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Sex differences in olfactory behaviour in Namibian and Czech children

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Abstract

Sex differences in olfaction are well established, but explanations for those sex differences remain incomplete. One contributing factor could be individual- or cultural-level differences in exposure to odors. We tested whether frequent engagement with common sources of domestic odors (cooking, domestic animals, siblings) was linked to individual differences in olfactory reactivity and awareness among children in southern Namibia, and also compared study populations in southern Namibia and the Czech Republic using the established COBEL (Children's Olfactory Behaviour in Everyday Life) questionnaire. We did not find any effects of engagement with odor sources on olfactory behavior, but our results were consistent with usual olfactory sex differences in that girls scored higher than boys in measures of olfactory reactivity and awareness. Further, among the Czech children (but not among the Namibian children), odor identification abilities were positively linked to COBEL scores. Our data contribute to the literature that finds that sex differences in olfactory awareness are apparent across a diverse range of cultures and age groups.

1. Introduction

Sex differences in olfaction are well established, but explanations for those sex differences remain incomplete. On average, women outperform men in odor identification, discrimination, memory, and awareness (e.g. Doty et al. 1985; Havlicek et al. 2008; Herz and Inzlicht 2002; Lehrner 1993; Platek et al. 2001; Velle 1987), and sex differences may be apparent even from very early infancy (Makin and Porter 1989, Balogh and Porter 1986). Brand and Millot (2001) review factors that may contribute to these sex differences, including hormonal (e.g. Doty 1986, Doty and Cameron 2009, Velle 1987), physiological (Hornung et al. 1999), and cognitive (e.g. Öberg et al. 2002).

A factor of a different type that might contribute to sex differences in odor abilities could be greater female than male exposure to, and trained awareness of, different odorants (Brand and Millot 2001). It has been suggested that women may, in general, encounter olfactory cues more often (Brand and Millot 2001), and girls from an early age may be implicitly or explicitly encouraged to pay more attention to environmental and personal odors (Mallet and Schaal 1998; Wysocki et al. 1991). Differences in odorant exposure can lead to measurable differences in olfactory function or awareness. For example, laboratory exposure to odorants or purposeful olfactory training can alter olfactory function (Boulkroune et al. 2007; Dalton et al. 2002; Wysocki et al. 1989). Outside the laboratory, cultural differences in reactions to odors may arise from the prevalence of that odor within that cultural context (Ferdenzi et al. 2008b; Ferdenzi et al. 2011). Researchers have noted cultural differences in reactions to food odors (Distel et al. 1999; Hudson, 1999; Pangborn et al. 1988; Schleidt et al. 1988), in assessment of odors as pleasant or unpleasant (e.g. Ayabe-Kanamura et al. 1998; Distel et al. 1999; Pangborn et al. 1988; Schleidt et al. 1981), and in differential categorization of odors (Chrea et al. 2004). Seo et al. (2011) report several cross-regional differences in attitudes towards odors; for example, odor is more important in relation to emotions and memories, and is used more in day-to-day life, by Mexican respondents compared with Korean, Czech and German respondents. Similarly, Finnish children report more reactivity and attention to odors than French children (Ferdenzi et al. 2008b). Further, people who report greater exposure to olfactory activities (such as cooking) in childhood and adulthood score higher on a questionnaire about their tendency to react to odors in everyday life (Nováková et al., 2014). Finally, twin studies have shown that environmental effects account for a substantial proportion of the variation in people's perceptions of the intensity and pleasantness of some odors (e.g. Finkel, Pedersen and Larsson 2000; Knaapila et al. 2007; Knaapila et al. 2008a; Knaapila et al. 2008b). That is, differences in olfactory reactivity may be acquired partly from cultural and social norms and exposure.

Needless to say, endogenous and exogenous factors do not act separately, but interact to give rise to individual differences in olfaction. Nevertheless, we wanted to focus on this question of exogenous factors in individual differences in odor orientation, by examining two questions. Firstly, we examined whether sex differences in olfaction are apparent in a culture and age group that is distinct from more frequently-studied groups; olfaction is very little studied in non-industrialized countries. Secondly, we examined whether individual differences in odor-related activities are associated with individual differences in odor orientation in children.

To test sex differences and the effect of odor-related activities, we examined olfactory awareness and recognition in children in southern Namibia, using odor identification tests and the COBEL (Children's Olfactory Behaviour in Everyday Life) questionnaire (Ferdenzi et al. 2008a). In order to learn about a child's olfactory environment, we collected data on exposure to pets and other animals, engagement in cooking activities, and number of siblings, because these may represent regular exposure to potential sources of odors in the environment; adult reports of odors that are likely to stimulate nostalgic feelings tend to focus around foods and cooking, family member odors (e.g. perfume, hair spray), and odors linked to nature and animals (e.g. manure, hay) (Hirsch, 2006), and exposure to some of these types of odors has been linked to odor awareness (Nováková et al. 2014). A subsidiary aim of our study was to evaluate the ease and practicality of the usage of the COBEL outside of the

European cultures where it has been previously used (Ferdenzi et al. 2008a, 2008b). We were also able to make use of COBEL scores and olfactory identification scores that had been collected from children in the Czech Republic, in order to contrast olfactory behavior in two different cultures.

