on component loadings with respect to sample size was followed, and component loadings greater than 0.512 for N ranging between 100 and 140 at $\alpha = 0.01$ were considered statistically significant. Also, it has been suggested that of these, only loadings sharing at least 15 % of their variance with the components (i.e., loadings of about 0.40 or greater) should be considered practically significant and useful for interpretation purposes (Stevens 2009:332). This rule of thumb, in the present case, was overridden by the previous recommendation. The CATPCA yielded three components: (i) Odor control and naming, (ii) Food, and (iii) Environmental odors. The resulting components, the individual items and their wording, response format, and loadings are given in Table 2.

Children's Olfactory Behaviors in Everyday Life Questionnaire (COBEL)

Having been developed with six to 10-year-olds, COBEL (Ferdenzi et al. 2008a) consists of 16 questions designed to evaluate self-reported awareness and reactivity to odors in significant everyday contexts. The questions fall into three categories: Food (for instance, whether children try to guess what they will eat for dinner from cooking smells), Social (for instance, whether children realize that people have a natural odor), and Environmental (for instance, whether children seek out smells when they are feeling sad). The question format varies, including multiple choice, rating, and open-ended questions. Each item was coded on a 3-point scale, rating the behavior as poorly (0), moderately (0.5), or highly (1) olfaction-oriented in the given situation. Although it had been used in a previous study with slightly older Czech children (Saxton et al. 2014), a pilot study ($N = 30$) has revealed that most children were unfamiliar with the rating format of Item 3 ("Senses in nature"), which involved ranking the following activities in order of preference: touching, smelling, watching, listening. Therefore, the item has been excluded from the interview. Thus, the total COBEL score, computed as a sum of the 15 items, ranged from 0 to 15. In addition to the total score, component scores for food, social, and environmental odors were computed following previous usage of COBEL (Ferdenzi et al. 2008a, b; Saxton et al. 2014), ranging from 0 to 3, 0 to 4, and 0 to 8, respectively. For the sake of comparison with previous studies (Ferdenzi et al. 2008a; Saxton et al. 2014), Cronbach's alpha coefficients were calculated on the basis of the inter-item gamma correlation matrix following Ferdenzi et al. (2008a) using SPSS Crosstabs option. These results are shown in Table 3.

Olfactory Measures

The Sniffin' Sticks test (Hummel et al. 1997), manufactured by Burghart Messtechnik GmbH, was used to obtain odor identification and discrimination. This is one of the most widely used tests of olfactory performance, based on pen-like odor dispensing devices. Odor threshold has not been tested because used as is, in this age group it only appears to place excessive demands on the attentional capacity of the younger children and prolong the testing time (e.g., Hummel et al. 2007a). The Sniffin' Sticks test has been widely used by clinicians and researchers across Europe to test olfactory abilities in adults (Hummel et al. 2007b) and children (Ferdenzi

Table 3 Cronbach's alpha and inter-item gamma correlations for the COBEL scores and the COBEL components

		Overall COBEL	Food component	Social component	Environmental component
Cronbach's alpha		0.687	0.086	0.562	0.523
Inter-item gamma correlation range	Range	−0.308 [−0.655; 0.072] to 0.599 [0.321; 0.826]	−0.113 [−0.373; 0.142] to 0.343 [0.089; 0.557]	0.245 [−0.038; 0.479] to 0.464 [0.187; 0.677]	−0.164 [−0.592; 0.570] to 0.599 [0.321; 0.826]
	Mean	0.224 [0.190; 0.258]	0.054 [−0.105; 0.206]	0.366 [0.317; 0.415]	0.234 [0.164; 0.300]

95 % bias corrected and accelerated bootstrap confidence intervals are given in brackets. Please note that Item 3 (comprising the environmental component) has been excluded

et al. 2008b; Renner et al. 2009; Sorokowska et al. 2015), including Czech ones (Dudova et al. 2011; Hrdlicka et al. 2011; Martinec Nováková et al. 2015; Saxton et al. 2014). The two 16-item identification tests ("blue" and "purple") both consist of odorants familiar to the general European population, such as orange, rose, garlic, and fish. The rationale behind the use of two identification tests instead of one was to prevent the possible ceiling effect. Cued identification is employed, in which participants select the name of the target odor from a candidate list of four. The resulting score is the sum of correct answers. Since most children were only beginning to learn reading, both the target descriptors and the three alternatives were presented as pictures instead of verbal labels. Selection of pictures was based on a pilot study ($N=30$) carried out in two sessions. In the first session, children were interviewed about their understanding of the individual verbal descriptors, both the targets and the distractors. Prompted by the question "What do you think … is, when or where can you smell it?," children were encouraged to share their notions of the nature of the odor represented by the given source name. Based on these accounts, images depicting items most frequently associated with the given verbal label were selected. For instance, since the majority of children tended to associate "mint" with chewing gum and mints, a picture of confectionery was used instead (see Bastos et al. 2015 for a similar approach). These interviews had also revealed that a majority of children expressed uncertainty about what most of the spices, menthol, and turpentine were, looked, smelled like, and in which edibles or products they could be found. Therefore, items 3, 8, 12, and 15 (cinnamon, turpentine, clove, and anise) of the "blue" set and 7, 8, 9, and 16 (eucalyptus, ginger, coconut, and onion) of the "purple" set were discarded. In the next session of the pilot study, four color pictures arranged in a 2 × 2 square on an A4 page were presented. The researcher pointed at each of them, asking "Do you know what this is?" and noted down the child's answers. Having thus verified correct understanding of the selected images, the same sets of pictures have been employed in the study (see Online Resource 1 and 2). Understanding what each image depicted was always ensured prior to the identification task itself, which consisted in sequential presentations of each odor in the order recommended by Hummel et al. (1997), upon which the child chose a picture by pointing at it. Given the exclusion of four items from each set of odorants, the maximum score was 12 instead of 16 for both tests. Percentages of correct identifications for the individual items are shown in Table 4. No alterations had to be made to the discrimination test. Data collection took place between April and June 2015, therefore possible seasonal effects on olfactory performance have not been taken into account. The two identification tests only showed a weak correlation, Kendall's $\tau=0.260$ [0.132; 0.362], $p<0.001$, Cohen's $d=0.87$.

Table 4 Percentages of correct identifications of the individual items of the "blue" and "purple" Sniffin' Sticks identification tests

	Item	Percent identified (%)
"Blue" set	Orange	90.15
	Leather	22.73
	Mint	96.97
	Banana	78.03
	Lemon	46.21
	Liquorice	64.39
	Garlic	52.27
	Coffee	84.85
	Apple	34.09
	Pineapple	70.45
	Rose	46.97
	Fish	90.15
"Purple" set	Pear	36.36
	Cola	62.12
	Lilac	78.79
	Grapefruit	72.73
	Grass	53.03
	Raspberry	64.39
	Lavender	83.83
	Melon	43.94
	Peach	60.61
	Mushroom	82.58
	Smoked meat	30.30
	Caramel	95.45

Verbal Fluency

Verbal fluency, which is known to modulate both odor identification (e.g., Larsson et al. 2000) and COBEL scores (Ferdenzi et al. 2008a) was tested using a Czech version of the category verbal fluency test adapted for use with children (Preiss 1997). First, variability of responses to the three categories (animals, fruits, and things that can be bought in a supermarket) had been explored in a pilot study. The animal category, which showed the greatest response variability (8.17 ± 2.10 compared to 7.47 ± 1.70 and 8.77 ± 1.85 for fruits and supermarket, respectively), has been selected. During the testing session itself, a training trial was conducted using the transport category, in which a child was asked to name as many means of transport as he or she could think of. Understanding was ensured by asking the child whether he or she knew what transport meant and by giving an example (e.g., a car). Next, the child was encouraged to name as many animals as he or she could think of in 60 s, while the answers were being immediately written down by the researcher.

Procedure

Parents had been instructed to only encourage their children to attend the testing sessions when in good respiratory health. The children participated in individual testing sessions, which were always scheduled after school dinners at a time between 12:30 p.m. and 3 p.m. (i.e., a time when most children attend after-school care centre in the school premises). Testing took place in a secluded, well-ventilated room without strong ambient odors. At the beginning of the session, the researcher briefly familiarized the child with the tasks, presenting them as a game, and ensured him or her that he or she could stop or quit whenever he or she felt like it. Then the child was interviewed about his or her odor awareness based on the COBEL questionnaire. Next, the two identification tests ("blue" and "purple") followed in a randomized order. Within each set, the stimuli were presented in the order recommended by Hummel et al. (1997). After that, the odor discrimination test was administered. Finally, verbal fluency was assessed with the animal category verbal fluency test. The entire session took, in most participants, 30–40 min.

The pilot study consisted of two sessions. During the first one, children's understanding was assessed of the individual verbal descriptors of the two identification tests and of the questions asked during the interview based on COBEL. The second session consisted of verification of correct understanding of the selected pictures and the three category fluency tests. The order of the tasks within both the sessions was randomized.

Statistical Analysis

All analyses were carried out with IBM SPSS 22.0. Normality of the raw data was checked, firstly, by visually examining the individual histograms of all relevant variables, secondly, by producing skewness and kurtosis values and their respective standard errors, from which z scores were computed and compared to the value of 1.96, as suggested by Field (2005:72), and, thirdly, with multiple Shapiro-Wilk's W tests. Since departure from normality in nearly all variables was detected, nonparametric tests have been used where possible.

Exploratory Kendall's rank correlations τ, given in Table 5, revealed that in the total sample, neither verbal fluency nor age was associated with either olfactory abilities or COBEL scores, with the exception of an association between verbal fluency and the Food component of COBEL, Kendall's $\tau = 0.152$ [0.004; 0.302], $p < 0.05$, Cohen's $d = 0.49$. As expected, age was significantly associated with verbal fluency, Kendall's $\tau = 0.167$ [0.031; 0.307], $p < 0.01$, Cohen's $d = 0.54$. Furthermore, separate Kendall's rank correlations τ for boys and girls showed that age and verbal fluency were associated with olfactory abilities and COBEL scores in girls, but not boys (except for a link between age and odor discrimination).

Therefore, in addition to the overall nonparametric categorical regression (CATREG) analysis run with the SPSS Optimal Scaling option, separate analyses have been carried out for both genders. Thus, in boys, multiple CATREG analyses were run with the three components of odor exposure as independent variables in each case and the three olfactory measures (the two identification scores and the discrimination one) and COBEL scores (total and food, social, and environmental components) as dependent ones. Moreover, age, which had been previously found to correlate with odor discrimination in boys, was included in the regression of odor discrimination on the components of odor exposure. In girls, age and verbal fluency were included in the analyses regressing variables with which they had been found to correlate. Preliminary correlations between the three components showed that multicollinearity was not a problem. All variables have been scaled as numeric and discretized by ranking. A numerical initial configuration was selected, leaving all other settings to default. Group comparisons were computed using Mann–Whitney U tests.

95 % bias corrected and accelerated bootstrap confidence intervals are given in square brackets. Even though Kendall's τ itself is an effect size measure, for convenience, it has been converted to Cohen's d after Walker (2003). For Mann–Whitney U tests, r has been computed after Field (2013:227) and then converted to Cohen's d after Rosenthal (1994:239). Although R^2 and adjusted R^2 themselves represent measures of effect size, as do betas, for convenience, adjusted R^2s have been converted to Cohen's f^2 after Cohen (1988).

Table 5 Kendall Tau correlational analyses of age, verbal fluency, the three components of odor exposure (Odor control and naming, Food, and Environmental odors), COBEL scores (total and the food, social, and environmental component), and olfactory measures (odor identification "blue" and "purple" and odor discrimination)

	Components of odor exposure			Age	Verbal fluency	COBEL total	COBEL food	COBEL social	COBEL environmental
	Odor control and naming	Food	Environmental odors						
Total									
Age	0.111*** [0.001; 0.209]	−0.048 [−0.171; 0.083]	−0.051 [−0.174; 0.074]		*0.167*** (*0.54*) [*0.031*; *0.307*]	0.061 [−0.064; 0.186]	−0.003 [−0.132; 0.133]	0.005 [−0.120; 0.129]	0.091 [−0.033; 0.220]
Verbal fluency	0.072 [−0.053; 0.186]	−0.007 [−0.125; 0.124]	0.013 [−0.098; 0.131]	*0.167*** (*0.54*) [*0.031*; *0.307*]		0.103 [−0.033; 0.225]	0.054 [−0.088; 0.192]	*0.152** (*0.49*) [*0.004*; *0.302*]	0.042 [−0.095; 0.170]
COBEL total	*0.171*** (*0.55*) [*0.050*; *0.288*]	−0.022 [−0.140; 0.087]	0.038 [−0.072; 0.150]	0.061 [−0.064; 0.186]	0.103 [−0.033; 0.225]		*0.539*** (*2.26*) [*0.439*; *0.639*]	*0.586*** (*2.63*) [*0.491*; *0.670*]	*0.722*** (*4.29*) [*0.653*; *0.785*]
COBEL food	0.090 [−0.047; 0.227]	0.057 [−0.072; 0.183]	0.055 [−0.077; 0.181]	−0.003 [−0.132; 0.133]	0.054 [−0.088; 0.192]	*0.539*** (*2.26*) [*0.439*; *0.639*]		*0.242*** (*0.80*) [*0.102*; *0.375*]	*0.342*** (*1.19*) [*0.207*; *0.481*]
COBEL social	*0.175*** (*0.56*) [*0.051*; *0.291*]	−0.042 [*−0.169*; *0.075*]	0.027 [−0.101; 0.146]	0.005 [−0.120; 0.129]	*0.152** (*0.49*) [*0.004*; *0.302*]	*0.586*** (*2.63*) [*0.491*; *0.670*]	*0.242*** (*0.80*) [*0.102*; *0.375*]		*0.315*** (*1.08*) [*0.187*; *0.437*]
COBEL environmental	0.121*** [−0.005; 0.246]	−0.038 [−0.166; 0.083]	0.008 [−0.131; 0.144]	0.091 [−0.033; 0.220]	0.042 [−0.095; 0.170]	*0.722*** (*4.29*) [*0.653*; *0.785*]	*0.342*** (*1.19*) [*0.207*; *0.481*]	*0.315*** (*1.08*) [*0.187*; *0.437*]	
Identification "blue"	0.049 [−0.074; 0.163]	0.093 [−0.041; 0.219]	0.004 [−0.128; 0.139]	0.040 [−0.079; 0.170]	−0.063 [−0.190; 0.063]	−0.038 [−0.164; 0.085]	0.029 [−0.116; 0.165]	−0.040 [−0.171; 0.095]	−0.077 [−0.212; 0.047]
Identification "purple"	0.051 [−0.071; 0.170]	0.113*** [−0.010; 0.234]	0.068 [−0.062; 0.206]	0.092 [−0.046; 0.226]	0.034 [−0.093; 0.168]	−0.045 [−0.191; 0.117]	−0.091 [−0.227; 0.054]	−0.001 [−0.163; 0.150]	−0.062 [−0.206; 0.088]
Identification total	0.054 [−0.057; 0.163]	0.115*** [−0.009; 0.230]	0.061 [−0.075; 0.195]	0.080 [−0.042; 0.205]	−0.002 [−0.132; 0.133]	−0.047 [−0.186; 0.101]	−0.054 [−0.191; 0.092]	−0.004 [−0.157; 0.142]	−0.082 [−0.236; 0.056]
Discrimination	0.096 [−0.015; 0.210]	−0.039 [−0.163; 0.082]	−0.035 [−0.169; 0.097]	0.111 [−0.032; 0.252]	−0.057 [−0.171; 0.066]	0.080 [−0.048; 0.201]	0.030 [−0.110; 0.169]	*0.162** (*0.52*) [*0.030*; *0.288*]	0.014 [−0.116; 0.146]
Boys									
Age	0.088 [−0.112; 0.277]	−0.146*** [−0.329; 0.069]	*−0.185** (*−0.60*) [*−0.362*; *0.021*]		0.160 [−0.034; 0.345]	−0.027 [−0.216; 0.156]	−0.042 [−0.221; 0.134]	−0.032 [−0.218; 0.146]	−0.006 [−0.208; 0.192]
Verbal fluency	0.042 [−0.161; 0.242]	−0.043 [−0.223; 0.131]	−0.116 [−0.298; 0.071]	0.160 [−0.034; 0.345]		−0.079 [−0.291; 0.110]	−0.008 [−0.202; 0.166]	0.061 [−0.153; 0.263]	−0.180 [−0.386; 0.013]
COBEL total	0.076 [−0.139; 0.283]	0.006 [−0.163; 0.180]	−0.041 [−0.219; 0.142]	−0.027 [−0.216; 0.156]	−0.079 [−0.291; 0.110]		*0.589*** (*2.66*) [*0.431*; *0.712*]	*0.558*** (*2.40*) [*0.375*; *0.715*]	*0.739*** (*4.60*) [*0.649*; *0.816*]
COBEL food	0.023 [−0.168; 0.224]	0.153*** [−0.023; 0.317]	0.013 [−0.186; 0.202]	−0.042 [−0.221; 0.134]	−0.008 [−0.202; 0.166]	*0.589*** (*2.66*) [*0.431*; *0.712*]		*0.287*** (*0.97*) [*0.060*; *0.480*]	*0.385*** (*1.38*) [*0.191*; *0.545*]
COBEL social	0.041 [−0.143; 0.216]	−0.076 [−0.264; 0.109]	−0.033 [−0.224; 0.178]	−0.032 [−0.220; 0.154]	0.061 [−0.146; 0.278]	*0.558*** (*2.40*) [*0.375*; *0.715*]	*0.287*** (*0.97*) [*0.060*; *0.480*]		*0.304*** (*1.03*) [*0.116*; *0.478*]
COBEL environmental	0.115 [−0.079; 0.308]	−0.011 [−0.207; 0.195]	−0.061 [−0.254; 0.118]	−0.006 [−0.175; 0.183]	−0.180 [−0.369; 0.026]	*0.739*** (*4.60*) [*0.649*; *0.816*]	*0.385*** (*1.38*) [*0.191*; *0.545*]	*0.304*** (*1.03*) [*0.116*; *0.478*]	
Identification "blue"	0.030 [−0.168; 0.214]	0.129 [−0.056; 0.293]	−0.058 [−0.233; 0.113]	0.053 [−0.123; 0.225]	−0.121 [−0.313; 0.084]	−0.128 [−0.330; 0.077]	−0.072 [−0.273; 0.146]	−0.101 [−0.318; 0.118]	−0.160 [−0.340; 0.026]
Identification "purple"	−0.041 [−0.213; 0.131]	0.126 [−0.030; 0.272]	0.030 [−0.155; 0.223]	−0.001 [−0.157; 0.168]	−0.064 [−0.286; 0.139]	*−0.248*** (*−0.82*) [*−0.427*; *−0.090*]	*−0.257*** (*−0.85*) [*−0.435*; *−0.071*]	−0.132 [−0.338; 0.066]	*−0.205** (*−0.67*) [*−0.393*; *−0.025*]
Identification total	−0.013 [−0.181; 0.153]	0.139 [−0.029; 0.294]	−0.015 [−0.185; 0.157]	0.022 [−0.142; 0.180]	−0.093 [−0.269; 0.097]	*−0.237** (*−0.78*) [*−0.420*; *−0.047*]	*−0.228** (*−0.75*) [*−0.433*; *−0.019*]	−0.124 [−0.343; 0.100]	*−0.223** (*−0.73*) [*−0.392*; *−0.062*]
Discrimination	−0.008 [−0.176; 0.171]	−0.088 [−0.288; 0.098]	−0.111 [−0.306; 0.094]	*0.190** (*0.62*) [*−0.014*; *0.371*]	−0.080 [−0.265; 0.104]	0.151 [−0.031; 0.347]	0.064 [−0.147; 0.286]	0.185 [−0.017; 0.391]	0.117 [−0.055; 0.296]
Girls									
Age	0.150*** [−0.041; 0.320]	0.035 [−0.137; 0.193]	0.041 [−0.141; 0.209]		*0.184** (*0.59*) [*0.005*; *0.374*]	*0.172** (*0.55*) [*−0.010*; *0.341*]	0.036 [−0.123; 0.197]	0.061 [−0.143; 0.269]	*0.205** (*0.67*) [*0.027*; *0.392*]
Verbal fluency	0.025 [−0.161; 0.206]	0.013 [−0.148; 0.165]	0.098 [−0.068; 0.263]	*0.184** (*0.59*) [*0.005*; *0.374*]		*0.218** (*0.71*) [*0.062*; *0.383*]	0.105 [−0.084; 0.311]	*0.195** (*0.63*) [*−0.019*; *0.405*]	*0.186** (*0.60*) [*0.040*; *0.343*]
COBEL total	0.166*** [−0.019; 0.331]	−0.053 [−0.207; 0.106]	0.096 [−0.086; 0.264]	*0.172** (*0.55*) [*−0.010*; *0.341*]	*0.218** (*0.71*) [*0.062*; *0.383*]		*0.486*** (*1.91*) [*0.339*; *0.614*]	*0.568*** (*2.48*) [*0.446*; *0.678*]	*0.699*** (*3.91*) [*0.586*; *0.795*]
COBEL food	0.124 [−0.071; 0.322]	−0.032 [−0.241; 0.182]	0.066 [−0.113; 0.250]	0.036 [−0.123; 0.197]	0.105 [−0.084; 0.311]	*0.486*** (*1.91*) [*0.339*; *0.614*]		0.169 [−0.004; 0.351]	*0.281*** (*0.94*) [*0.077*; *0.465*]
COBEL social	*0.221** (*0.72*) [*0.036*; *0.398*]	−0.011 [−0.182; 0.144]	0.061 [−0.106; 0.234]	0.061 [−0.143; 0.269]	*0.195** (*0.63*) [*−0.019*; *0.405*]	*0.568*** (*2.48*) [*0.446*; *0.678*]	0.169 [−0.004; 0.351]		*0.278*** (*0.93*) [*0.096*; *0.450*]