2. Materials and Methods

2.1 Participants

We recruited 119 participants. Data from 13 of those were excluded because we did not have enough data to use their responses in any of the analyses below (due in particular to problems in COBEL question comprehension). The final sample of 96 Namibian participants whose data are used below comprised 46 boys aged 10-15 (mean +/-SD = 12.4 +/-1.4 years) and 50 girls aged 9-15 (mean +/-SD = 11.9 +/-1.5 years) who reported speaking Afrikaans (*n* = 49), Nama (*n* = 27), Oshiwambo (*n* = 13), and other languages (*n* = 7) at home. Sample size varies in the analyses below because we did not have a complete data set for each child, due to issues including problems in question comprehension, lack of access to an indoor bathroom (required to answer one of the questionnaire items), and participation during a preliminary stage of the study before the odour identification tests were incorporated.

The participants were recruited from schools in a suburban site (township) in the Karas region in a southern Namibian town with a population of around 19,000. The site is characterized by a semi-arid environment, based on goat and cattle farming, with restricted plant cultivation. The land is mainly owned by large farms, and the majority of participants come from landless and relatively low socio-economic conditions. The community is prevailingly Christian of various denominations, with a relatively strong western-like influence of South African media and lifestyle.

The Czech sample consisted of 92 children (36 boys aged 8-11 years, mean +/-SD = 9.4 +/-0.8 years; and 56 girls aged 8-11 years, mean +/-SD = 9.2 +/-0.7 years) from the third and fourth grades of two mixed-sex general education elementary schools in Prague.

2.2 Measures

2.2.1 COBEL questionnaire

The COBEL questionnaire has been published previously in full (Ferdenzi et al. 2008a; http://dx.doi.org/10.1177/0165025408093661). It is presented as an interview, and consists of 16 questions designed to understand the importance of odor in children's everyday life. The questions fall into three categories: Food (e.g. whether a child tries to guess what is for dinner from cooking smells), Social (e.g. whether a childs realizes that people have a natural odor), and Environmental (e.g. whether a child seek out smells when feeling sad). For the Namibian participants, questionnaire acceptability was checked with local contacts. For the Czech participants, the English and French versions of the COBEL questionnaire were translated into Czech, and then independently back into the source languages, to reveal any discrepancies.

The COBEL questionnaire required adjustment for use in Namibia. Item 9 of the questionnaire asks about the odor of the child's parents' car, and was excluded because most of the Namibian participants' parents would not have had a car; we initially tried asking about the odor of the local supermarket, and a friend's house, as potential replacements, but found that these locations were not visited by all of our participants. Item 11, which asked whether the family members were thought to have a smell, and Item 7, which asked participants to imagine there were no smells outside any more and report how they would feel, were discarded due to frequent comprehension difficulties in the interviews with Namibian children. Responses to Items 7, 9 and 11 were also deleted from the Czech dataset to allow comparison. Following the deletions, the Social component of the COBEL questionnaire was made from three rather than four items, the Environmental component from seven instead of nine items, and the Food component maintained three items. Due to interviewer error, five Namibian participants for whom we had complete COBEL scores were asked to name things in their bathroom that had a smell, rather than to name things in their bathroom and subsequently to identify which did and did not have a smell (Item 10). These children were given a score of 1 if they named three or more items; 0.5 if they named two items; and 0 if they named one or no items. In Namibia, Items 6 and 8, which both contribute to the Environmental component, were also problematic. Item 6, which asks whether there are things that are liked just because they smell good, seemed often to be interpreted as though it were asking for items that people liked the smell of. Item 8, which asks whether the participant smells his or her school things (i.e. personal possessions), was often answered in relation to things within the school grounds that have an odor. These items were retained to avoid diverting too much from the original questionnaire, but they do suggest that any country-level differences in Environmental scores must be treated with caution.

Descriptive statistics of the three COBEL questionnaire components from the participants for whom we had complete questionnaire data (n=82 Namibian and 92 Czech participants; see 2.5 Participants) are listed in Table 1. The COBEL scores of our participants were broadly in line with those reported for French and Finnish children (Ferdenzi et al. 2008a; 2008b and Figure 1 therein; maximum scores in the current study are three points lower than in the previous studies because we removed Items 7, 9 and 11 from the questionnaire).

Table 1: Range, mean and standard deviation of COBEL scores, calculated from the data of participants for whom we had complete COBEL questionnaire answers (see section 2.5)

	Namibian participants (*n* = 82)			Czech participants (*n* = 92)		
	Food component (3 items)	Social component (3 items)	Environmental component (7 items)	Food component (3 items)	Social component (3 items)	Environmental component (7 items)
Range	0 – 2.5	0 - 3	1 – 6.5	0 - 3	0 – 2.5	0.5 – 5.5
Mean	1.2	1.4	3.9	1.1	1.0	2.4
Standard deviation	0.5	0.7	1.2	0.6	0.6	0.9

2.2.2 Olfactory identification tests

Use of a common test such as the Sniffin' Sticks (see below), which uses odors such as rose, is inappropriate in a culture that does not commonly encounter such odors. Accordingly, for our Namibian participants, we constructed our own test to identify relative strengths and weaknesses in olfactory identification, following discussion with local people, based on locally common odors, and covering a range of different odor types (i.e. fruits, spices, drinks, household products). The tests made use of 12 odorous substances: bottled lemon, orange and peppermint essence, garlic salts, powdered ginger, a crushed cigarette, coffee grounds, beer soaked into a cotton wad, oil/petrol odor sampled onto tissue paper, and a couple of tablespoons of three locally well-known household products (a standard branded washing powder, fabric softener, and cleaning liquid, which are widely and commonly used in the local community). Odor sources were concealed in plastic cups of approximately 0.25 l volume with a perforated aluminum foil cap to allow sniffing. Visual cues to the odorous substances were concealed as necessary (e.g. covering the crushed cigarette with tissue paper). For each odor, the Namibian participants were shown four labeled pictures (one target plus three distractors), and asked which one matched the odor. When it transpired after 11 participants that scores were likely to be at ceiling (range:9 – 12; mean +/-SD = 11.0 +/-1.3), we extended the test to precede it by a free identification test of those same odors, where one point was awarded each time an item was correctly identified (score range: 1 – 10; mean +/-SD = 4.8 +/-2.1). Near-misses (e.g. ‘lemon’ for ‘orange’) were not accepted. A child was only given the four-alternative forced-choice odor test for an odor if s/he did not identify that odor correctly in the free identification test.

All but one of the Czech children participated in a Sniffin´ Sticks odor identification test, where odor-dispensing devices shaped like pens were used to test nasal chemosensory performance. This is a well-established test that has been used by researchers in a number of previous studies on children (e.g. Dudova et al. 2011; Ferdenzi et al. 2008b; Renner et al. 2009), as well as by many clinicians across Europe (e.g. Hummel et al. 1997; Kobal et al. 1996). The test consists of 16 odors widely known within European cultural settings (e.g. orange, rose, garlic, fish); participants are asked to select the name of the target odor from a list of four. Scores ranged from 5-13 (mean +/-SD = 9.2 +/-1.9).

2.2.3 Olfactory environment

Based on pilot interviews with local people, we noted salient aspects of the olfactory environment by asking the Namibian participants how many siblings they had and how many animals their family owned (recorded as continuous numeric variables), and how frequently they helped to cook at home. Cooking frequency was binned into two categories: never (child replied “no” or “never”; n = 17), and sometimes or often (child said “sometimes”, “often”, or indicated a specific cooking frequency, such as twice a week; n = 35). Two children indicated that their family owned several farm animals, and so they were not included in the analysis of animal data.

2.3 Procedure

The study of Namibian children was approved by the Philosophy, Psychology and Language Sciences Ethics Committee of the University of Edinburgh (the affiliation of the first author at the time the study was designed). The study of Czech children was approved by the IRB of the Faculty of Sciences of Charles University. For the Namibian participants, research permission was granted by local school principals and teachers, and letters explaining the study were provided to schools for transmission to parents. Teachers arranged for pupils to attend the interviews during school time. Data were collected anonymously during structured interviews with assenting children. Interviews followed the COBEL questionnaire (Ferdenzi et al. 2008a), and also collected basic demographic details such as number of siblings, and language spoken at home. We asked for information on language spoken at home instead of (and as) an indication of ethnicity, which is considered a sensitive issue. RJ carried out interviews in English (the official language of Namibia), Afrikaans, and Nama, and TS carried out interviews in English, but we were not able to interview every child in the language that he or she spoke at home. However, the official language of Namibia is English, and Afrikaans is commonly used (e.g. in education), and so the participants would have had frequent contact with those languages, even if they were not their native language. Questions about the olfactory environment were included, and an odor identification test given (details below). The order of the procedure for most children was to provide demographic data, and then answer the COBEL questions, and then answer questions about the olfactory environment, and then carry out the odour identification test.

For the Czech participants, informed consent was obtained from the participants' parents. The data were collected in the form of structured interviews performed by AŠ and DK in Czech following the COBEL questionnaire (Ferdenzi et al. 2008a). Odor identification data from the Czech participants are also used in (Nováková et al., submitted). Children answered the COBEL questions first, and then proceded to the odour identification test.