Table 5 (continued)

	Components of odor exposure			Age	Verbal fluency	COBEL total	COBEL food	COBEL social	COBEL environmental
	Odor control and naming	Food	Environmental odors						
COBEL environmental	0.065 [−0.137; 0.252]	−0.077 [−0.249; 0.107]	0.060 [−0.132; 0.236]	*0.205* (0.67)* *[0.027; 0.392]*	*0.186* (0.60)* *[0.040; 0.343]*	*0.699** (3.91)* *[0.586; 0.795]*	*0.281** (0.94)* *[0.077; 0.465]*	*0.278** (0.93)* *[0.096; 0.450]*	
Identification "blue"	0.070 [−0.108; 0.248]	0.067 [−0.145; 0.271]	0.052 [−0.143; 0.261]	0.032 [−0.141; 0.219]	−0.011 [−0.185; 0.179]	0.065 [−0.115; 0.248]	0.139 [−0.059; 0.329]	0.004 [−0.169; 0.181]	0.012 [−0.174; 0.200]
Identification "purple"	0.129 [−0.041; 0.314]	0.091 [−0.094; 0.265]	0.097 [−0.072; 0.267]	*0.193* (0.63)* *[0.018; 0.376]*	0.118 [−0.068; 0.300]	0.123 [−0.079; 0.337]	0.073 [−0.110; 0.268]	0.120 [−0.085; 0.328]	0.045 [−0.165; 0.245]
Identification total	0.110 [−0.071; 0.288]	0.076 [−0.095; 0.245]	0.119 [−0.064; 0.306]	0.164 [−0.010; 0.337]	0.083 [−0.084; 0.269]	0.140 [−0.044; 0.346]	0.128 [−0.071; 0.331]	0.104 [−0.094; 0.308]	0.067 [−0.124; 0.279]
Discrimination	*0.183* (0.59)* *[−0.018; 0.368]*	0.006 [−0.167; 0.174]	0.010 [−0.180; 0.194]	0.018 [−0.184; 0.210]	−0.084 [−0.238; 0.088]	−0.039 [−0.203; 0.134]	−0.026 [−0.213; 0.163]	0.094 [−0.079; 0.282]	−0.138 [−0.278; 0.022]

95 % bias corrected and accelerated bootstrap confidence intervals and Cohen's *d* for significant results are given in square brackets and parentheses, respectively. Significant correlations are given in italics.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.1$

Results

Regressions of Olfactory Abilities and COBEL on Components of Odor Exposure in the Total Sample

Overall CATREG analyses performed on boys and girls together showed that the component Odor control and naming predicted the total COBEL score, $\beta = 0.245$, $F(1) = 9.322$, $p < 0.01$. The model was significant, explaining 6.2 % of variability in the total COBEL scores in the present sample and an estimated 4 % in the population, $R^2 = 0.062$, adjusted $R^2 = 0.040$, $F(3, 128) = 2.839$, $p < 0.05$, $f^2 = 0.066$. It also predicted the social component score of COBEL, $\beta = 0.231$, $F(1) = 7.768$, $p < 0.01$; with the model being significant and explaining 8.1 % of variability in the COBEL's social component score in the present sample and an estimated 5.2 % in the population, $R^2 = 0.081$, adjusted $R^2 = 0.052$, $F(3, 128) = 2.789$, $p < 0.05$, $f^2 = 0.088$.

Gender-Specific Regressions of Olfactory Abilities and COBEL on Components of Odor Exposure

Separate analyses in boys have yielded null results, with none of the three components predicting either olfactory abilities or COBEL scores. In contrast, in girls, the total COBEL scores were predicted by component Odor control and naming, $\beta = 0.242$, $F(1) = 4.113$, $p < 0.05$, as well as by verbal fluency, $\beta = 0.246$, $F(1) = 7.004$, $p < 0.05$. The model was significant, explaining 13.9 % of variability in the COBEL scores in the present sample and an estimated 8.3 % in the population, $R^2 = 0.139$, adjusted $R^2 = 0.083$, $F(5, 61) = 2.495$, $p < 0.05$, $f^2 = 0.16$. Also, the COBEL's social component was predicted by Odor control and naming, $\beta = 0.306$, $F(1) = 7.390$, $p < 0.01$, with the model being significant and explaining 15.6 % of variability in the COBEL's social component in the present sample and an estimated 10.1 % in the population, $R^2 = 0.156$, adjusted $R^2 = 0.101$, $F(4,62) = 2.854$, $p < 0.01$, $f^2 = 0.19$.

Between-Gender Variability in Olfactory Abilities, COBEL Scores, and Odor Exposure

Girls did not outperform boys on either of the two identification tests or on the discrimination one. Girls only outperformed boys on the identification of rose at $p < 0.01$ ("blue" set), lilac at $p < 0.01$, and mushroom at $p < 0.05$ (both from the "purple" set). Girls, however, exhibited higher COBEL scores, namely the total score and its social and environmental components, Mann–Whitney $U = 1485.5$, 1551.0, and 1624.0, respectively, all ps < 0.05. Cohen's ds were 0.52, 0.45, and 0.39, respectively. As verbal fluency had been previously found to correlate with the social component, additionally, an ANCOVA has been run with gender as an independent variable, the social component of COBEL as a

dependent variable, and verbal fluency as a covariate, yielding similar results. Parental reports of odor exposure did not differ depending on whether the child was a boy or a girl.

Link Between Olfactory Abilities and COBEL Scores

Olfactory abilities were not systematically related to COBEL scores in the total sample or in girls, whereas in boys there were negative associations between COBEL scores and odor identification (purple) on the one hand, and sum of the two identification scores on the other, Kendall's $\tau = -0.25$ and -0.24, respectively, both $ps < 0.05$, Cohen's $d = -0.82$ and -0.78, respectively. Significant results of similar effect sizes have also been found for the food and environmental component of COBEL. Complete results are shown in Table 5.

Discussion

The aim of the present study was to investigate whether children's odor exposure in everyday contexts, as reported by their parents, could predict their olfactory abilities and odor awareness, as measured by an interview based on the COBEL questionnaire. As expected, parental reports of the children's odor exposure predicted odor awareness in the total sample. This is in line with the findings reported by Nováková et al. (2014) in adults, although in the present study reports have been provided by parents, not the participants themselves, and given the different demographics a different measure of odor awareness has been employed, namely, the Odor Awareness Scale (OAS) by Smeets et al. (2008). Specifically, children whose parents reported more frequent use of various scented products in the household and teaching their children to recognize and name various odors and their sources scored higher on the COBEL measure than those whose parents indicated a lesser degree of olfactory stimulation. On the other hand, in the study by Saxton et al. (2014), Namibian children who, according to their own words, had more siblings, kept more animals in the household or reported more frequent cooking had not attained higher COBEL scores. However, as the authors note, more sensitive measures of individual differences in odor exposure were possibly needed. Besides, a word of caution should be sounded about the effect sizes: both the adjusted R^2 and β coefficients in the present study represent what has been referred to as a "recommended minimum effect size for representing a 'practically' significant effect for social science data" (Ferguson 2009).

As regards regressions of odor identification and discrimination scores on parental reports in the total sample, these yielded non-significant results, which corroborates the findings of Saxton et al. (2014). Since Nováková et al. (2014) did find an association between retrospective self-reports and odor identification in adults, it may be argued that such experience needs a longer time to exert any effect on olfactory performance and hence is not yet seen in children. Another possible explanation is that parents with olfactory interests or those who care about the impression they and their children give about socially desirable behaviors, such as control of unwanted odors, may, if unknowingly, exaggerate their responses and encourage their children to do the same. Even though parents or other caregivers have not been present during the interview, children who (begin to) realize that (de)odorization is widely encouraged within the Western sociocultural context (e.g., MacPhee 1992) may be eager to share this knowledge with the interviewer and, at the same time, will likely live in a household in which odors are controlled more vigorously. Thus, they may not necessarily live in an environment which is richer in olfactory stimuli, it might be as well that their parents are very careful about their image in this respect and, if unconsciously, pass this message onto their children. Other pieces of evidence that would favor this explanation include the fact that COBEL scores were only predicted by the component Odor control and naming, but not by the other two components (Food and Environmental odors). Also, odor identification and discrimination scores, which, in contrast to COBEL scores, are unlikely to be thus affected, showed no association with parental reports of odor exposure.

When boys' and girls' data have been analyzed separately, there were no significant regression models in boys but in girls the component Odor control and naming predicted total COBEL scores and the social component of COBEL. This finding may be interpreted in terms of girls being more "social" than boys, and thus more sensitive to social cues and reinforcement. This assertion is supported by a fair body of evidence in children as young as of preschool age (e.g., Haun and Tomasello 2011). Gender-specific correlations also revealed several negative correlations between COBEL and identification scores in boys. Although these analyses were purely exploratory, this somewhat unexpected finding might perhaps be attributed to a greater fluctuation in attention during the session in boys (Groot et al. 2004; Pascualvaca et al. 1997).

Whereas parental reports of children's odor exposure did not differ depending on whether the child was a boy or a girl, children's own reports in the COBEL-based interview did show a gender difference. This is in line with the findings reported by Saxton et al. (2014), even in terms of the individual COBEL components: in both the studies, girls tended to be more oriented towards olfactory stimuli in the social and environmental contexts. It is nevertheless possible that the higher COBEL scores are a by-product of girls' generally greater social competence because verbal fluency, which has been controlled for in the present study, is only one of the theoretically and empirically supported mediators of social competence (Nigg et al. 1999; Riggs et al. 2003). Finally, no gender difference has been found in the olfactory tasks, also consistent with the results

obtained by Saxton et al. (2014), albeit in a group of slightly older children. Other recent studies on this topic (e.g., Cameron and Doty 2013; Schriever et al. 2014) seem to challenge the view held by some researchers that the sex/gender difference in olfaction is a robust phenomenon that can be considered an inborn sexually dimorphic trait (Doty 1992).

COBEL scores and olfactory performance were not related in the present study, consistent with the findings reported by Ferdenzi et al. (2008b) in the original use of the instrument. On the other hand, Saxton et al. (2014) had reported a positive correlation between COBEL scores and odor identification in the sample of Czech children aged 8–11 years, but not in Namibian ones (9–15-year-olds). It could be argued that olfactory knowledge only tends to manifest itself in performance on olfactory tasks and metacognitive measures in a systematic way from a certain age on. However, in the previous studies with adults no systematic relationship between odor identification and odor awareness has emerged. For instance, Smeets et al. (2008) reported that individuals scoring high on OAS did not outperform the low-scoring ones on the test of odor identification, and the results of the study by Dematte et al. (2011) yielded no association between the participants' self-reported odor awareness and odor identification performance. Nováková et al. (2014) do report positive correlations between OAS scores on the one hand and odor identification and the composite olfactory score (TDI) on the other, yet after controlling for the effect of age on both the OAS and odor identification scores the association marginally missed significance. The answer may lie in whether the olfactory measures used are cued or not: in the study by Arshamian et al. (2011), adults who were highly oriented towards olfactory stimuli performed better than those who were not on the test of free odor identification, but not cued odor identification. Future studies should therefore employ both cued and free odor identification for the sake of comparison.

Although the cued Sniffin' Sticks identification test employed in the present study has been successfully used with children before, more specifically the "blue" one, with performance above chance level in children aged 6 years and over (e.g., Hummel et al. 2007a), in the present study the use of pictures instead of verbal labels has been necessitated by the fact that the majority of children were only beginning to learn to read. Even so, the pilot study revealed children's uncertainty about what most of the spices were, smelled like, and in which edibles or products they could be found, which was also the case with menthol and turpentine. As a result, four items had to be excluded from each set. In the previous studies with a similar demographic or still younger children, some researchers have used the Sniffin' Sticks test in its entirety, employing the standard verbal descriptors (e.g., Hummel et al. 2011; Konstantinidis et al. 2005; Romanos et al. 2008). Nevertheless, this approach is far from optimal and has proved rather challenging due to children's limited attention span and odor experience, among other things. Lesser familiarity with some of the odors and descriptors may lead, for instance, to children's reliance on the use of an exclusion heuristic and loss of motivation. To deal with these challenges, various pediatric odor identification tests have been devised (e.g., Cameron and Doty 2013; Renner et al. 2009) but there have also been efforts to adapt the existing tests for use with children (e.g., Bastos et al. 2015; Monnery-Patris et al. 2009; Schriever et al. 2014). These efforts have all been of relatively recent date and the studies available highlight the need for cultural adaptations of the most widely used odor identification tests such as the Sniffin' Sticks to multiple subadult age groups. Children frequently tend to be treated as a single age category, e.g., individuals under 18 years of age, even though there is a robust body of literature showing marked developmental changes in odor identification across childhood and adolescence (e.g., Cameron and Doty 2013; Schriever et al. 2014). Particularly in the youngest children, the use of pictures instead of verbal labels may greatly aid understanding and correct identification, as evidenced by the comparison of the present data given in Table 4 with those previously reported for Czech children aged 8–11 years (Martinec Nováková et al. 2015). Despite the 2- to 5-year age advantage, the older children have been outperformed by the younger ones on the identification of apple, fish, and orange at $p < 0.001$ and lemon, mint, and pineapple at $p < 0.05$, which might be, partly at least, attributed to the use of pictures instead of verbal labels with the younger group. However, this approach poses several challenges, such as those reported in the present study and by Bastos et al. (2015). These include, for instance, the identification of foods, products, objects etc., strongly associated with a given verbal label and more familiar to children than the original item itself (e.g., association of "mint" with chewing gum) and their visual representation in a readily comprehensible way, as well as other issues discussed by Martinec Nováková et al. (2015), which are likely to be age- and culture-specific.