2.4 Analysis

Following previous usage of the COBEL (Ferdenzi et al. 2008a; 2008b), we calculated scores for the three components of the questionnaire (Social, Environmental and Food), and summed these together to create a total COBEL score. All of the data arrays that are used in the analysis below are non-normally distributed (Shapiro-Wilk test, $p < .03$), but ANCOVA was used because it is fairly robust to non-normal distribution (Olejnik & Algina 1985). Greenhouse-Geisser correction was used in repeated-measures analyses when data appeared to violate assumptions of sphericity (i.e. Mauchley's test of sphericity $p < .05$). Reliability analysis was carried out in Statistica 11; all other analysis was carried out in SPSS 21. Effect sizes (r) are reported for significant findings.

3. Results and Discussion

3.1 Olfactory awareness in everyday life

Alpha coefficients were calculated on the basis of the inter-item gamma correlation matrix (following Ferdenzi et al. 2008a). The alpha coefficients and gamma correlations are summarised in Table 2. The Cronbach's alpha for the Food component for Namibian participants is a negative value. This is particularly driven by Item 1 (proportion of hated food items that are described with reference to an unpleasant taste or odor): Item 1 is correlated negatively with Item 16 (-0.20) and at <.01 with Item 3, whereas Items 3 and 16 are correlated at .13, and the alpha value becomes .23 if Item 1 is removed.

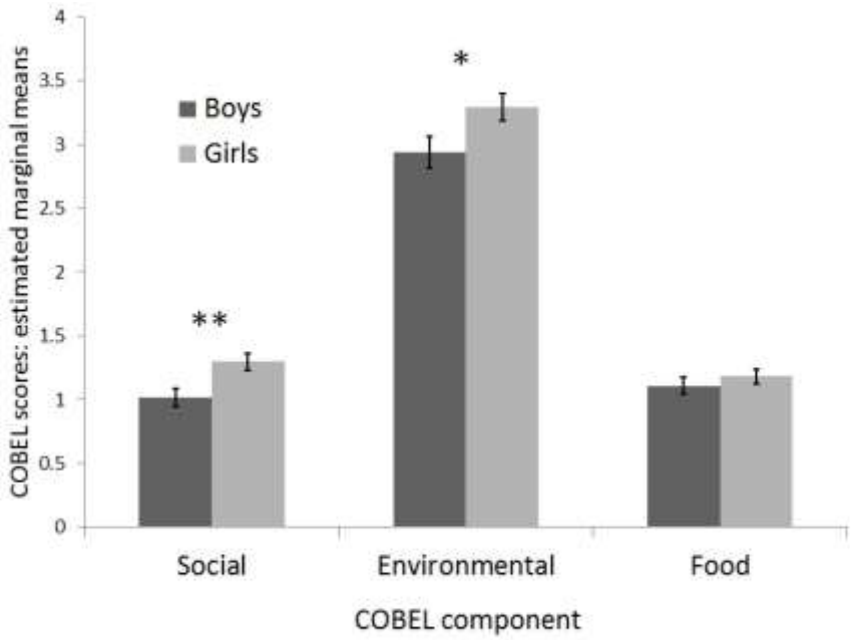
Table 2: Cronbach's alpha and inter-item gamma correlations for the COBEL scores and the COBEL components

		Ferdenzi et al. (2008a)	All participants (*n* = 174)	Namibian participants (*n* = 82)	Czech participants (*n* = 92)
Cronbach's alpha	Overall COBEL	0.78	0.74	0.66	0.74
	Food component	Not reported separately	.20	-.11	.63
	Environmental component		.65	.60	.44
	Social component		.51	.58	.54
Inter-item gamma correlation range (mean)	Overall COBEL	-.22 to .66 (.19)	-.19 to .71 (.19)	-.39 to .54 (.13)	-.37 to .85 (.21)
	Food component	Not reported separately	-.01 to .14 (.08)	-.20 to .13 (-.02)	.23 to .56 (.36)
	Environmental component		-.05 to .71 (.22)	-.16 to .54 (.17)	-.37 to .62 (.13)
	Social component		.13 to .41 (.27)	.26 to .35 (.32)	.12 to .43(.29)

We carried out a repeated-measures ANCOVA using the scores on the Social, Environmental and Food components of the COBEL as within-subjects factors, and including the between-subjects factors of sex and country of residence, and the covariate of age (n = 174). Age was included as a covariate because it had been shown previously to be associated with COBEL scores (Ferdenzi et al. 2008a; 2008b).