Finally, although there is a fair body of evidence suggesting that verbal fluency modulates both odor identification (e.g., Larsson et al. 2000) and COBEL scores (Ferdenzi et al. 2008a), no such effect has been found in the present study in the total sample. Separate analyses in boys and girls revealed a link between verbal fluency and COBEL scores, both total and the social and environmental components, in girls only. Since verbal fluency is associated with age (e.g., Brocki and Bohlin 2004), as was the case in the present study, although the correlation was rather weak, the absence of the effect might be attributed to the low variability in age in the present sample.

Conclusion

The present study addressed the research question of whether parental reports of children's odor exposure in everyday

contexts may predict the children's olfactory abilities and self-reports of odor awareness. Our predictions have been only partly supported, as we have found an effect of odor exposure on one aspect of the children's olfactory knowledge as reflected in their reports of olfactory behavior, but not olfactory abilities. In so doing, we replicated some of the previous findings in the literature of the female advantage in the olfactory domain. Namely, we have found that girls showed greater metacognitive knowledge of their sense of smell and a greater degree of olfaction-oriented behavior, which was not accounted for by a gender difference in verbal fluency. This was especially the case as regards items focused on social and environmental odor sources. Nevertheless, girls did not outperform boys on any of the measures of olfactory performance. Semi-longitudinal and longitudinal studies in verbally proficient children, employing both self- and parental reports of children's odor exposure and repeated olfactory testing might provide insight into whether children exposed more frequently to a greater variety of odors over the longer term come to exhibit greater odor awareness and superior performance in some olfactory abilities. Better yet, answers to this question might come from studies employing olfactory games to provide children with olfactory training over the longer term in a playful, ecologically valid way.

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Compliance with Ethical Standards

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Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval Details of institutional ethical approval for the research, and ethical procedures followed, are given in the "Participants" section.

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Temperamental Influences on Children's Olfactory Performance: the Role of Self-Regulation

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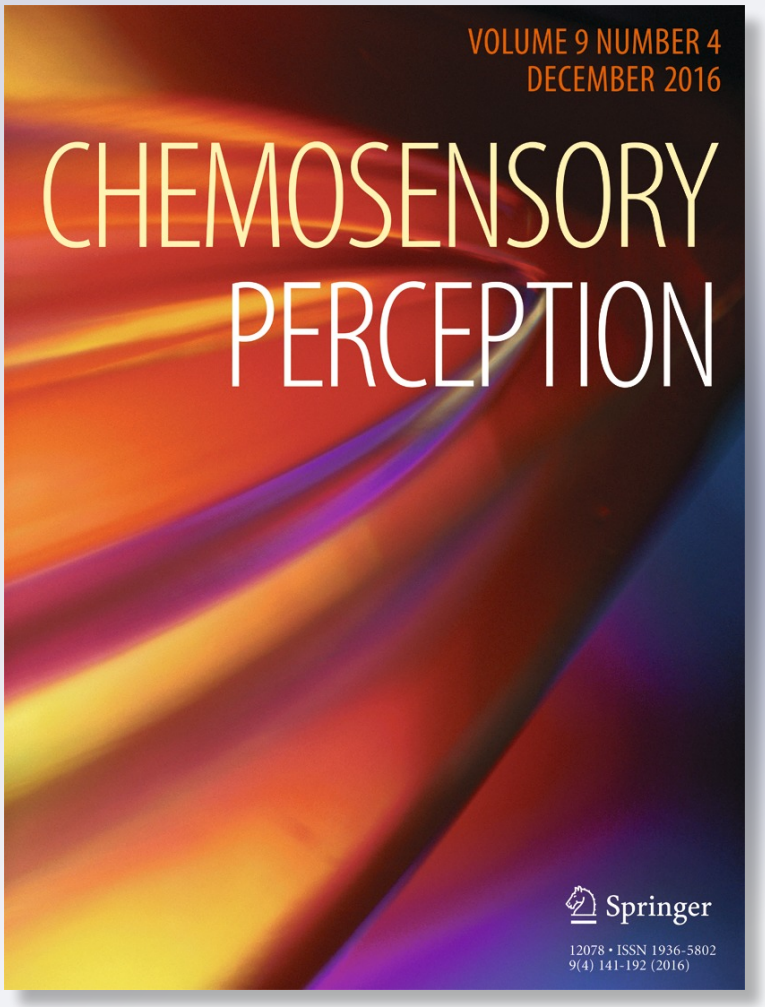

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Temperamental Influences on Children's Olfactory Performance: the Role of Self-Regulation

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Abstract
Introduction A body of research predominantly in young adults has suggested a link between olfactory perception, especially sensitivity, and personality characteristics, particularly neuroticism. Nevertheless, it is not clear whether these associations are present outside this particular age range and whether they involve other olfactory abilities, such as odor identification and discrimination, and temperamental differences in reactivity and self-regulation. On the one hand, extrapolating from studies with adults to children, participants scoring high on negative affectivity, which broadly maps onto neuroticism, should outperform the low-scoring ones. On the other hand, well-developed self-regulatory processes, referred to as effortful control, which modulate the expression of such tendencies, might also contribute to better olfactory performance.
Aim Thus, the aim of the present study was to investigate the effect of the temperamental factors on olfactory performance. Namely, we hypothesized that superior olfactory performance would be delivered by children scoring relatively higher on negative affectivity but also by those perceived as exhibiting greater self-regulation.
Methods Odor identification and discrimination in 143 children (72 boys) aged 6 to 8 years were assessed with the Sniffin' Sticks, controlling for verbal fluency. Parents provided reports of their children's temperament by means of a short form of the Children's Behavior Questionnaire. The potential influence of parental responsiveness and demands on temperamental attributions was controlled for with hypothetical vignettes representing parenting styles.
Results There was an effect of effortful control (but not negative affectivity) on the total identification (but not discrimination) scores. Namely, children who were perceived as more capable of self-regulation exhibited higher odor identification scores. Girls did not outperform boys on either of the olfactory tests, but they were deemed by their parents to show greater self-regulation.
Conclusion Our findings indirectly point to the effect of self-regulatory tendencies on odor identification in young children. However, they did not corroborate the idea that children varying in negative affectivity (underlying neuroticism) differ in terms of olfactory performance. Given the narrow age range of children recruited in the present study, further studies with preadolescent and adolescent participants are needed to gain more insight into the nature of these relationships.

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Keywords Big five · Children · Cognitive control · Conscientiousness · Extraversion · Gender differences · Identification · Olfaction · Olfactory abilities · Negative affectivity · Neuroticism · Parenting styles · Personality · Psychophysics · Smell · Sniffin' sticks · Surgency · Temperament · Verbal fluency

Introduction

Links Between Olfactory Perception and Personality in Adults

A body of literature has been devoted to investigations of links between olfactory perception and personality in adults and adolescents. Personality manifests itself in sensory processing and cognitive styles (e.g. Aron and Aron 1997; Isaksen et al. 2003; Riding and Wigley 1997; Smolewska et al. 2006; Soubelet and Salthouse 2011), including olfactory abilities, which represent a special case of cognitive abilities (Flanagan and Harrison 2012:132). The focus has been especially on olfactory sensitivity, which can be expected to correlate with a characteristic referred to as sensory-processing sensitivity. This characteristic has been proposed to underlie differences in strategies employed in the face of novel stimulation in general, i.e. exploration or quiet vigilance (Aron and Aron 1997). Having been extensively investigated in humans as well as in other species, the latter strategy is linked to what is termed "introversion" in adults (e.g. Eysenck 1991), "inhibitedness" in children (e.g. Kagan 1994), or "innate shyness" in both (e.g. Daniels and Plomin 1985; Cheek and Buss 1981). One of the first attempts to conceptualize this trait was Eysenck's (1957) theory of introversion-extraversion, which was seen as a matter of balance between cortical excitation and inhibition and later revised in terms of cortical arousal (Eysenck 1967). His three-dimensional personality model of extraversion, neuroticism, and psychoticism had inspired researchers in the field of chemosensory perception to seek associations between olfactory sensitivity on the one hand and extraversion and neuroticism on the other (Koelega 1970, 1994). Specifically, Eysenck's theory predicted that introverts should exhibit higher sensory sensitivity (i.e. lower thresholds) than extraverts, but these early studies have lent little support to this hypothesis. As can be seen from Table 1, in more recent studies (e.g. Croy et al. 2011; Havlíček et al. 2012; Larsson et al. 2000), Eysenck's model and its modification by Gray (1972) have been completely superseded by the five-factor personality model ("Big Five"; Costa and McCrae 1992). Moreover, in addition to olfactory sensitivity, researchers have come to include odor identification, discrimination, and odor detection response times as measures of olfactory performance. Table 1 also reveals that of particular interest in this research area has been the effect of neuroticism and, more specifically, its facet (trait) anxiety on olfactory perception. The rationale behind such studies is that amygdala and hippocampus, which are involved in both olfactory (e.g. Zald and Pardo 2000) and emotional processing (e.g. Phelps and LeDoux 2005; Richardson et al. 2004), exhibit structural and functional changes in anxious persons (Bremner 2004; Milad et al. 2006), with possible implications for the olfactory domain. The findings of the more recent studies seem to tentatively point to variability in olfactory perception on the behavioral level with respect to neuroticism or anxiety. On the whole, even though Table 1 presents some evidence that highly neurotic individuals may be more sensitive to certain odors, and identify and discriminate them more easily, many questions arise. For instance, it is not clear whether individuals scoring high on this personality characteristic as a rule perform better than the low-scoring ones on any olfactory test. Rather, the significance and direction of the association appears to depend on the difficulty and nature of the task (e.g. Eysenck and Calvo 1992).

As the bulk of research has focused on olfactory sensitivity, more studies employing other olfactory measures, such as odor identification and discrimination, are needed. Also, participants in the absolute majority of the studies were young adults, predominantly university students, raising the question as to whether the links between personality and olfaction exist outside this particular age range and social background. Since the cumulative, potentially much stronger effects of physiological aging, lifestyle, medical history, and environmental exposure on chemosensory perception are likely to obscure this relationship in older adults, a somewhat more attractive idea is to turn to children. Such a research topic is justified by the fact that associations between alterations of the limbic system and trait anxiety and fearfulness have also been observed in young healthy children (Qin et al. 2014; Tottenham et al. 2010; van der Plas et al. 2010). If these changes have implications for emotional as well as olfactory processing, one might expect to see differences in olfactory performance among children with varying levels of temperamental anxiety. Moreover, this approach also allows testing of the implicit assumption that the links between personality and olfaction are generalizable. If that should be so, they should already be detectable in young children and stem from general, constitutionally based tendencies to react in a certain way, which (unlike personality) can be assessed at a very young age. Such tendencies may be subsumed under the term temperament.

Temperamental Assessment in Children

As indicated above, in children of preschool and school age the more viable approach is to focus on temperament instead of personality, which, in the present study, was defined as the constitutionally based individual differences in reactivity and self-regulation that represent the initial state from which adult personality eventually arises (Rothbart 2007; Rothbart et al. 2000). In this definition, the term constitutional basis refers to the individual's biological make-up that is shaped over time by interactions of genetic endowment, maturation, and experience. Reactivity is the arousability of motor, affective, and sensory response systems, whilst self-regulation is the process

Table 1 A chronological overview of studies on links between olfactory perception and personality. Shown are the participant samples used, odorants (or odors) employed as stimuli, olfactory tasks and personality measures administered, and main findings

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
Koelega (1970)					
Study 1	140 (74 M) undergraduate psychology students (age not given)	12 $\log_4$ dilutions (highest) of amyl acetate† (0.25 M), exaltolide (1 M), muscone (0.5 M), 2-butanol† (4 M) in benzyl benzoate, which also served as a blank; 5 ml of each presented in 25 ml glass flasks † indicates that based on preliminary analyses, last third of data had scale changed to $\log_2$ starting with 7th dilution of amyl acetate and 5th dilution of 2-butanol	Sensitivity (4-AFC, number of correct responses summed up), 3 sessions in weekly intervals	Amsterdamse Biografische Vragenlijst (ABV; Wilde 1962)	Sensitivity (number of positive responses over 4 substances and 3 sessions) positively correlated with extraversion in men, no link between sensitivity and neuroticism ($p < .05$)
Study 2	20 (10 M) students scoring the highest and 20 (10 M) scoring the lowest, respectively, on extraversion	Amyl acetate and 2-butanol in the same concentrations as the last third of data in study 1	Sensitivity (see above); 1 session within which each concentration was presented twice	Maudsley Personality Inventory (MPI; Eysenck 1959) and Minnesota Multiphasic Personality Inventory (MMPI; Hathaway and McKinley 1943)	A trend of male extraverts exhibiting greater sensitivity than introverts for amyl acetate and 2-butanol ($p < .08$); a trend of female extraverts being more sensitive
Rovee et al. (1973)	30 F university students (age not given) selected from a pretested population of 160 F on the basis of extreme quartiles of the anxiety measure	17 $\log_2$ dilutions of *n*-octanol in diethyl phthalate, ranging from 100 to 0.001 %; 1 ml of each kept in 10 × 75 mm test tubes, odorants presented on a cotton tip	Sensitivity: AT and DT; indicate presence/absence of odor. AT: two trials, increasing concentration until positive response on two consecutive trials occurred. AT defined as a geometric mean of the weaker of the two consecutive concentrations in each trial series. DT measured by means of a modified method of limits (Rovee 1969).	Taylor Manifest Anxiety Scale (TMAS; Taylor 1953)	High-anxious group exhibited a significantly higher AT (lower sensitivity) than the low-anxious group ($p < .001$) and responded within a narrower range of concentrations ($p < .01$). Both groups responded equally quickly but vacillation measured by the number of reversals was higher in the highly anxious group ($p < .05$).
Filsinger et al. (1987)	195 (41 M) students, mean age 20.6 ± 3.4 years	5-alpha-androst-16-en-3-one (androstenone), 5-alpha-androst-16-en-3-alpha-ol (androstenol), exaltolide, and pyridine diluted to a 1 % solution in 100 % ethanol; unknown volume presented in 500 ml bottles	Pleasantness, intensity, and familiarity rated on a seven-point scale anchored with unpleasant–pleasant, no odor–strong odor, and familiar–unfamiliar, respectively	Eysenck Introversion-Extraversion Scale (Eysenck and Eysenck 1967)	Correlation between introversion-extraversion and perceived strength of exaltolide ($r = -0.13$, $p < .04$)
Herbener et al. (1989)					
Study 1	37 M undergraduates aged 18–23 years (mean age not given) selected from a pretested population of 215 M on the basis	11 dilutions (1.1193 to 0.0238 ppm) of butanol in water, which also served as a blank, presented in squeeze bottles	Monorhinal sensitivity: 2-AFC (indicate which stimulus smells stronger); threshold defined as the lowest concentration at which	Cheek and Buss Shyness Scale (RCBS; Cheek 1983)	A trend of extremely shy men exhibiting greater sensitivity, $t(28.4) = 1.85$, $p < .1$

Table 1 (continued)

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
	of extreme scores (bottom and top 20 %, respectively) on the Cheek and Buss Shyness Scale (RCBS; Cheek 1983)		the participant indicated the stimulus four times in a row		
Study 2	36 M undergraduates (age not given) selected from a pretested population of 326 M on the basis of being both shy and blue-eyed (group 1, $N = 17$) on the one hand and non-shy and brown-eyed (group 2, $N = 19$) on the other	See above	See above; threshold defined as the lowest concentration at which the participant indicated the stimulus six times in a row	See above	The two groups did not significantly differ in sensitivity.
Metaanalysis of studies 1 and 2					*P* values were converted into *Z*-scores, summed, and divided by the square root of 2; the resulting *Z*-score was converted back into a *p* value (Rosenthal and Rosnow 1984). Differences in olfactory sensitivity between groups 1 and 2 approached the significance level, $p = .05$.
Koelega (1994)	112 (55 M) psychology students, mean age 20 years (SD not given)	7 $\log_2$ dilutions (highest) of amyl acetate (1:312,000), *n*-butanol (1:39,000), isovaleric acid (1:6,240,000), exaltolide (1:800), musk R-1 (1:800) in paraffin oil, which also served as a blank; 5 ml of each presented in 25 ml glass flasks	Sensitivity (4-AFC of constant stimuli), four sessions	MPI (Eysenck 1959)	Extreme extraverts did not differ from extreme introverts in sensitivity. Introversion significantly correlated with sensitivity to *n*-butanol. Higher neuroticism scores were associated with greater sensitivity to *n*-butanol in female nonsmokers, whilst in males they were linked to lower sensitivity to isovaleric acid and exaltolide (exact values not given).
Pause et al. (1998)					
Study 1	20 M aged 20–30 (mean age not given)	14 0.5 $\log_{10}$ dilutions of linalool in 1,2-propanediol beginning with a 1:2 dilution (*v*/*v*), diluent also served as a blank; 6.5 ml of each	Monorhinal sensitivity (3-AFC staircase detection threshold procedure); threshold defined as the lower of two consecutive concentrations for which four successive correct detections were obtained. Thresholds tested repeatedly 13 times over 30 min. intervals with two 1-h breaks. Both the averaged value and the	Freiburger Personality Inventory (FPI-R; Fahrenberg, Hampel, and Selg 1989)	Emotionality (neuroticism) was significantly positively correlated with the averaged sensitivity ($r = 0.60$, $p < .05$) but not with the first threshold measurement. No associations with extraversion were found. The single (but not the averaged) measurement of sensitivity to linalool was significantly predicted by scales other than emotionality or