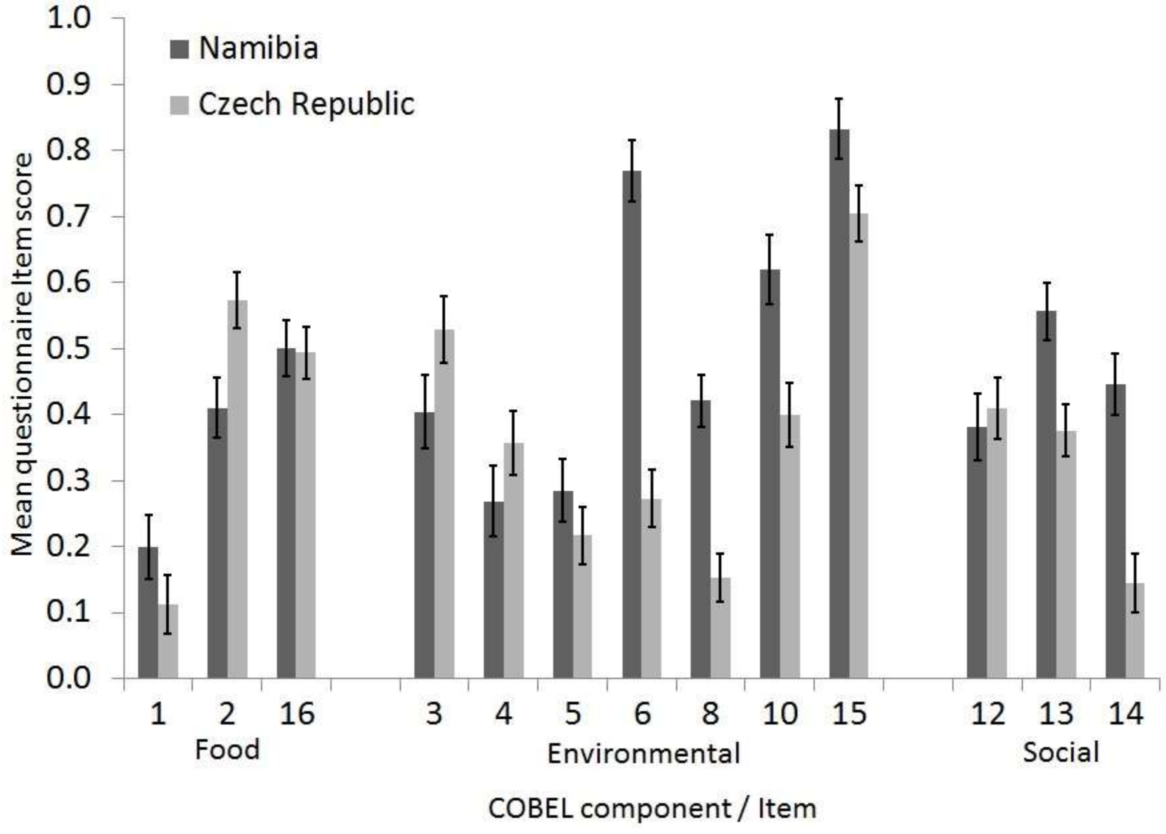
Girls scored significantly higher than boys (F(1,169)= 7.95, p=.005, r = .21). This replicates findings from Finnish and French children (Ferdenzi et al. 2008a; 2008b), and is consistent with the general finding that the olfactory domain is more significant to females than males. There was no significant interaction between participant sex and COBEL component, but because our main hypothesis concerned sex differences, for completeness, we also examined sex differences for each COBEL component in three separate ANCOVAs (including the between-subjects factor of country of residence, and the covariate of age). Girls scored higher than boys in relation to the Social (F(1,169)= 7.93, p=.005, r = .21) and Environmental (F(1,169)= 4.58, p=.034, r=0.16) components of the COBEL, but not in relation to the Food component (F(1,169)= .754, p=.387) (Figure 1).

Figure 1: Boys' and girls' estimated marginal mean scores (controlling for participant age and country of residence) on the three components making up the COBEL (bars = mean +/- SE). * *p*<.05; ** *p*<.01



The Namibian children, controlling for sex and age, scored significantly higher on the COBEL than the Czech children ($F(1,169)=11.88$, $p=.001$, $r=.26$), and this effect was moderated by a significant interaction between the scores on the three components, and the participant's country of origin ($F(1.7,294.6)=9.41$, $p<.001$). In order to understand this interaction, the scores from the Namibian and Czech children were compared for each of the three COBEL components separately, controlling for sex and age. Namibians scored significantly higher than Czechs in relation to the Environmental ($F(1,169)=14.18$, $p<.001$, $r=.28$) and Social components ($F(1,169)=8.49$, $p=.004$, $r=.22$), but not the Food component ($F(1,169)=.269$, $p=.605$). This is consistent with previous research showing that children from different cultural backgrounds respond differently to the COBEL (Ferdenzi et al. 2008b). Figure 2 gives scores on an item-by-item basis in order to illustrate the extent to which the country-level differences are generalizable across the questionnaire Items. The differences in the Social scores are driven by item 13, which asked participants to report the frequency with which they would smell their own clothes, and item 14, which asked participants to report the frequency with which they would smell their own body. Both items included a non-scored follow-up question that asked why participants did this. Namibian participants frequently reported that they would smell their clothes or body because they liked the smell (for example, of the washing powder or body cream used), or in order to check for unpleasant odors and avoid causing offence. There were fairly frequent mentions of needing to check for unpleasant self-odors after playing, particularly in hot weather. In contrast, the Czech children's answers referred to smelling their clothes, but only referred to smelling their body infrequently; body smells, when mentioned, tended to be linked to cosmetic products (e.g. hands or hair after washing). It might be that taboos surrounding personal odors, and talking about them, vary between the two cultures studied. Possible frequent misinterpretation by Namibian participants of Items 6 and 8 (see Section 2.2) likely artificially elevated Namibian scores on the Environmental component. However, of the other Environmental items, Namibians also scored substantially higher than Czechs on Item 10 (which examines the proportion of bathroom objects that participants perceive as having an odor) and Item 15 (emotional reactions to the smell of tobacco smoke), whereas Czechs scored higher on Item 3 (which asks the participant to evaluate the relative importance of their sense of smell, relative to their other senses, when walking in nature). Again, cultural values may direct children's attention differently to environmental odors.

Figure 2: Namibian and Czech estimated marginal mean scores (controlling for participant sex and age) showing pattern of country-level differences across each questionnaire Item of the COBEL (bars = mean +/- SE). Items 7, 9 and 11 were not included (see Section 2.2). The complete questionnaire Item text is available in (Ferdenzi et al. 2008a, 2008b). Abbreviated item text (from Ferdenzi et al. 2008b) Item 1: Odor in food dislikes. Item 2: Response to unknown food. Item 3: Senses in nature. Item 4: Yesterday odors. Item 5: Odors sought when sad. Item 6: Treasured odorous objects. Item 8: Smelling school tools. Item 10: Odor of bathroom objects. Item 12: People's natural odor. Item 13: Smelling clothes. Item 14: Smelling self-odor. Item 15: Tobacco smell. Item 16: Guessing food odor.



COBEL scores increased with age (F(1,169)= 5.51, p=.020), but this was modified by a significant interaction between age and the COBEL components (F(1.7,294.6)= 5.60, p=.006). Scores increased significantly with age in the Environmental (F(1,169)= 7.71, p=.006) and Food (F(1,169)= 4.75, p=.031) components, but not the Social component (F(1,169)= .304, p=.582). Previous research on the COBEL also found age-linked increases in scores in children aged 6 – 10 and 7 – 11 (Ferdenzi et al. 2008a, 2008b), which were attributed to a combination of general cognitive maturation (including memory, verbal ability skills, and the ability to interpret and report on the environment), together with increasing odor exposure. Scrutiny of the correlations between score and age for each questionnaire item suggested that this pattern of results arises because there are significant positive correlations between item score and age for two of the three Food items, and five of the seven Environmental items, whereas the Social item scores constitute two significant positive relationships with age and one significant negative relationship with age (Item 12). Item 12 asks about participants' awareness of people's natural odor; if the negative correlation between scores and age is robust, it might reflect the increasing personal space that develops with age (Aiello & Aiello, 1974) and that could lead to decreasing opportunities to be physically close enough to others to detect their natural odors. Alternatively, it could be a consequence of a possible reluctance to discuss personal body odors that could develop with age. Note, though, that Finnish and French children aged 9 – 11 scored higher on Item 12 than Finnish and French children aged 7 – 8 (Ferdenzi et al. 2008b), and so our conflicting finding merits replication.