Table 1 (continued)

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
			first measurement were used for analyses.		extraversion, namely by physical complaints, satisfaction with life, and shyness, with a higher score on these personality traits correlating with lower sensitivity.
Study 2	30 twin pairs (half monozygotic, 23 M); only 13 pairs (8 M) aged 21–64 years used in analyses for technical reasons	Citral and isoamyl acetate (in diethyl phthalate) prepared as specified above. Androstenone (in 1,2-propanediol) diluted twofold for each consecutive concentration, with 1.25 mg/ml being the highest	Sensitivity (3-AFC staircase detection threshold procedure); threshold defined as outlined above. Five threshold values were obtained: two for citral and isoamyl acetate each (monorhinal), one for androstenone (birhinal). Value from the more sensitive nostril was taken as a predictor of general olfactory sensitivity.	See above	Emotionality (neuroticism) was significantly positively associated with sensitivity to isoamyl acetate (but not to androstenone or citral). No correlations with extraversion were found. Sensitivity to isoamyl acetate (but not to androstenone or citral) was predicted by scales other than emotionality or extraversion. Individuals scoring high on honesty, excitement, and low on social orientation exhibited lower sensitivity.
Larsson et al. (2000)	A subset of 506 twins (288 M) from the Swedish Twin Registry (Cederlöf and Lorich 1978) aged 45 to 87 years (65.4 ± 8.5)	Androstenone (0.1 % *w/v*), isoamyl acetate (neat), galaxolide (42.5 % *w/v*), eugenol (neat), a mixture of mercaptans: 76 % *tert*-butyl mercaptan, 18 % isopropyl mercaptan, 4 % *n*-propyl mercaptan, and 2 % *sec*-butyl mercaptan (4 % *v/v*), rose synthetic fragrance (80 % *v/v*), all in the scratch-and-sniff microencapsulated form	Ability to detect ("Did you smell something?", yes/no), 12-AFC cued identification, and perceptual ratings (pleasantness and intensity on a 5-point scale) using a Swedish version of the National Geographic Smell Survey (Wysocki and Gilbert 1989). Odor identification was scored as correct for the following odorant-adjective pairings: androstenone-musky or urine; isoamyl acetate-fruity; galaxolide-musky; eugenol-spicy; mercaptans-foul; rose-floral. Output was the number of correct pairings.	Extraversion and neuroticism from Eysenck Personality Inventory (EPI; Floderus 1974), lack of assertiveness scale and impulsivity scale from the Karolinska Scales of Personality (KSP; Schalling 1986; Schalling et al. 1983), and a shortened version of the openness to experience scale (25 of the original 48 items) from the NEO Personality Inventory (NEO-PI; Costa and McCrae 1985; Leong and Dollinger 1990)	No correlation (partial, corrected for pack-years) between detection and personality measures; negative association of identification with impulsivity and lack of assertiveness, both $r_{partial} = -0.14$, $ps < .001$, with individuals high in impulsivity and with a greater lack of assertiveness exhibiting lower identification scores, respectively. Individuals with higher scores in the openness to experience domain identified more odors, $r_{partial} = 0.14$, $p < .01$. Also, identification was predicted by neuroticism, $\beta = 0.11$, impulsivity, $\beta = -0.12$, and lack of assertiveness, $\beta = -0.15$, all $ps < .05$.
Spinella (2002)	28 participants (mostly students, 8 M) aged 19–70 years (29.18 ± 2.80)	Odors contained in the Alberta Smell Test (AST; Green and Iverson 2001) (scented markers with authentic essences of lemon,	8-AFC monorhinal cued identification (10 trials in each nostril), output is the number of correct responses out of ten for each nostril	Mehrabian and Epstein Empathy Questionnaire (MEEQ; Mehrabian and Epstein 1972)	Total empathy score significantly correlated with right nostril identification score, $r = 0.44$, $p < .01$, and identification score

Table 1 (continued)

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
		orange, licorice, cinnamon, mint, raspberry, grape, and melon)			averaged for both the nostrils, $r = .41$, $p < .05$.
Chen and Dalton (2005)	75 young adults (38 M), F aged 23 ± 0.77 years, M 24 ± 0.79 years	Pleasant lemon/orange scent (96 + % mixture of cis and trans, 50 % diluted in filtered mineral oil), 0.05 % of 3-methylindole diluted in propylene glycol (unpleasant odor), and rubbing alcohol (5 % isopropyl alcohol diluted in propylene glycol; neutral odor); intensities were ascertained by a panel of four judges to be approximately the same.	Olfactory intensity was rated on a scale of 1–9 (from extremely mild to extremely strong).	Neuroticism and introversion were measured by the Eysenck Personality Questionnaire Revised—Short (EPQ-RS; Eysenck and Eysenck 1994), and anxiety by the TMAS (Taylor 1953). Participants were median split into those scoring either high or low on anxiety.	There was no main effect of personality on ratings of olfactory intensity. There was an interaction effect between personality and emotional odorants in women, $F(1.74,61) = 4.44$, $p = .020$. Women high in trait anxiety perceived the two emotionally valenced odorants stronger than the neutral odorant, 6.00 and 6.99 versus 4.90, $SE = 0.25$, 0.35 versus 0.27, for pleasant, unpleasant, and neutral, respectively, $p = .005$ and .0001, $F(2,18) = 15.91$, $p < .0001$. Women low in anxiety did not, $F(2,15) = 1.38$, $p > .05$. No personality by intensity effect was found in men ($p > .05$).
Cornell Kärnekull et al. (2011)					
Study 1	101 (46 M) psychology students aged 27.01 ± 8.12 years	None	Environmental chemosensory responsivity was assessed with the Chemical Sensitivity Scale (CSS; Nordin et al. 2003).	Big Five Inventory (BFI; John et al. 1991), Positive and Negative Affect Schedule (PANAS; Watson et al. 1988)	Moderate positive correlations were found between CSS scores and neuroticism, $r = 0.36$, $p < .01$, and between neuroticism and negative affect, $r = 0.54$, $p < .01$. CSS scores did not correlate reliably with negative affect. Extraversion, agreeableness, conscientiousness, and openness were uncorrelated with CSS scores.
Study 2	40 healthy individuals (19 M) aged 26.97 ± 8.54 years randomly selected from the pool of participants in study 1	Sniffin' Sticks threshold test (*n*-butanol used for threshold testing) (Hummel et al. 1997); perceptual evaluation of 32 odorants: 2-heptanone, 2-phenylethyl ethyl ether, 2-phenylethyl pentyl ether, 3,7-dimethyloctanenitrile, anise, bitter almond, bornyl acetate, calone (7-methyl (2H,4H)-1,5,benzodioxepin-3-one),	Birhinal sensitivity was tested with the Sniffin' Sticks threshold test (see above). Pleasantness and intensity were rated on a 7-point scale (1 = very unpleasant/not intense at all, 7 = very pleasant/very intense). Environmental chemosensory responsivity was assessed with the Chemical Sensitivity Scale (CSS; Nordin et al. 2003).	BFI (John et al. 1991)	Neuroticism was unrelated to both the hedonic and intensity ratings ($ps > .20$).

Table 1 (continued)

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
		caraway, cedarwood, chocolate, cinnamon, citrowanil (2-ethenyl-2-methyl benzenepropanal), clove, dec-9-en-1-ol, elderflower, eucalyptus, heptanal, heptyl acetate, juniper berry, lemon, lilac, menthyl acetate, methyl benzoate, octanol, pine needle, plicatone (1,4-methano-7-methyl-(2H)-octahydro naphtalene-6-one), rose, tridec-2-enenitrile, vanilla, violet, α-pinene (hydrocarbon). They were divided in 2 sets, each consisting of 8 unfamiliar and 8 familiar odors, with each participant having been randomly assigned to an odor set. The odorants were kept in 160 ml opaque glass jars and presented by injecting 10 ml on a cotton pad covered with another pad.			
Croy et al. (2011)	124 (41 M) graduate students and staff aged 18–52 years (24 ± 5)	16 1:2 dilutions of phenyl ethyl alcohol (PEA) starting from a 4 % solution	Birhinal sensitivity assessed with the Sniffin' Sticks test (Hummel et al. 1997); 3-AFC staircase detection threshold procedure. Threshold value was defined as the mean of the last four out of seven staircase reversals.	German version of the NEO Five Factor Inventory (NEO-FFI; Borkenau and Ostendorf 2007)	Agreeableness positively correlated with sensitivity to PEA, $r = 0.269$, $p < .05$.
Havlíček et al. (2012)					
Study 1	71 high-school students (30 M) aged 17–22 years (18.0 ± 0.81), data from 68 used in analyses	Sensitivity, 16 1:2 dilutions of PEA starting from a 4 % solution (Sniffin' Sticks, Hummel et al. 1997); identification, 16 odors same as those used in the "blue" Sniffin' Sticks identification test (orange, leather, cinnamon, mint, banana, lemon, liquorice, turpentine, garlic, coffee, apple, clove, pineapple, rose, anise, fish; exact odorants not given), 10 μl of each presented on a cotton pad kept in a glass jar.	Birhinal sensitivity tested with the Sniffin' Sticks test (see above). 4-AFC cued identification (verbal labels identical to those used in the Sniffin' Sticks identification test); output was the number of correct responses.	Czech version of the NEO Personality Inventory (NEO-PI-R; Hřebíčková 2004); dominance assessed with 11-item questionnaire from the international personality item pool (Goldberg et al. 1999)	More neurotic individuals exhibited greater sensitivity, Kendall's tau = 0.17, $p < .05$; the correlation approached the formal level of significance in men but was nonsignificant in women. Sensitivity was linked to anxiety, Kendall's tau = 0.31, $p < .02$, and self-consciousness, Kendall's tau = 0.27, $p = .05$. Odor identification was not linked to any personality dimensions.

Table 1 (continued)

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
Study 2	156 university students or alumni (89 M) aged 19–35 years (24.2 ± 4.1), 83 nonheterosexual	Sniffin' Sticks extended test (*n*-butanol used for threshold testing) (Hummel et al. 1997). See above for odors used for identification (exact odorants not given). Target/nontarget odorant pairs used for discrimination: butanol/2-phenyl ethanol; isoamyl acetate/anethole; anethole/eugenol; limonene/fenchone; (−)carvone/(+)carvone; eugenol/cinnamon aldehyde; dihydrorosenoxide/menthol; acetaldehyde/isoamyl acetate; citronellal/linalool; pyridine/limonene; limonene/citronellal; eucalyptol/dipyridyl; dipyridyl/cyclopentadecanoate; butanol/fenchone; octyl acetate/cinnamon aldehyde; carvone/acetaldehyde	Birhinal sensitivity (see above), 3-AFC discrimination (16 triplets, choose the odd odor in each), and 4-AFC cued identification assessed with the Sniffin' Sticks. Discrimination and identification output was the number of correct responses.	Czech version of the NEO-Five Factor Inventory (NEO-FFI, Hřebíčková and Urbánek 2001)	No association between neuroticism and any of the olfactory measures for sex, sexual orientation, or any of the 4 groups (non/heterosexual female/male) analyzed separately. Of the neuroticism subscales, discrimination was linked to anxiety, Kendall's tau =0.12, $p < .05$. This pattern of findings was only found in heterosexual individuals, Kendall's tau =0.17, $p < .05$.
Mahmut and Stevenson (2012)	79 students; 39 M (mean age 21 years), 40 F (mean age 19 years)	Sniffin' Sticks extended test (*n*-butanol used for threshold testing), see above (Hummel et al. 1997)	Birhinal sensitivity, discrimination, and identification assessed with the Sniffin' Sticks (see above)	The Self-Report Psychopathy scale IV (SRP-IV; Paulhus et al. 2012)	Psychopathy negatively correlated with odor identification and discrimination, $r = -0.24$, $p < .05$ and −0.26, $p < .01$, respectively. Moreover, psychopathy significantly predicted odor discrimination, $\beta = -0.23$; $sr^2 = 5.2$ %; $F(2, 78) = 5.69$, $p < .01$.
La Buissonnière-Ariza et al. (2013)	38 students (20 M) aged 18–35 years (24.3 ± 4.5), data from 36 used in the analyses	Strawberry and fish odor (exact odorants not given) diluted in propylene glycol to concentrations of 10 and 25 %, respectively; stimuli delivered using a customized olfactometer. Odor chambers were 50 ml glass bottles filled with 4 ml of odorant, airflow was 3 l/min., stimuli lasted 500 ms.	Birhinal detection, odor pleasantness, and intensity ratings. Participants were instructed to detect and indicate the presence of the odor as fast as possible by pressing a button. On average, participants received a nasal stimulus every 30 s (25–35 s). Pleasantness and intensity were assessed with visual analog scales.	Spielberger State-Trait Anxiety Inventory (Spielberger et al. 1983)	High- and low-anxious individuals did not differ significantly in terms of hit rates for either odor. However, there was an effect of trait anxiety on response times, with highly anxious participants exhibiting faster responses to both odors, $F(1,31) = 7.86$, $p < .01$, $\eta^2 = 0.20$. There was no effect of anxiety on pleasantness or intensity ratings.
Lehrner et al. (2015)	16 patients (7 M) complaining about smell problems of diverse	Sniffin' Sticks identification, see above (Hummel et al. 1997)	Identification (Sniffin' Sticks), self-assessment of olfactory	Big Five Plus One personality inventory (B5PO; Holocher-Ertl	There was a significant difference between the 2 groups in the

Table 1 (continued)

Reference	Participants	Stimuli	Olfactory measure(s)	Personality measure(s)	Findings
	etiologies, median age 61.5 years (range not given), and 17 normosmic controls (10 M), median age 49 years		function with Assessment of Self-Reported Olfactory Functioning (ASOF; Pusswald et al., 2012) and adapted version of the Questionnaire of Olfactory Dysfunction (QOD; Frasnelli and Hummel 2005; Croy et al. 2011)	et al. 2003)	identification score and self-assessed olfactory function, with patients exhibiting higher neuroticism scores than controls, $p < .05$.
Takahashi et al. (2015)	124 (62 M) university students, hospital staff, and members of the local community aged 20.2–49.1 years (27.2 ± 6.0)	8 $\log_{10}$ dilutions of PEA, methyl cyclopentenolone, isovaleric acid, γ-undecalactone, and skatole in propylene glycol, presented on a strip of litmus paper impregnated with the odorant	Birhinal sensitivity (DT and RT) was tested by means of a stepwise presentation starting with the lowest concentration. Participants were asked to indicate if odor was present and to identify it (free naming). Criteria for scoring an answer as "correct" were not specified. DT was defined as the lowest concentration at which an odor was perceived but not identified. RT was defined as the lowest concentration at which both detection and correct identification occurred. DTs and RTs were averaged across the five odorants for the participant.	Japanese version of the State–Trait Anxiety Inventory (STAI-JYZ; Iwata et al. 1998)	Reduced sensitivity to certain odorants was found in individuals scoring high on state and trait anxiety. Despite significant positive correlations of trait anxiety with DTs for all odorants except γ-undecalactone and RTs for PEA and isovaleric acid, only the latter two (along with the mean RT) remained significant after Bonferroni correction. State anxiety correlated with all DTs and RTs for PEA, isovaleric acid, and γ-undecalactone, but only the link with the mean DT, mean RT, and RT for PEA remained significant after Bonferroni correction.

M male, *F* female, *AFC* alternative forced choice, *AT* absolute threshold, *DT* difference threshold, *RT* recognition threshold

which modulates reactivity, including attentional focusing and inhibitory control (Rothbart et al. 2001). From the first months of age, infants exhibit marked interindividual differences in their interactions with the environment (Rothbart 1981), namely variability in emotional, motor, and attentional reactivity measured by latency, intensity, and recovery of response, and in self-regulation processes such as effortful control that modulate reactivity (Rothbart and Derryberry 1981).

Investigations of links between temperament and olfactory performance in childhood pose several challenges. Firstly, temperamental assessments in childhood are made difficult by the fact that temperament is undergoing developmental changes and behaviors indicative of a certain trait in younger children may not be equally informative for measuring the same trait in older ones. This is overcome by employing age-specific instruments to assess temperament across infancy and childhood (Capaldi and Rothbart 1992; Putnam et al. 2006; Rothbart 1981; Rothbart et al. 2001). Nevertheless, despite developmental changes, temperament also shows relative stability and heterotypic continuity (i.e. relations between different sets of behavior across different ages) (e.g. Durbin et al. 2007; Shoda et al. 1990) and predicts personality in young adulthood (e.g. Caspi and Silva 1995). Secondly, adult data are based on self-reports, whilst a similar approach is clearly not viable in young children. Assessment of child temperament is thus dependent on other-reports, especially by parents and teachers. There seems to be reasonable consistency between parental reports and indicators of temperament that are based on both home and laboratory observations (Kochanska et al. 1996; Schaughency and Fagot 1993). Also, self-reports and parental reports using measures for which both the child and parent forms are available show significant correlations on most of the scales (e.g. Capaldi and Rothbart 1992). Therefore, use of parental assessment of child temperament seems an acceptable trade-off between the opportunity to address this research question in the youngest cohorts and precision of measurement. Given the conceptual and empirical links between temperament and personality, especially the Big Five model, extrapolation of hypotheses from adults to children is possible.

Mappings Between Temperament and Personality

In order to be able to discuss the links between temperament and olfaction in the context of previous research, mappings between temperament and personality, particularly within the Big Five framework, must be considered. As mentioned above, of particular interest has been the dimension of neuroticism (also termed anxiety). The underlying set of temperamental traits, referred to as negative affectivity, reflects sensitivity to cues of punishment, frustrative nonreward, and novel stimuli or, in general, threat sensitivity with accompanying negative affect. Behaviorally, it is manifested in anxious and fearful reactions, inhibition of ongoing behavior, increased readiness for action, and heightened attention to environmental stimuli (Halverson et al. 2014). The set of temperamental traits underlying extraversion, termed surgency, encompasses sensitivity to signals of reward and an active engagement with the surrounding world. It is manifested behaviorally through sociability, impulsivity, sensation seeking, and activity level, and partly also via intensity of affective response, in particular positive affect (Halverson et al. 2014). Negative affectivity and surgency seem to map fairly well onto the Big Five (Costa and McCrae 1992) dimension of neuroticism and extraversion, respectively (for review see Rothbart and Posner 2006), although the authors show that the expression of both is substantially modulated by self-regulatory processes subsumed under effortful control. This refers to a self-regulatory

Table 2 Mean ± SD, their respective 95 % bias corrected and accelerated bootstrap confidence intervals (in *square brackets*), and range for age, verbal fluency, olfactory measures, and temperamental factors in boys ($N = 62$) and girls ($N = 67$). Note that for temperament-related descriptive statistics, the sample size is 72 and 71 for boys and girls, respectively. Both the identification tests were only comprised of 12 instead of the original 16 items

	Boys			Girls		
	Mean	SD	Range	Mean	SD	Range
Age (months)	82.21	5.03	73.30–95.00	81.78	4.55	75.30–99.10
Verbal fluency	12.76 [11.68; 13.94]	4.37 [3.49; 5.20]	5.00–27.00	13.90 [13.00; 14.87]	4.02 [3.24; 4.66]	7.00–27.00
Identification blue	7.82 [7.43; 8.24]	1.63 [1.38; 1.82]	4.00–11.00	7.81 [7.42; 8.20]	1.53 [1.34; 1.70]	4.00–10.00
Identification purple	7.53 [6.97; 8.05]	2.15 [1.80; 2.52]	1.00–12.00	7.94 [7.54; 8.35]	1.72 [1.51; 1.90]	4.00–11.00
Identification total	15.35 [14.58; 16.13]	3.19 [2.76; 3.56]	8.00–22.00	15.75 [15.08; 16.40]	2.57 [2.17; 2.95]	9.00–20.00
Discrimination	8.19 [7.36; 9.03]	3.36 [2.81; 3.84]	2.00–16.00	9.07 [8.46; 9.67]	2.66 [2.24; 3.01]	4.00–15.00
Surgency	4.56 [4.35; 4.79]	0.90 [0.76; 1.02]	2.08–6.22	4.38 [4.18; 4.58]	0.90 [0.76; 1.03]	2.04–6.14
Negative affectivity	3.94 [3.77; 4.11]	0.73 [0.62; 0.81]	2.35–5.49	3.92 [3.77; 4.06]	0.71 [0.60; 0.81]	2.66–5.92
Effortful control	4.94 [4.78; 5.10]	0.67 [0.58; 0.75]	3.36–6.74	5.43 [5.30; 5.57]	0.55 [0.46; 0.64]	3.92–6.61

system superordinate to the other two that manifests itself in the ability to *voluntarily* sustain focus on a task, shift attention from one task to another, initiate action, and inhibit it (for review see Ahadi and Rothbart 2014). More recent studies with preschool children in which temperamental as well as various personality measures within the Big Five framework were used reported moderate to high correlations between negative affectivity and neuroticism on the one hand and extraversion and surgency on the other (e.g. Grist and McCord 2010).

Potential Modulators of Links Between Temperament and Olfaction

Among the potential modulators of the links between temperament and olfaction the most important ones to consider are age and verbal fluency. Odor identification scores in children have been found to improve with age (e.g. Cameron and Doty 2013; Ferdenzi et al. 2008b), but see, for instance, Martinec Nováková and Vojtušová Mrzílková (2016); Saxton et al. (2014) for conflicting results in prepubertal children. Verbal fluency, which is itself influenced by age (e.g. Ferdenzi et al. 2008a), has been found to affect semantic tasks such as odor identification (e.g. Hedner et al. 2010; Larsson et al. 2000). Hence, despite using age-specific measures of temperamental dispositions, age as well as verbal fluency need to be controlled for. Finally, complex interactions have been found between parental perceptions of their children's temperament and the parenting style employed, i.e. the emotional atmosphere created by the parent at home (for review see Rothbart and Bates 2006; Rothbart and Posner 2006). Importantly, perceptions of a child's temperament, parenting style, and their mutual interactions tend to differ depending on the child's gender (for review see Putnam et al. 2002). In assessments of children's temperament it is thus crucial to control for the effect of parenting style separately in boys and girls.

Rationale and Hypotheses

A body of research predominantly in young adults (especially university students) has suggested a link between olfactory perception, mainly sensitivity, and personality characteristics, particularly neuroticism. Nevertheless, it is not clear whether the associations between personality and olfaction are present outside this particular age range and whether they involve other olfactory abilities, such as odor identification and discrimination. Also, the implicit assumption that such associations are generalizable needs to be addressed. If that should be so, they should already be evident in children and involve general, constitutionally based tendencies to react in a certain manner which can be observed and assessed at a very young age. Mappings between temperament and personality on the one hand and correlations between self-reports and parental reports of temperament on the other allow extrapolation of hypotheses previously formulated in studies with adults to children. On the one hand, evidence from such studies suggests that individuals scoring high on temperamental traits underlying neuroticism should outperform the low-scoring ones. On the other hand, well-developed self-regulatory processes, which modulate the expression of anxiety-related tendencies and manifest themselves in the ability to voluntarily sustain focus on a task, shift attention from one task to another, initiate action and inhibit it, might also contribute to better olfactory performance. Thus, the aim of the present study was to investigate the effect of the individual temperamental factors on olfactory performance. Namely, we hypothesized that superior olfactory performance would be delivered by children relatively higher on negative affectivity (which broadly maps onto neuroticism) as well as those exhibiting greater self-regulation (effortful control).

Materials and Methods

Participants

The participants were 143 children of Czech origin (72 boys, mean age 6.84 ± 0.41 years, range 6.11–8.26 years) and their parents (124 mothers). The children were first-graders from six public mixed-sex general education elementary schools in Prague, Czech Republic, and its suburbs. The schools were attended by children from varied social backgrounds. School principals were contacted via telephone and e-mail to inform them about the planned study. Those who had provided permission to perform the study on the school's premises were asked to pass the information on to the teachers. They distributed leaflets to children, who, in turn, handed them over to their parents. Girls and boys did not differ in terms of mean age or age distribution, boys = 6.89 ± 0.45 years, range 6.11–7.93 years, girls = 6.80 ± 0.38 years, range 6.28–8.26 years, respectively, Kolmogorov-Smirnov $Z = 0.93$, $p = .36$. According to parental reports, 12 children suffered from various allergies, chronic asthma, or other chronic conditions, and three had sustained concussion with loss of consciousness. However, as the data obtained from these children did not manifest themselves as outliers, they were not excluded from the analyses. In 10 boys and 4 girls some of the demographic data, verbal fluency, or olfactory measures were missing, resulting in $N = 129$ (62 boys) with the complete set of data, whilst parental reports of children's temperament were available for the total of 143 children (72 boys). Therefore, the descriptive statistics of age, verbal fluency, olfactory measures, and correlations involving these variables are given for $N = 129$, whilst the

temperament-related descriptives are shown for $N = 143$. The descriptive data are given in Table 2. Furthermore, 30 preschool children (15 boys, mean age 5.99 ± 0.43 years, range 5.25–6.75 years), all resident in Prague, Czech Republic, and its suburbs, participated in a pilot study, which has been described in full detail in Martinec Nováková and Vojtušová Mrzílková (2016).

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). The study has been approved by the IRB of the Charles University (Approval Number 2015/11). Written informed consent was obtained from the children's parents, and oral informed consent was provided by the children in the presence of a teacher employed by the school. The children-parents pairs each received 300 CZK (approximately 11 EUR or 12 USD) in compensation.

Olfactory Measures

General Considerations

The Sniffin' Sticks test (Hummel et al. 1997), manufactured by Burghart Messtechnik GmbH, was used to assess odor identification and discrimination. This is one of the most widely used tests of olfactory performance, based on pen-like odor dispensing devices. Odor threshold was not tested because used as is, in this age group it only appears to place excessive demands on the attentional capacity of the younger children and prolong testing time (e.g. Hummel et al. 2007a). The Sniffin' Sticks test has been widely used by clinicians and researchers across Europe to test olfactory abilities in adults (Hummel et al. 2007b) and children (Ferdenzi et al. 2008b; Renner et al. 2009; Sorokowska et al. 2015), including Czech ones (Dudova et al. 2011; Hrdlicka et al. 2011; Martinec Nováková et al. 2015; Saxton et al. 2014). Olfactory data collection for the present study took place between April and June 2015, meaning that possible seasonal effects on olfactory performance did not need to be taken into account. Since this study was part of a larger project, descriptive data concerning olfactory measures in the present sample and analyses of gender differences in olfactory performance (which were nonexistent) have previously been published elsewhere (Martinec Nováková and Vojtušová Mrzílková 2016).

Odor Identification

The two 16-item identification tests ("blue" and "purple", as they are referred to by the manufacturer) both consist of odorants familiar to the general European population, such as orange, rose, garlic, and fish. To the best of our knowledge, the "purple" identification set has not been validated yet. The rationale behind the use of two identification tests instead of one was to prevent the possible ceiling effect. In the original version of the tests cued identification is employed, in which participants select the verbal label of the target odor from a candidate list of four alternatives. The resulting score is the sum of correct answers. In the present study, both the tests were adapted to children who were only beginning to learn reading. This was done by presenting both the targets and distractors in the form of color pictures instead of verbal labels. The process of adaptation of the tests has been described in full detail in Martinec Nováková and Vojtušová Mrzílková (2016). In short, children had been interviewed about their understanding of both the target and distractor odor sources, upon which images depicting items most frequently associated with the given verbal label were selected. These interviews had also revealed that most children were rather unfamiliar with most of the spices (anise, cinnamon, clove, ginger, nutmeg, vanilla), eucalyptus, menthol, and turpentine. Thus, items involving these odor sources either as a target or distractor were excluded, resulting in the maximum score of 12 for each of the identification tests. During testing, understanding what each image depicted had always been checked prior to the identification task itself. Odor presentation was carried out in a manner recommended by Hummel et al. (1997). The scores on both the tests were added together to produce the total identification score with a maximum of 24.

Odor Discrimination

No alterations had to be made to the discrimination test. The test of odor discrimination assesses the degree to which an individual can differentiate between odors in suprathreshold concentrations. The set comprises 16 triplets of odorized pens, of which two are identical, and the participant is asked to indicate the odd one. The odorants used in the test are given in Hummel et al. (1997). The score is the total of correct trials (0–16), with higher scores indicating a better ability of odor discrimination.

Temperamental Assessment: Short Form of the Children's Behavior Questionnaire (CBQ-SF)

Being widely used in developmental research, the Children's Behavior Questionnaire (CBQ; Rothbart et al. 2001) affords a highly differentiated caregiver report assessment of temperament in 3- to 8-year-olds. It is grounded in a definition of temperament as constitutionally based individual differences in reactivity and self-regulation that are influenced by heredity and experience (Rothbart and Derryberry 1981). Domains covered by the instrument include positive and negative emotion, motivation, activity level, and attention. The standard 195-item form is comprised of 15 scales of 12 to 14 items each (activity level, anger/frustration, approach/positive

Table 3 Spearman's rank correlational analyses of age, verbal fluency, olfactory measures (total odor identification and odor discrimination), and the three temperamental factors (surgency, negative affectivity, and effortful control) in the total sample ($N = 129$)

	Age	Verbal fluency	Identification total	Discrimination	Surgency	Negative affectivity	Effortful control
Age		*0 .232*** [*0.055*; *0.389*]	0.115 [−0.057; 0.264]	0.154† [−0.027; 0.331]	−0.027 [−0.244; 0.179]	*0.218** [*0.042*; *0.367*]	−0.045 [−0.220; 0.111]
Verbal fluency	*0.232*** [*0.055*; *0.389*]		0.001 [−0.162; 0.163]	−0.083 [−0.255; 0.081]	0.119 [−0.094; 0.301]	−0.065 [−0.247; 0.108]	0.134 [−0.040; 0.303]
Identification total	0.115 [−0.057; 0.264]	0.001 [−0.162; 0.163]		0.170† [−0.014; 0.336]	0.020 [−0.166; 0.187]	−0.055 [−0.238; 0.130]	*0.216*** [*0.045*; *0.390*]
Discrimination	0.154† [−0.027; 0.331]	−0.083 [−0.255; 0.081]	0.170† [−0.014; 0.336]		-0.118 [−0.300; 0.077]	−0.028 [−0.204; 0.140]	0.138 [−0.045; 0.300]

Values of 95 % bias corrected and accelerated bootstrap confidence intervals are given in *square brackets.* Significant correlations are given in *italics*
*$p < .05$, **< .01, † trend at $p < .1$

anticipation, attentional control, discomfort, falling reactivity/soothability, fear, high intensity pleasure, impulsivity, inhibitory control, low intensity pleasure, perceptual sensitivity, sadness, smiling and laughter, and shyness). In the present study a short, 94-item form consisting of these 15 scales of six to eight items each (CBQ-SF; Putnam and Rothbart 2006) was used. Both the instruments give statements describing a child's behavior in various everyday situations, e.g. "Seems always in a big hurry to get from one place to another" (activity level), "Will move from one task to another without completing any of them" (attentional focusing), or "Has temper tantrums when (s)he does not get what (s)he wants" (anger/frustration). Both are used in such a way that parents rate their child on a seven-point scale ranging from 1 (extremely untrue of the child) to 7 (extremely true of him or her). If a child has not been observed in the given situation by the responding person, a "not applicable" response category is selected. Thus, the minimum score for the individual scales is 6 to 8 and the maximum is 42 to 56, depending on the number of items. Based on the recommendations of Rothbart et al. (1994), the score for surgency was computed as the average of the scale scores for activity level, high intensity pleasure, impulsivity, and the reversed shyness score. The negative affectivity score was calculated according to these authors by averaging the scale scores for anger, discomfort, fear, sadness, and the reversed soothability score. Finally, the effortful control score was computed as the average of attention focusing, inhibitory control, low intensity pleasure, and perceptual sensitivity. The questionnaire was translated to Czech and a back translation was produced by Jitka Lindová and Jan Havlíček. The individual CBQ-SF scales and the three broader factors along with their definitions and descriptive statistics are listed in Online Resource 1.

Parenting Styles

Having been outlined in the seminal work of Baumrind (1971), parenting styles refer to the emotional atmosphere created by parents at home (Darling and Steinberg 1993). They can be classified into the following three categories: authoritative (responsiveness towards children combined with demands), authoritarian (demanding but not very responsive), and permissive (high in responsiveness and low in demands). They were briefly assessed using hypothetical vignettes after Barnhart et al. (2013). These include descriptions of three hypothetical interpersonal situations between a parent and his or her two children (son and daughter) aged 7 and 11 years, respectively, in which the response of the parent to the situation represents one of the three parenting styles. For instance, in the hypothetical vignette representing the permissive parenting style, the mother believes that children should be free to do what they want, and so when the children want to go outside to play without having done their homework before, she nevertheless lets them go outside for as long as they want. The parents were asked to indicate the degree to which they associated themselves with the hypothetical parent's response to the given situation on a 10-cm visual analog scale. The rating for each vignette was obtained by measuring the distance in millimeters between zero and the marked point on the line.