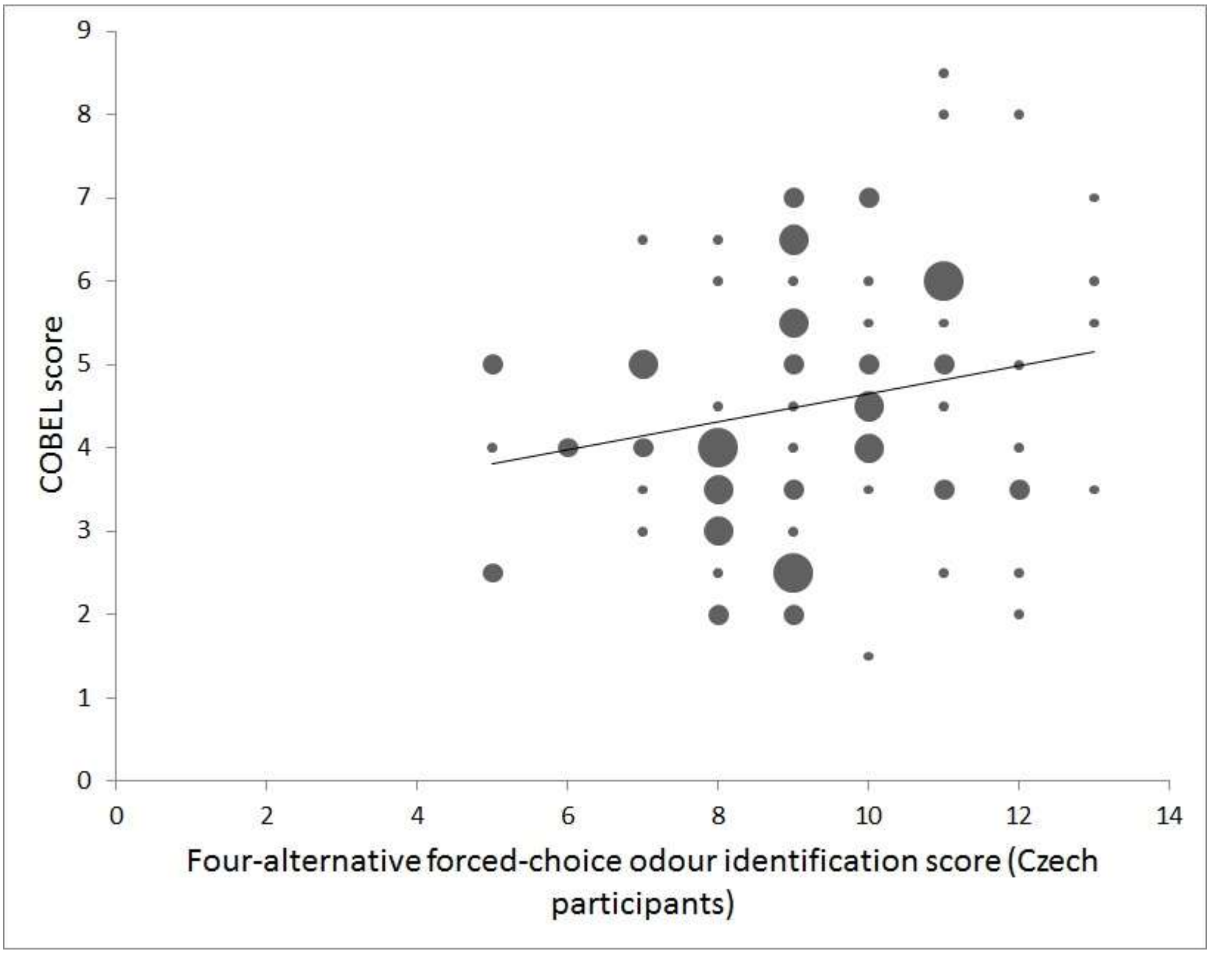
3.2 Odor identification

We examined possible sex and age differences in odor identification by carrying out ANCOVAs on the odor identification test scores with sex as a between-subjects factor, and age as a covariate. Direct comparison of Czech and Namibian children on the olfactory tests was not possible as the tests were constructed to fit each culture. Girls' and boys' scores did not differ significantly in relation to the Namibian four-alternative forced choice odor test (F(1,74)=1.74, *p*=.191, n=77), the Namibian free identification odor test ($F(1,63)=.299$, $p=.586$, n=66), or the Czech four-alternative forced choice odor test ($F(1,88)=.294$, p=.589, n=91). There were no significant effects of age (all $p>.12$). Among French and Finnish children in very similar age groups in a similarly sized sample (n=91) using the 'Sniffin' Sticks' odor presentation devices that were used here for the Czech children (Ferdenzi et al. 2008b), girls performed better than boys, and older children performed better than younger children. This apparent contrast may simply be due to a lack of statistical power; in particular, among the Czech children, mean scores increased with age and were numerically very similar to those of the French and Finnish children by age group (Czech mean scores +/- SD = 8.3 +/- 1.6, 9.2 +/- 2.1 and 9.6 +/- 1.9 for the 8-, 9- and 10-year olds respectively; 11-year-olds omitted due to an *n* of 3).

3.3 Link between olfactory awareness and odor identification

Next, we looked for possible correlations between odor identification scores and COBEL scores. Among the Namibian participants, there were no significant relationships between overall COBEL scores and either free identification odor scores ($r = .044$, $p=.757$, n=52) or four-alternative forced-choice odor identification scores ($r = .030$, $p=.818$, n = 63; but note low variability in the odor identification scores, where the children in this analysis scored between 9 and 12 points). Among the Czech participants, higher overall COBEL scores were associated with higher four-alternative forced-choice scores ($r = .233$, $p=.026$, n=91; Figure 3). Results were identical in patterns of statistical significance when non-parametric correlations were used, or when partial correlations controlling for age were used. A similar link was predicted (but not found) in a comparison of odor identification abilities of the highest and lowest quartile of COBEL scores in a smaller sample of French and Finnish children by Ferdenzi et al. (2008b), but other researchers have also found positive relationships between olfactory sensitivity and self-reported attitudes towards olfaction (Seo et al. 2011). Longitudinal studies would help us understand the direction of any possible causal relationship between olfactory identification and olfactory orientation.