Verbal Fluency

Verbal fluency is known to modulate odor identification, with individuals who exhibit greater verbal fluency outperforming the low-scoring ones (e.g. Larsson et al. 2000), and to correlate with some personality traits, e.g. extraversion (Burton and Henninger 2013). It was tested using a Czech version of the category verbal fluency test adapted to children Preiss (1997). First, variability of responses to the three categories (animals, fruits, and things that can be bought in a supermarket) had been explored in a pilot study described in full detail in Martinec Nováková and Vojtušová Mrzílková (2016). The most variable results were obtained for animals, which were chosen as the test category. During the testing session itself, a

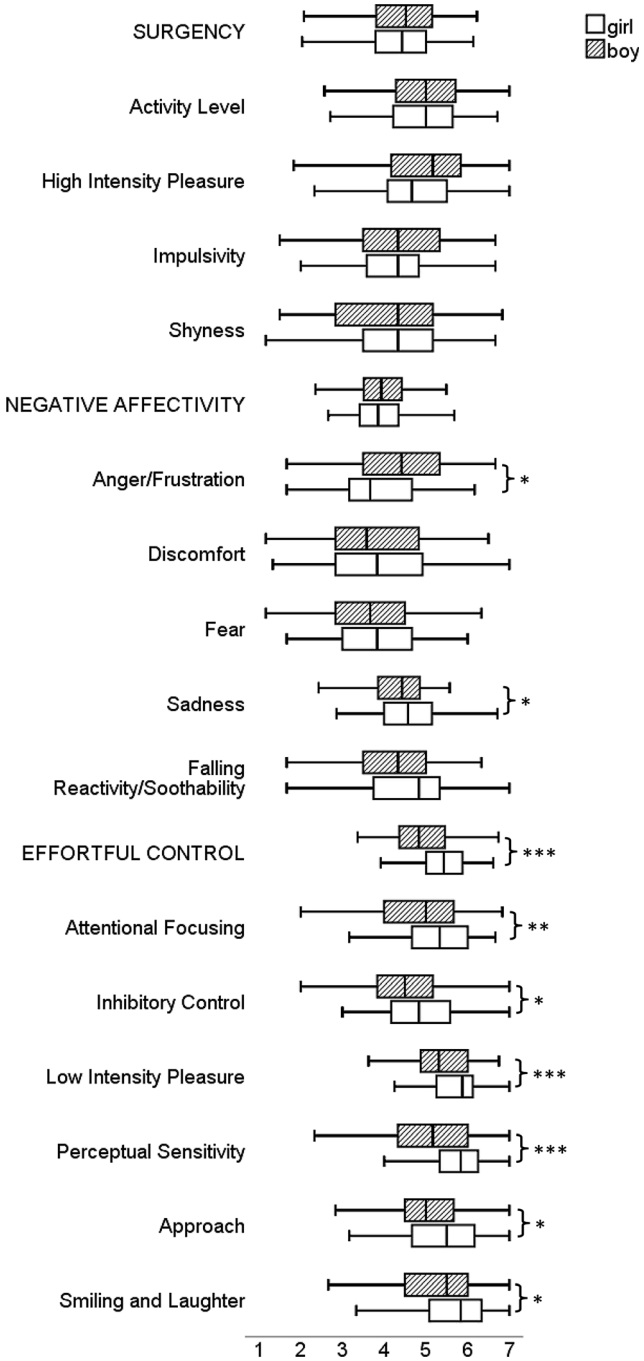

Fig. 1 Comparison of surgency, negative affectivity, and effortful control and their subscales in boys and girls. Whiskers indicate minimum and maximum, respectively. *$p < .05$, **$p < .01$, ***$p < .001$

training trial was conducted using the transport category, on which a child was asked to name as many means of transport as possible. Understanding was assured by asking the child what transport meant and by giving an example (e.g. a car). Next, the child was encouraged to name as many animals as possible in 60 s, whilst the answers were being immediately written down by the researcher.

Procedure

Parents were instructed to only encourage their children to attend the testing sessions when in good respiratory health. The children participated in individual testing sessions, which were always scheduled after school dinners at a time between 12:30 p.m. and 3 p.m. (i.e. a time when most children attend after-school care centre in the school premises). Testing took place in a secluded, well-ventilated room without strong ambient odors. At the beginning of the session, children were briefly familiarized with the tasks, which were presented as a game, and ensured that they could stop or quit at any time. Since the present study was part of a larger project, at the beginning of the session, children were first interviewed about their odor awareness (see Martinec Nováková and Vojtušová Mrzílková 2016 for results). Next, the two identification tests ("blue" and "purple") followed in a randomized order. Within each set, the stimuli were presented in the order recommended by Hummel et al. (1997). After that, the odor discrimination test was administered. Finally, verbal fluency was assessed with the animal category verbal fluency test. The entire session took, in most participants, 30–40 min. Parents completed the CBQ-SF and provided ratings of the hypothetical vignettes at home via a web-based survey tool, Qualtrics (Qualtrics, Provo, UT). They were never present in the room during the session.

Statistical Analysis

All analyses were carried out with IBM SPSS 22.0. Normality of the raw data was checked, firstly, by visually examining the individual histograms of all relevant variables, secondly, by producing skewness and kurtosis values and their respective standard errors, from which z-scores were computed and compared to the value of 1.96, as suggested by Field (2005:72), and, thirdly, with multiple Shapiro-Wilk's W tests. Since departure from normality in nearly all variables was detected, nonparametric tests were used where possible.

Gender differences were analyzed using Mann-Whitney U tests, and correlations were performed with Spearman's rank correlations. A general linear model (GLM) was produced with gender as a factor, surgency, negative affectivity, and effortful control as covariates (that is, independent variables, IVs), and the total identification score and the discrimination score as multiple dependent variables (DVs). Besides the main effects of gender and the three temperamental factors, interactions between the former and the latter were included in the model. To further explore the contribution of the individual scales of effortful control to the effect on odor identification scores, another GLM model was run with the scales (attentional focusing, inhibitory control, low intensity pleasure, and perceptual sensitivity) as IVs and identification as a DV, with the model only testing the main effects. The values 95 % bias

corrected and accelerated bootstrap confidence intervals, 95 % BCa CIs, are given in brackets.

Results

Exploratory Correlations

Exploratory Spearman's rank correlations involving age, verbal fluency, and olfactory measures on the one hand and the three temperamental factors or the 15 temperamental scales on the other are given in Table 3 and Online Resource 2, respectively. For correlations involving the temperamental scales, a Bonferroni correction was employed, with α level set to 0.05/105 = 0.0005. In the total sample, neither verbal fluency nor age was associated with olfactory abilities. As expected, age was significantly associated with verbal fluency, Spearman's ρ = 0.232, p = .008 [0.072; 0.399]. In the total sample, surgency and negative affectivity were both correlated with effortful control, Spearman's $\rho = -0.212$, $p = .012$ [−0.387; −0.027] and $\rho = -0.210$, p = .012 [−0.358; −0.029], respectively. When analyzed separately, in boys the correlations reflected those found in the total sample, whilst in girls effortful control was only associated with surgency. Parenting styles were not significantly associated with any of the three broad temperamental factors in the total sample, boys, or girls.

Effect of Temperamental Factors on Olfactory Measures

Multivariate tests of the general linear model (GLM) revealed a significant effect of effortful control on the olfactory measures, Pillai's trace = 0.052, $F(2,120) = 3.323$, p = .039. Between-subject tests showed that children's total identification scores (but not discrimination ones) differed with respect to effortful control, $F(1,121) = 5.512$, $p = .021$. To be specific, children reported by their parents to exhibit greater effortful control had higher total identification scores, Spearman's ρ = 0.216, p = .014 [0.047; 0.388]. There was no effect of gender or the other two temperamental factors on odor identification or discrimination. However, it should be noted that the model for identification only explained 7.5 % of variation in identification performance in the present sample, with an estimated 2.1 % in the population, R^2 = 0.075, adjusted R^2 = 0.021.

Effect of Effortful Control Scales on Odor Identification

Subsequently, the potential effect of the individual scales constituting effortful control on odor identification was examined. Perceptual sensitivity was associated with the vignette representing the authoritative style, Spearman's ρ = 0.192, p = .025 [0.020; 0.340]. The effect of the authoritative parenting style on perceptual sensitivity was controlled for in a semi-partial (part) correlation, from which residuals were obtained, interpreted as "the part of perceptual sensitivity that was not due to the child being perceived as such by a parent with an authoritative style". Next, two GLM models with effortful control constituent scales as IVs and the identification score as a DV were run, one on the raw values of perceptual sensitivity and the other on the residuals. Similar results were obtained in both cases, with no effect of any of the scales on odor identification performance.

Between-Gender Variation in Olfactory Abilities, Temperament, Parenting Styles, and Verbal Fluency

There were no gender differences in odor identification or discrimination. Girls only were more likely to correctly identify the floral odors of rose and lilac (both ps < .01) and mushroom ($p < .05$). Boys and girls significantly differed in the temperamental factor of effortful control, Mann-Whitney $U = 1386$, $p = .0001$, as well as all the four of its constituent scales, and four other scales, namely anger, approach, sadness, and smiling and laughter, as shown in Fig. 1. Ratings of agreement with the hypothetical responses portrayed by the vignettes representing parenting styles did not differ depending on whether the child was a boy or a girl. Finally, as for verbal fluency, girls and boys did not produce significantly different words counts per minute.

Discussion

A body of research has suggested that highly neurotic individuals may tend to exhibit greater sensitivity to certain odorants, better odor discrimination, and identification. However, it is not clear whether these links between personality and olfaction can be generalized beyond young adults. If that should be so, they should already be present at younger ages and involve individually specific tendencies towards reactivity and self-regulation which give rise to personality. The aim of the present study was to investigate the effect of the individual temperamental factors on olfactory performance. Namely, we hypothesized that superior olfactory performance would be delivered by children relatively higher on negative affectivity (which broadly maps onto neuroticism) as well as those exhibiting greater self-regulation (effortful control). These predictions have been only partly supported by the present data: there was an effect of effortful control (but not negative affectivity) on odor identification (but not discrimination) scores. Specifically, children who were

deemed by their parents to be more capable of self-regulation scored higher on odor identification.

The present pattern of findings with respect to the influence of self-regulatory processes seems perfectly understandable in children: the construct of effortful control (cognitive control, persistence) substantially overlaps with the construct of behavioral inhibition, also encompassing working memory and the ability to carry out decisions under highly salient emotional situations. It is related to the development of executive attention (for review see Posner and Fan 2008), which is itself linked to olfaction. Namely, olfactory input activates brain regions (midfrontal, orbital frontal, and cingulate cortical areas) that are also involved in executive attention (Li et al. 2010; Plailly et al. 2008). Children perceived by their parents as better able to ignore irrelevant stimuli, withhold prohibited responses, and activate required ones exhibited higher odor identification scores.

Although there was no effect of the individual scales of effortful control on odor identification, it correlated with attentional focusing and inhibitory control. Executive functions (i.e. the capacity to control and coordinate one's thoughts and behavior) are available to young children, but they continue to develop well into adulthood (e.g. De Luca et al. 2003), accompanied by structural changes in both grey and white brain matter (Blakemore and Choudhury 2006). The ongoing development of the frontal lobes has implications for executive functions which rely heavily on this brain region, such as selective attention and response inhibition skills (Blakemore and Choudhury 2006), and also odor memory (Pirogovsky et al. 2006). Odor identification is one of the primary tasks used in the study of odor memory; the other is odor recognition (Schab 1991). Thus, driven by the developmental changes in the brain, concurrent improvements in these executive as well as olfactory functions can be expected, possibly explaining the association reported in the present study. A robust body of evidence suggests an age-related improvement in odor identification scores (e.g. Ferdenzi et al. 2008b; Monnery-Patris et al. 2009; Richman et al. 1995), with exceptions (e.g. Martinec Nováková and Vojtušová Mrzílková 2016; Saxton et al. 2014) possibly being attributable to a lack of statistical power. Likewise, the various capacities subsumed under effortful control begin to increase markedly in the preschool years (e.g. Carlson 2005; Leon-Carrion et al. 2004; Williams et al. 1999). However, in the present study neither effortful control nor odor identification was associated with age, perhaps due to the low variability in age in the present sample. Still, an alternative explanation is simply that some of the behaviors may be more readily accessible to observation and assessment by parents. Indeed, one can relatively easily tell whether a child is able to focus attention or suppress inappropriate behaviors, whereas evaluations of the amount of a child's enjoyment derived from low intensity stimuli or ability to detect them require somewhat more insight.

Presumably, some of these capacities may thus enhance performance on olfactory tests and could be expected to contribute, at least to a certain degree, to girls' olfactory superiority over boys in the younger age categories and especially on tests not adapted to children. Reported to be present from preschool years (Ferdenzi et al. 2008a; Monnery-Patris et al. 2009; Richman et al. 1992), in the younger children, gender differences in olfaction could be at least partly driven by differential self-regulatory capacities of girls and boys, although this was not the case in the present study. Here girls tended to be perceived by their parents as more capable of cognitive control in all of its aspects but did not outperform boys on any of the olfactory tests. Nevertheless, it should be noted that odor identification employed in the present study had been adapted to children, reducing the possible variation in olfactory performance, perhaps including gender differences. Still, if differences in self-regulation between boys and girls were to be an explanatory factor for between-gender variation in olfaction, in the present study, one would expect girls to outperform boys on odor discrimination which had not been adapted to children. However, this was not the case.

Parental reports of girls' greater self-regulatory capacities could be interpreted in two ways, which, however, are not mutually exclusive. It may be that girls, on average, really exhibited greater persistence tendencies than boys. However, the possibility of parents' differential approach to temperamental assessment depending on whether the child was a boy or a girl must also be taken into account. Differential beliefs of parents about the acceptability and desirability of temperamental attributes for girls and boys have been extensively researched. For instance, greater parental acceptance of shyness in girls and of irritability in boys has been reported (for review see Putnam et al. 2002), which might have modulated parental responses in the present study. Parental perceptions of children's temperament also tend to differ depending on the gender of the parent, which nevertheless did not play a major role in the present study since in 87 % of cases the questionnaires had been completed by mothers.

A further alternative explanation to consider involves a phenomenon known as "self-fulfilling prophecy" whereby beliefs and expectations create social reality. Although an individual may have self-imposed expectations of himself or herself, in young children, the more likely scenario is that these expectations are generated from external sources, particularly by parents and teachers. For example, it has been shown that parental and teachers' expectations predict students' achievement and academic competence, partly because of their general accuracy but also due to small self-fulfilling prophecies and biases (for review see Jussim and Harber 2005). Importantly, parental and teachers' beliefs about children's abilities in turn relate to these children's self-perceptions of capacity and competence (e.g. Rubie-Davies

2006; Tiedemann 2000). Other diverse instances include children's self-fulfilling effect on their mothers' hostility (Madon et al. 2004), postoperative pain experience (Logan and Rose 2005), or associations of parental expectations with children's subsequent alcohol (Madon et al. 2006) and marijuana use (Lamb and Crano 2014). Thus, in the present study, children more capable of self-regulation might exhibit superior olfactory performance simply because they were expected to do so by their parents, as reflected by the temperamental assessments. At least as far as academic performance is concerned, expectancy effects seem to be more powerful among girls (e.g. Jussim and Harber 2005). Our results are in line with such findings as separate analyses in girls and boys revealed that the effect of effortful control was only evident in girls' (but not boys') olfactory performance. As parental and teacher's beliefs and expectations predict children's cognitive performance, an interesting research topic would be to examine to what extent they affect children's scores on olfactory tasks relative to their school performance.

As summarized in the introduction, studies in young adults have suggested a link between olfactory performance and neuroticism, or, more specifically, anxiety (e.g. Havlíček et al. 2012; La Buissonniere-Ariza et al. 2013). Leaving now aside the extent to which the present findings obtained for temperament are actually comparable with the previous research on links between olfaction and personality traits, they only provide little support for such a relationship in children. Namely, there was no association of either of the olfactory measures with either the whole factor of negative affectivity or its constituting scales. The present study has not produced any significant results involving negative affectivity, the temperamental trait underlying neuroticism. Hence, our findings failed to lend support to the assumption that neuroticism and olfactory perception are linked, at least to a certain degree, over a wider age span. This link tends to be explained in terms of structural and functional changes to amygdala and hippocampus in anxious persons, which manifest themselves in both olfactory (e.g. Zald and Pardo 2000) and emotional processing (e.g. Phelps and LeDoux 2005). In pediatric literature, there is a fair body of evidence of alteration in the structure and function of the limbic system (particularly amygdala) in conjunction with increased anxiety and poorer emotional regulation in children who have experienced early adversity such as maternal anxiety and stress, particularly in early gestation (Buss et al. 2012), or poor caregiving during the first years of life (Tottenham et al. 2010). These links have been observed even in children with trait anxiety and fearfulness who did not meet criteria for a psychiatric disorder (Qin et al. 2014; Tottenham et al. 2010; van der Plas et al. 2010). Indeed, differences in amygdalar volume between children with high and low anxiety levels did not seem to be driven by the presence of an anxiety disorder (Tottenham et al. 2010).