Figure 3: Bubble plot to represent overall COBEL scores and four-alternative odor identification scores among the Czech participants. Size of bubbles represents frequency of response combinations (frequencies vary from 1 – 4)



3.4 Link between olfactory environment and odor identification/awareness (Namibian sample)

To test for possible relationships between the Namibian participants' regular odor-oriented activities and their olfactory scores, we ran an ANCOVA (n = 52) that included the covariates of number of siblings, number of animals, and age, and the factor of participant sex and cooking frequency. Girls and boys did not differ significantly on any of these factors or covariates (all interactions with sex *p* >.14, in full and custom models). The overall COBEL scores did not differ according to number of siblings (F(1,45)= .212, p=.647), number of animals in the family household (F(1,45)= 1.661, p=.204), or cooking frequency (F(1,45)= 2.422, p=.127). Similarly, free identification odor scores did not differ significantly according to cooking frequency, or number of siblings or animals (all $p>.6$; ANCOVA as previously, with free identification odor scores instead of overall COBEL scores as dependent variable; $n = 64$). It may be that more sensitive measures of individual differences in odor exposure are required. For example, a simple measure of number of siblings and animals may not well capture variability in exposure to odors, if there is a lot of variability within siblings and animals in terms of their quality as an odor source (such as variability in the extent to which siblings make use of scented cosmetics, or the type of animal and the proximity of its housing location to the home, or the frequency of interactions with the animal). Further, some siblings might not live together with the participant, or their interactions might be restricted. It is relatively common in Namibia (partly as a result of parents travelling for work opportunities, and partly as a consequence of the HIV/AIDS pandemic) for siblings to be raised in different households (e.g. by grandparents or aunts). However, given the evidence for significant environmental effects on odor reactivity (see Introduction), future research could pursue this, perhaps by testing whether training in olfactory awareness or odor identification corresponds to subsequent greater levels of olfactory reactivity. In adults, self-reported engagement in childhood and adulthood olfaction-related activities, such as use of herbs and spices in cooking, has been linked to adulthood odor identification and odor awareness (Nováková et al., 2014).

3.5 Use of the COBEL in African cultures

A subsidiary aim of the study was to evaluate the ease and practicality of the use of the COBEL in a population that is geographically and culturally distinct from those in which it has been used previously. The lack of car ownership was the main factor that required adjustments to be made to the questionnaire, although it is also possible that less overt practices, such as potential cultural differences in the salience and proportion of scented bathroom products, might have also had systematic influences on answers. The psychometric properties of the Food component scores also showed that the Food questionnaire items were not measuring a single underlying construct.

Namibia suffers relatively extreme inequality as measured by the Gini Index (Central Intelligence Agency, 2013), and many of the Namibian participants came from a low socio-economic background and might frequently experience hunger. Further, for the same economic reasons, the variety of foods they have experience with might be relatively restricted (i.e. centered around cereals such as maize, prepared as a porridge). This is in contrast with the variety of foods available in the local supermarkets which, in many respects, resembles the food commonly available in European supermarkets. However, we were repeatedly told that most of the children (and, to some extent, this similarly applies to the low class adults) have diets centered around a restricted range of cheaper foods. Due to these socio-economic circumstances, questionnaire items that ask about responses to unknown foods, or guessing food odors, might give rise to limited responses in situations in which hunger, frugality and diet invariance are frequently experienced. This might contribute to the psychometric properties of the Food component among the Namibian participants, and demonstrates some of the challenges of cross-cultural research.

3.6 Conclusion

We replicated some of the standard findings in the literature of female over male advantage in the olfactory domain, using data on olfactory behavior within cultures that are rarely studied in the context of psychological testing. That is, we found that girls scored higher than boys in a questionnaire that measured olfactory awareness in everyday life, specifically in relation to questions focused on social and environmental odor sources; we did not find sex differences in odor identification scores. Cultural differences in COBEL scores provide evidence for the importance of cultural practices in acquiring olfactory reactivity norms, although within a culture, frequency of engagement with the odor sources that we explored (cooking, siblings, pets) were not linked to differences in olfactory behavior. Despite the different cultural environments, sex and age were linked to COBEL scores in ways that were consistent across the Namibian and Czech children, and consistent with previously-studied populations, suggesting that the COBEL usefully reveals individual differences in olfactory behavior in diverse cultures. To fully understand sources of variation responsible for sex and individual differences in odor awareness, future studies should develop research tools capturing local practices. This is certainly a challenge for researchers, however, if we do not do so, our attempts to generalize some of the previous findings based on people from western societies, will be unjustified. With all the shortcomings of the current study in mind, we tried to make a first step in that direction.

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