Given the evidence presented above, one would expect to see differences in olfactory performance in healthy young children with varying levels of temperamental traits underlying neuroticism or, specifically, anxiety. The failure to do so in the present study could possibly be attributed to the use of olfactory or temperamental measures which might not have been sensitive enough. For instance, parental assessments of their children's negative affectivity might not effectively discriminate among children in the present sample. However, studies on comparable samples reported similar amounts of variability in this temperamental factor (e.g. DeThorne et al. 2011; Grist and McCord 2010; Mullineaux et al. 2009) and our olfactory data did not exhibit insufficient variability, either. An alternative explanation involves the possibility of overregulation of anxiety-related tendencies, referred to as repressive style (for review see Weinberger 1990). In short, repressors are identified as individuals who report very low susceptibility to negative affect and marked tendencies towards behaviors that are socially desirable but are improbable of occurrence. Notably, some studies suggest that repressors may be even more stressed than low-anxious individuals despite their claims of lower trait anxiety (e.g. Weinberger et al. 1979). Their outward behaviors are nevertheless such that they may even be rated by other people as showing low levels of anxiety. Whilst it is impossible to tell whether any of the children in the present study exhibited such tendencies, certainly some parents might want to create a favorable impression of their child. However, exploration of individual temperamental scores did not reveal any parental tendencies towards underestimating children's negative affectivity or overestimating effortful control and they were comparable to those obtained by other researchers (DeThorne et al. 2011; Grist and McCord 2010; Mullineaux et al. 2009). Hence, the most likely interpretation of the present pattern of results is that the link between olfactory performance and neuroticism (or the underlying set of temperamental traits) may not yet be present in middle childhood.

In the previous research, personality was linked not only to the olfactory measures themselves but also to variables which affect performance on olfactory tests. For instance, Burton and Henninger (2013) reported that extraversion, which is known to predict odor identification (Larsson et al. 2004, 2005), was correlated with verbal fluency in both men and women. In addition, in men, verbal fluency was also positively associated with agreeableness, whilst in women there was a link with openness to experience and conscientiousness. Links of verbal fluency with temperament were also found in the present study, namely with impulsivity, low intensity pleasure, and smiling and laughter. This finding seems in line with the above-mentioned study, since there are conceptual and empirical links between impulsivity (constituting surgency) and low intensity pleasure (comprising effortful control) on the one hand and extraversion and conscientiousness on the other,

respectively (Rothbart et al. 2000). However, it must be noted that they turned nonsignificant after Bonferroni correction was applied.

Despite some parallels between the present study and those on links between personality and olfaction in adults, they are not directly comparable. The reasons include, besides the obvious fact that the participants here were children, use of parental report, which is, as has been outlined above, subject to various influences that were not controlled for in the present study, except for parenting styles. Also, temperament does not directly translate into personality and vice versa. Besides, in the present study, the individual scales did not correlate with the broad temperamental factors as neatly as reported, for instance, by Ahadi et al. (1993). Half of the scales correlated with surgency or negative affectivity on the one hand and effortful control on the other. A full third of them correlated with surgency and negative affectivity at the same time. Since the factors were computed as recommended by Rothbart et al. (1994), the factors in the present study were not as clearly defined as in the original research.

Conclusions

The present study addressed the research question of whether young children's olfactory performance is affected by temperamental influences. Our assumptions have been only partly supported, as there was an effect of the factor of effortful control (but not negative affectivity) on the total identification (but not discrimination) scores, with children deemed by their parents to be more capable of self-regulation scoring higher on odor identification. Our findings thus indirectly point to the effect of self-regulatory processes on odor identification in young children. Since negative affectivity did not influence olfactory scores, the present study did not corroborate the idea that individuals varying in neuroticism differ in terms of olfactory performance. Given the narrow age range of the children recruited in the present study, further studies with preadolescent and adolescent participants are needed to gain more insight into the nature of these relationships.

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Compliance with Ethical Standards All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). The study was approved by the IRB of the Charles University, Faculty of Science (Approval Number 2015/11). Written informed consent was obtained from the children's parents and oral informed consent was provided by the children in the presence of a teacher employed by the school. The children-parents pairs each received 300 CZK (approximately 11 EUR or 12 USD) in compensation.

Conflict of Interest The authors declare that they have no conflicts of interest.

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Gender differences in influences of temperament on olfactory reactivity and awareness

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Children's olfactory performance is associated with temperament but whether there is a link with olfactory reactivity and awareness is not known. In adults negative affectivity is linked to reactivity to environmental odours but it is not clear whether these associations extend to children. We aimed to investigate the effect of temperamental factors on olfactory reactivity and awareness. In so doing, we controlled for the effect of parenting styles on temperamental assessment and of verbal fluency on children's olfactory reactivity and awareness. We hypothesised that children with a high degree of negative affectivity would show greater olfactory reactivity and awareness. 129 children (62 boys, mean age 6.83 ± 0.40 years) were interviewed about their olfactory reactivity and awareness in everyday life using the established Children's Olfactory Behavior in Everyday Life questionnaire (COBEL). Parents assessed their child's temperament using the 94-item short form of the Children's Behavior Questionnaire. We found that the relationship between negative affectivity and total COBEL scores varied between the genders: there was a positive, medium to large effect in boys and a negative, small one in girls. Future studies could include behavioural observations of temperament and olfactory reactivity and awareness.

A high degree of interindividual variability in olfactory perception has been reported, particularly in olfactory abilities[1] and various olfaction-related metacognitive measures[2]. The latter lend insight into people's interactions with their everyday olfactory environments, which are not directly observable or reproducible in the laboratory. Termed "odour awareness"[2,3] or "olfactory reactivity and awareness"[4,5], this metacognitive aspect of olfactory perception encompasses the degree to which individuals pick up olfactory stimuli in their vicinity, let them affect their attitudes and behaviours, seek pleasant olfactory stimulation and avoid unpleasant, potentially disturbing or offensive odours. Differences in olfactory reactivity and awareness are apparent from a young age[4,6,7].

Variability in the ways in which olfactory environment is experienced has been related to various between- and within-gender differences[3,8–10]. One of the probably relatively less influential factors in general, which nevertheless deserves attention, is personality or temperament. Links have been sought particularly with the personality trait of neuroticism or its subscale, anxiety, for an overview see Martinec Nováková and Vojtušová Mrzílková[11]. The rationale behind such studies is that amygdala and hippocampus, which are involved in both olfactory[12] and emotional processing[13], exhibit structural and functional changes in anxious persons[14], with possible implications for the olfactory domain. The evidence available indeed seems to suggest differences in olfactory performance in people relatively higher on neuroticism and anxiety, see[11] for an overview of adult literature. However, little is known about whether such effects also pertain to the metacognitive aspects of olfaction, namely olfactory reactivity and awareness. Smeets, *et al.*[2] reported that awareness of odours to be avoided was linked to experiencing health effects attributed to environmental odours, which, in turn, was associated with negative affectivity. Negative affectivity appears to influence reactivity to environmental odours and reports of subjectively assessed exposure-related olfactory and respiratory symptoms[15,16]. In line with this is the finding that highly neurotic individuals respond more negatively to environmental odours[17]. Buron *et al.*[18] also reported a link between the Relational Scale of Olfaction (EROL) and anxiety. On the other hand, Seo, *et al.*[19] did not show any associations between neuroticism and attitudes towards olfaction.

Another research gap is the lack of studies in individuals of a wider age range. As can be seen from the overview of literature on links between personality and olfaction[11], participants in most of the studies were young

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	Mean ± SD					
	boys	girls	total	Mann-Whitney U	p	r (d)
Age	6.85 ± 0.42	6.81 ± 0.38	6.83 ± 00.40	1938.50	0.514	−0.06 (−0.12)
Verbal fluency	12.76 ± 4.37	13.90 ± 4.02	13.35 ± 4.21	2427.50	0.097	−0.14 (−0.28)
COBEL total	5.60 ± 2.45	6.75 ± 2.20	6.20 ± 2.39	1485.50	**0.005**	−0.25 (−0.52)
COBEL food component	1.27 ± 0.79	1.47 ± 0.68	1.38 ± 0.74	1798.50	0.181	−0.12 (−0.24)
COBEL social component	1.25 ± 0.97	1.70 ± 0.97	1.48 ± 0.99	1551.00	**0.012**	−0.22 (−0.45)
COBEL environmental component	3.07 ± 1.32	3.58 ± 1.27	3.34 ± 1.32	1624.00	**0.032**	−0.19 (−0.39)
Surgency	4.57 ± 0.93	4.37 ± 0.91	4.46 ± 0.92	1822.50	0.230	−0.11 (−0.22)
Negative affectivity	3.97 ± 0.73	3.88 ± 0.70	3.92 ± 0.72	1850.50	0.286	−0.09 (−0.18)
Effortful control	4.94 ± 0.66	5.42 ± 0.56	5.19 ± 0.65	1188.50	**<0.001**	−0.37 (−0.80)
Parenting style – Authoritarian	54.00 ± 32.11	55.51 ± 27.49	54.78 ± 29.69	2056.00	0.921	−0.01 (−0.02)
Parenting style – Permissive	11.90 ± 14.12	16.78 ± 23.85	14.43 ± 19.86	2044.50	0.877	−0.01 (−0.02)
Parenting style – Authoritative	76.78 ± 29.67	83.37 ± 25.20	80.20 ± 27.53	1815.50	0.196	−0.11 (−0.22)

Table 1. Descriptive statistics for boys, girls, and the total sample, Mann-Whitney U for differences between boys and girls, p value, and effect size *r*, which was converted to Cohen's *d*.

adults, predominantly university students, which raises the question as to whether the links between personality and olfaction exist outside this particular age range and social background. Due to the cumulative, potentially much stronger effects of physiological aging, lifestyle, medical history, and environmental exposure on chemosensory perception, which are likely to obscure the effect of personality and temperament in adults, a somewhat more attractive idea is to turn to children. As in adults, in children such a research topic is justified by the fact that associations between alterations of the limbic system and trait anxiety and fearfulness have been observed in young healthy children[20]. One would expect that if these changes have implications for emotional as well as olfactory processing, differences in olfaction among children with varying levels of anxiety should be seen. They should stem from general, constitutionally based tendencies to react in a certain way, which (unlike personality) can be assessed at a very young age. Such tendencies may be subsumed under the term temperament.

Indeed, in adults, individual differences have generally been conceptualized in terms of personality theory and traits, whilst in young children, temperamental measures have been employed. Since personality is formed gradually through experience as the child gets older, there is little consensus as to whether it is meaningful to measure personality in young children. Related to this, no single model of personality has been established as the most useful one in young children thus far, even though some researchers report that there are correlations between temperament and personality in children[21]. Their findings are, in general, in line with mappings between temperament and personality in adults. In short, the set of temperamental traits underlying neuroticism, referred to as negative affectivity, reflects, in general, threat sensitivity with accompanying negative affect. Behaviourally it is manifested in anxious and fearful reactions, inhibition of ongoing behaviour, increased readiness for action, and heightened attention to environmental stimuli[22]. Although the factor of negative affectivity seems to map fairly well onto the Big Five[23] dimension of neuroticism[24], its expression is substantially modulated by self-regulatory processes subsumed under effortful control. This refers to a self-regulatory system superordinate to it that manifests itself in the ability to voluntarily sustain focus on a task, shift attention from one task to another, initiate action, and inhibit it[25]. The set of temperamental traits underlying extraversion, termed surgency, encompasses sensitivity to signals of reward and active engagement with the surrounding world. It is manifested behaviourally through sociability, impulsivity, sensation seeking, and activity level, and partly also via intensity of affective response, in particular positive affect[22]. Surgency maps quite well onto extraversion, with its expression also being modulated by effortful control[24].

Research in adults has suggested a link between olfactory perception and personality. However, it is not clear whether these relationships extend beyond this particular age group and whether they involve olfactory reactivity and awareness. The aim of the study was to investigate the effect of temperamental factors on olfactory reactivity and awareness in children. In so doing, we controlled for the effect of parenting styles on temperamental assessment by parents and of verbal fluency on children's olfactory reactivity and awareness. To be specific, since neuroticism and negative affectivity (which maps broadly onto neuroticism) appear to heighten olfactory reactivity and awareness in adults, we hypothesized that children deemed to exhibit a high degree of negative affectivity would show greater olfactory reactivity and awareness. Furthermore, since children's olfactory reactivity and awareness have been shown to differ in boys and girls[4], as a subsidiary aim, we tested for gender differences.

Results

Exploratory Correlations. Descriptive statistics are shown in Table 1 and exploratory Spearman's ρ rank correlations are given in Supplementary Table S1. Children's total COBEL scores were not significantly linked to any of the temperamental factors, but the social component of COBEL correlated with effortful control, $\rho = 0.198$, $p = 0.02$, Cohen's $d = 0.46$, and the environmental component was associated with negative affectivity, $\rho = 0.176$, $p = 0.047$, Cohen's $d = 0.40$. The latter was also found in boys, $\rho = 0.264$, $p = 0.038$, Cohen's $d = 0.63$, but not in girls. Children's olfactory reactivity and awareness did not vary with respect to their age or verbal fluency, $\rho = 0.08$, $p = 0.35$, Cohen's $d = 0.12$, and $\rho = 0.15$, $p = 0.10$, Cohen's $d = 0.12$, respectively. Parenting styles were

	Model 1	Model 2	Model 3	Model 4
R^2	0.043	0.084	0.145	0.156
R^2 (adj.)	0.020	0.055	0.096	0.085
f^2	0.04	0.09	0.17	0.18
F	1.875	2.859	2.933	2.185
p	0.137	**0.026**	**0.007**	**0.023**
ΔR^2	0.043	0.041	0.061	0.011
p		**0.020**	**0.039**	0.674
Surgency	0.110	0.104	0.424	0.525
p	0.215	0.257	0.114	0.114
Negative affectivity	0.144	0.141	−0.491	−0.492
p	0.174	0.188	0.100	0.163
Effortful control	0.201	0.118	0.204	0.211
p	0.022	0.233	0.476	0.512
Gender		0.219	0.213	0.217
p		**0.021**	0.025	**0.028**
Gender*Surgency			−0.314	−0.436
p			0.270	0.198
Gender*Negative Affectivity			0.669	0.650
p			**0.034**	0.076
Gender*Effortful Control			−0.059	−0.082
p			0.849	0.798
Surgency*Negative Affectivity				0.093
p				0.358
Surgency*Effortful Control				−0.037
p				0.717
Negative Affectivity*Effortful Control				−0.024
p				0.834

Table 2. Categorical regression (CATREG) models in the total sample regressing the total COBEL scores on the three temperamental factors (Model 1), gender (Model 2), interaction of temperament and gender (Model 3), and interactions among the temperamental factors (Model 4). Gender is coded as 0 = boy and 1 = girl. The predictor-related values represent β*s*. Significant effects to be interpreted are highlighted in bold. The model that seems to provide the best explanation is Model 3.

not significantly associated with any of the three broad temperamental factors (ρ*s* ranging between −0.140 and 0.133, p*s* > 0.1). Therefore, only the effects of temperament, gender, and their interactions on total COBEL scores were modelled in the following analyses.

Influence of Temperament on Children's Olfactory Reactivity and Awareness. As can be seen from Table 2, showing categorical regressions on the total sample, Model 1 containing only the three temperamental factors was not statistically significant. Inclusion of gender and interactions thereof with each of the temperamental factors yielded significant models (Model 2 and 3), with significant R^2 change (ΔR^2) indicating the inclusion significantly improved the prediction. However, this was not the case with Model 4. Therefore, Model 3 was chosen as the most suitable one. It explained 14.5% of variation in olfactory reactivity and awareness in the present sample, with an estimated 9.6% in the population, which is slightly above the recommended minimum effect size for representing a "practically" significant effect for social science data[26]. Most importantly, it showed that although there was no main effect of any of the three temperamental factors, the interaction variable of gender*negative affectivity was a significant predictor of total COBEL scores. That is, the effect of negative affectivity on total COBEL scores varied between the genders, β = 0.669, p = 0.034.

As can be seen from Supplementary Table 1, in boys the link between negative affectivity and olfactory reactivity and awareness was positive, although marginally significant, Spearman's ρ = 0.247, p = 0.053, Cohen's d = 0.62. This represents a medium to large effect and can be interpreted in two ways. According to Cohen[27], an effect size of 0.6 indicates that the mean olfactory reactivity and awareness of boys high on negative affectivity was at about the 73rd percentile of those low on the trait. Alternatively, it suggests that there was about a 38% non-overlap in the distribution of COBEL scores of boys high and low on negative affectivity, respectively. On the other hand, in girls the association was negative and non-significant, ρ = −0.018, p = 0.887, Cohen's d = −0.18, indicating that the mean olfactory reactivity and awareness of girls low on negative affectivity was at about the 58th percentile of those high on the trait. Alternatively, the non-overlap between the distributions of COBEL scores was only about 15% in girls. When the total COBEL scores were then regressed on temperamental measures in boys and girls, respectively (see Table 3), it transpired that in boys, the model explained 10.8% of variation in olfactory reactivity and awareness in boys, with an estimated 6.2% in the population, although it missed significance at p = 0.083. Again, this effect size represents a "practically" significant effect for social science data[26]. However, this was not

	Boys (Model 5)	Girls (Model 6)
R^2	0.108	0.055
R^2 (adj.)	0.062	0.01
f^2	0.12	0.06
$F(df_1,df_2)$	2.339 (3,58)	1.225 (3,63)
p	0.083	0.308
Surgency	0.034	0.225
p	0.821	0.078
Negative Affectivity	0.353	−0.055
p	0.027	0.690
Effortful Control	0.152	0.125
p	0.294	0.298

Table 3. CATREG models in boys (Model 5) and girls (Model 6) regressing the total COBEL scores on the three temperamental factors. Df_1 and df_2 denote regression and residual degrees of freedom, respectively. The predictor-related values represent βs.

the case in girls, as there were only 5.5% of variation in olfactory reactivity and awareness explained by the model, with an estimated 1% in the population ($p = 0.308$). In sum, the effect size of the relationship between negative affectivity and olfactory awareness and reactivity seemed relatively larger in boys than in girls and of "practical" relevance in the former but not in the latter, although, with the present sample size, p-values well below the conventional 0.05 level were not seen.

Between-Gender Variation in Temperament, Verbal Fluency, and Parenting Styles. As can be seen from Table 1, girls and boys did not produce significantly different words counts per minute. Girls were thought to exhibit greater effortful control, but not negative affectivity or surgency. As reported previously[11], they were rated higher on all of the constituent subscales of effortful control. Furthermore, girls were more likely than boys to exhibit sadness, whilst boys showed a greater degree of anger and frustration[11]. Ratings of agreement with the hypothetical responses portrayed by the vignettes representing parenting styles did not differ depending on whether the child was a boy or a girl.

Discussion

The aim of the present study was to investigate the influence of parental assessments of children's temperament on their self-reported olfactory reactivity and awareness, operationalized in terms of COBEL scores. We hypothesised that children deemed by their parents to show a greater degree of negative affectivity would show greater olfactory reactivity and awareness. We found that the effect of negative affectivity on total COBEL scores varied between the genders. Overall, it transpired that the effect size of the relationship between negative affectivity and olfactory awareness and reactivity was relatively larger in boys than in girls and of "practical" relevance in the former but not in the latter, even though, with the present sample size, statistical significance in the conventional terms of $p < 0.05$ was not obtained. As statistical significance largely depends on sample size, e.g. Cumming[28], here we focus on interpretation of the effect sizes found. First of all, the findings in boys are partly in line with the findings reported by Smeets, *et al.*[2], who found a link in adults between awareness of odours (specifically those to be avoided) and experiencing health effects attributed to environmental odours, which was linked to negative affectivity. Dalton also[29] describes the results of several studies[30–32] investigating the effects of negative affectivity on perception of and reaction to ambient exposures to acetone and isopropyl alcohol (IPA; rubbing alcohol). For instance, when exposed to acetone at concentrations well within exposure limits, individuals exhibiting greater negative affectivity reported significantly higher levels of alleged health symptoms such as sensory irritation compared to participants relatively lower on this temperamental/personality characteristic. Also, participants showing greater negative affectivity rated IPA as more unhealthy, hazardous, and annoying (but not more intense or unpleasant) than those with low negative affectivity levels. The former group reported increased health symptoms as well. Another evidence that negative affectivity influences olfactory reactivity comes from Ihrig, *et al.*[16]. The authors found that individuals with high negative affectivity levels reported significantly more alleged olfactory and respiratory symptoms upon exposure to ammonia. Finally, highly neurotic individuals respond more negatively to environmental odours[17]. Altogether these studies suggest that negative affectivity seems to play a role in the way individuals experience their olfactory environment. Our results in boys are, to some extent, in line with those previously reported in adults, including the finding that the effect sizes found in them were relatively modest but still of practical significance. It is difficult to tell what effect sizes to expect based on the previous studies in adults, but, for instance, converting correlation coefficients to R^2 would give an effect size ranging between 0.005 and 0.14 for links between negative affectivity and irritative, respiratory, and olfactory symptoms in Ihrig[16]. If the same is done with Spearman's ρ for the link between boys' negative affectivity and self-reported olfactory reactivity and awareness, an R_s^2 of 0.06 is obtained, which places the effect found in the present study well in the middle of the range reported in adults. Even though direct comparison of R^2 and R_s^2 coefficients is not possible and different designs and methods were used in the studies, clearly the amount of variance shared by olfactory reactivity and awareness on the one hand and temperament on the other only reaches about 15% at maximum.

Secondly, it is difficult to tell what the cause of different effect sizes in boys and girls, respectively, might have been. As seen in adult research not only on negative affectivity, but also anxiety and neuroticism, it is possible that the sought effect indeed is stronger in one gender than in the other, e.g.[33,34], although the causes for this are not known. An alternative explanation might be that in boys, reports of disturbing, unpleasant odours might have primarily contributed to higher COBEL scores, whilst girls might have reported pleasant and unpleasant odours in equal parts or focus on the former. Since individuals with high negative affectivity levels are more likely to report adverse effects of unpleasant odours on their well-being[2,16,30–32], this might have led to the positive effect found in boys, but not in girls. Since use of the COBEL questionnaire does not allow further quantitative analysis of reports of pleasant and unpleasant odours, we have no evidence to support this idea and we present it as a suggestion for further research. On the other hand, ruled out as a potential cause can be characteristics of the present sample, such as gender differences in variation in negative affectivity or in olfactory reactivity and awareness.

Children's olfactory reactivity and awareness showed a gender difference in favour of girls, which is in line with the study by Saxton, *et al.*[4]. However, one of the key issues when interviewing children is that they can interpret the researcher's questions as a search for the "right answer" and thus may say what they believe he or she wants to hear. This is the case particularly in contexts in which the researcher is perceived as a person in authority and the interview is conducted at school[35]. With girls being in general more sensitive to the presence of a researcher[36], their superior performance on the interview might have been a by-product of their greater tendency to "please" the researcher. To counteract such effects, researchers may want to exclude the children's first answers as they may represent a response that the children believe is expected, desirable, or appropriate[37]. However, the research protocol in the present study did not allow for such an approach. Importantly, contrary to what had been proposed in the previous studies[5,7], gender differences in olfactory reactivity and awareness did not seem an expression of variability in verbal fluency in the present study. Girls, who have been reported to outperform boys on measures of verbal fluency[38,39], did not produce significantly more words per minute and, moreover, verbal fluency was not linked to olfactory reactivity and awareness.

Girls and boys were also found to differ on several temperamental traits. As discussed at length earlier[11], such differences may possibly be a result of parents' different approach to assessment of boys' and girls' temperament[40]. Parental assessments of children's temperament may also vary depending on whether the responses are provided by the child's mother or father[40]. This, however, did not play a major role in the present study, with 88% of temperamental assessments having been provided by mothers.

Children's olfactory reactivity and awareness did not vary with respect to their age or verbal fluency, which were correlated, as could be expected[41]. In previous studies, children's olfactory reactivity and awareness were found to increase with age[4,5,7], which was ascribable to the children's progressively better memory and verbal fluency. The absence of such links in the present study could be attributed to the low variability in age. Parenting styles were not significantly associated with any of the three broad temperamental factors in the total sample. As complex interactions tend to be found between parental perceptions of their children's temperament and the parenting style employed[24,42], the possible explanation is that the brief assessment using hypothetical vignettes was not sensitive enough. To the best of our knowledge, at present there are only two previous studies which used this approach to assess parenting styles: the original paper by Barnhart *et al.*[43] and the study by Martinec Nováková and Vojtušová Mrzílková[11], in which no effect on the temperamental measures was found. Thus, there are no data available on the reliability and validity of the tool.

Finally, there are several challenges when investigating links between olfactory metacognition and temperament in children. First and foremost, both undergo developmental changes so that behaviours indicative of a certain temperamental trait or a level of olfactory awareness in younger children may not be equally informative, reliable, or valid in the older ones. In the present study, this has been overcome by employing age-specific instruments to assess temperament and olfactory metacognition[5,44]. In spite of developmental changes, temperament is relatively stable and heterotypically continuous in that there are relations between different sets of behaviour across different ages[45,46] and it predicts personality in young adulthood[47]. Also, assessment of child temperament is largely dependent on other-reports, especially parental or those by teachers, which is the least time-consuming method. However, there is reasonable consistency between assessments based on home and laboratory observations on the one hand and parental reports on the other one[48,49]. There are also significant correlations for most of the scales of self- and parental reports where both of these are available[50]. Therefore, use of other-report measures, such as parental assessment, of child temperament appears an acceptable trade-off between the opportunity to address this research question in the youngest cohorts and precision of measurement. On the other hand, to the best of our knowledge, there are no published instruments for parents or teachers with which to assess children's olfaction-related behaviours. While correlating children's self-reports[5] with parental or teacher's assessments on the one hand reduces the possibility of obtaining significant results merely due to the fact that the questionnaires have been completed by a single person, on the other their responses may be subject to bias mentioned above.

The present study addressed the research question of the effect of temperament on children's olfactory reactivity and awareness. We hypothesised that children deemed by their parents to show a greater degree of negative affectivity would exhibit greater olfactory reactivity and awareness. We found that the effect of negative affectivity on total COBEL scores varied between the genders. The effect size of the relationship between negative affectivity and olfactory awareness and reactivity was relatively larger in boys than in girls and of "practical" relevance in the former but not in the latter. As the effect of negative affectivity on how olfactory environment is experienced seems to be mediated by the perceived characteristics of odours, future studies should investigate whether this temperamental trait affects specifically reactivity to and awareness of potentially disturbing or harmful odours. Even though parental (and teacher) assessments are largely consistent with behavioural observations of temperament, the latter could also be included in future studies. Also, given the narrow age range of children recruited in the present study, more studies with preadolescent and adolescent participants are needed to gain more insight into the nature of these relationships.

Materials and Methods

Participants. The participants were 129 children of Czech origin (62 boys, mean age 6.83 ± 0.40 years, range 6.11–8.25 years) and their parents (113 mothers). The children were first-graders from six public mixed-sex general education elementary schools in Prague and its suburbs. The schools were attended by children from varied social backgrounds. School principals were contacted via telephone and e-mail to inform them about the planned study. Those who had provided permission to perform the study on the school's premises were asked to pass the information on to the teachers. They distributed leaflets to children, who, in turn, handed them over to their parents. As shown in Table 1, girls and boys did not differ in terms of age.

Ethics Statement. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). The study was approved by the IRB of the Faculty of Science, Charles University (Approval Number 2015/11). Written informed consent was obtained from the children's parents, and oral informed consent was provided by the children in the presence of a teacher employed by the school. The children-parents pairs each received 300 CZK (approx. 11 EUR or 12 USD) in compensation.

Questionnaires. *Children's Olfactory Behaviors in Everyday Life Questionnaire (COBEL).* Olfactory reactivity and awareness was assessed by means of an interview based on the COBEL questionnaire[5]. Having been originally developed with 6- to 10-year-olds, it consists of 16 questions designed to evaluate self-reported awareness and reactivity to odours in significant everyday contexts, i.e. food, social, and environmental. Each item was coded on a 3-point scale, rating the child as poorly (0), moderately (0.5), or highly (1) olfaction-oriented in the given situation. Although it was used in a previous study with slightly older Czech children[4], a pilot study (N = 30) described in detail elsewhere[6] revealed that most children were unfamiliar with the rating format of Item 3 ("Senses in nature"), which involved ranking the following activities in order of preference: touching, smelling, watching, listening. Therefore, the item was excluded from the interview. Thus, the total COBEL score, computed as a sum of the 15 items, ranged from 0 to 15. In addition to the total score, component scores for food, social, and environmental odours were computed following previous usage of COBEL[4,5,7], ranging from 0 to 3, 0 to 4, and 0 to 8, respectively.

Short Form of the Children's Behavior Questionnaire (CBQ-SF). Being widely used in developmental research, the Children's Behavior Questionnaire CBQ[51]; affords a highly differentiated caregiver report assessment of temperament in three- to eight-year-olds. Domains covered by the instrument include positive and negative emotion, motivation, activity level, and attention. The short, 94-item form CBQ-SF[44], is comprised of 15 scales of six to eight items each comprising three temperamental factors, i.e. surgency, negative affectivity, and effortful control. Parents rate their child on a seven-point scale ranging from one (extremely untrue of the child) to seven (extremely true of him or her). Temperamental factor scores were computed after Rothbart, *et al.*[52]. The questionnaire was translated to Czech by LMN and a back-translation was produced by Jitka Lindová and Jan Havlíček. The individual CBQ-SF scales and the three broader factors along with their definitions and descriptive statistics are listed in Martinec Nováková and Vojtušová Mrzílková[11].

Parenting Styles. Parenting styles were briefly assessed to control for the influence of parental responsiveness and demands on temperamental attributions. Having been outlined in the seminal work of Baumrind[53], parenting styles refer to the emotional atmosphere created by parents at home[54]. They can be classified into the following three categories: authoritative (responsiveness towards children combined with demands), authoritarian (demanding but not very responsive), and permissive (high in responsiveness and low in demands). They were briefly assessed using hypothetical vignettes after Barnhart, *et al.*[43]. These include descriptions of three hypothetical interpersonal situations between a parent and his or her two children (son and daughter) aged 7 and 11 years, respectively, in which the response of the parent to the situation represents one of the three parenting styles. For instance, in the hypothetical vignette representing the permissive parenting style, the mother believes that children should be free to do what they want, and so when the children want to go outside to play without having done their homework before, she nevertheless lets them go outside for as long as they want. The parents were asked to indicate the degree to which they associated themselves with the hypothetical parent's response to the given situation on a 10 cm visual analogue scale. The rating for each vignette was obtained by measuring the distance in mm between zero and the marked point on the line.

Verbal fluency. In general, interview techniques are highly dependent on the child's verbal skills[55] and verbal fluency has been found to be an important modulator of olfactory reactivity and awareness when using the COBEL[4,5,7]. This is due to the fact that some of its items are open-ended questions requiring spontaneous reports of some activity, e.g. "Imagine your parents present you with a dish you do not know: will you do something before putting it in your mouth? What do you do?", while others rely on the child's naming ability, e.g. "Do you remember odours you smelled yesterday? Which ones?", which is virtually analogous to measures of verbal fluency. It was tested using a Czech version of the category verbal fluency test adapted to children[56]. First, variability of responses to the three categories (animals, fruits, and things that can be bought in a supermarket) had been explored in a pilot study described in full detail elsewhere[6]. Most variable results were obtained for animals, which were chosen as the test category. During the testing session itself, a training trial was conducted using the transport category, on which a child was asked to name as many means of transport as possible. Understanding was assured by asking the child what transport meant and by giving an example (e.g. a car). Next, the child was

encouraged to name as many animals as possible in 60 seconds, while the answers were being immediately written down by the researcher.

Procedure. The children participated in individual sessions, which were always scheduled after school dinners at a time between 12:30 p.m. and 3 p.m. (i.e. a time when most children attend after-school care centre on the school premises). Parents completed the CBQ-SF and provided ratings of the hypothetical vignettes at home via a web-based survey tool, Qualtrics (Qualtrics, Provo, UT). They were never present in the room during the session.

Statistical Analysis. All analyses were carried out with IBM SPSS 22.0. Non-parametric analyses were preferred since some of the data (COBEL scores, parenting styles) were not normal. Gender differences were analysed using the Mann-Whitney U test and associations were tested with Spearman's ρ rank correlations. Effect sizes for the Mann-Whitney U test were computed after Rosenthal[57] as follows: $r = \frac{z}{\sqrt{N}}$ and then converted to Cohen's d after Rosenthal[58]. Spearman's ρ rank correlations were converted to Cohen's d after Walker[59]. To test both the main effects of the temperamental variables and gender and their interactions, categorical regressions (CATREG) were run. Thanks to its optimal scaling option, this type of analysis allows exploration of the data in any way that makes sense and makes interpretation easier, regardless of their level of measurement[60]. Since the minimum scores achievable for each of the temperamental variables were greater than 0, for the purposes of meaningful interpretation of the CATREG including the intercept, the continuous variables of surgency (SY), negative affect (NA), and effortful control (EC) were centered first. This was done by subtracting the given variable's mean from the individual values. Then, interaction variables were created by multiplying the centered temperamental variables with one another or with the dummy variable of gender. Next, a CATREG was run using the SPSS Optimal Scaling option. The assumptions of the test were met since the number of valid cases exceeded the number of predictor variables plus one. Scale variables were treated as numeric and were discretized by multiplying, nominal variables were treated as such. A random initial configuration was selected, as recommended when at least one variable is treated as nominal[61]. Perfect multicollinearity (intercorrelations >0.9) did not appear a serious problem, which was further supported by reviewing the variance inflation factors (VIF), which were nowhere near the value of 10, and the average VIF was not greater than 1, as recommended e.g. by Field[62]. The models tested were as follows: in Model 1, the total COBEL score was regressed on SY, NA, and EC; in Model 2, gender was included; in Model 3, interaction variables of SY*gender, NA*gender, and EC*gender were included, and, finally, in Model 4, interaction variables of SY*NA, SY*EC, and NA*EC were added. As for Model 4, even though both SY and NA correlated with EC (−0.5 and −0.4, respectively), as can be seen from Supplementary Table 1, multicollinearity did not seem an issue. An additional analysis to which ridge regression was applied yielded very similar results. As Model 3, which seemed to provide the best explanation of the relationship between temperament, gender, and olfactory awareness and reactivity, showed that the effect of negative affectivity on total COBEL scores varied between genders, it was followed with two other models in boys and girls, respectively. Specifically, in Models 5 (for boys) and 6 (for girls), the total COBEL score was regressed on SY, NA, and EC. The settings was the same as for the models run on the total sample, with the only exception that a numerical initial configuration was selected, as recommended when all variables are treated as numeric. Significance of R^2 change across the models (ΔR^2) was computed after Field[62]. Although R^2 and adjusted R^2 themselves represent measures of effect size, as do betas, for convenience, R^2s were converted to Cohen's f^2 after Cohen[27].

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Author Contributions
Conceived and designed the study: L.M.N. and R.V.M. Performed the study: L.M.N. and R.V.M. Analyzed the data: L.M.N., R.V.M., and A.K. Wrote the paper: L.M.N., R.V.M., and A.K.

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