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Family Scents: Developmental Changes in the Perception of Kin Body Odor?

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Abstract There is increasing evidence that human body odors are involved in adaptive behaviors, such as parental attachment in infants or partner choice in adults. The aim of the present study was to investigate changes in body-odor perception around puberty, a period largely ignored for odor-mediated behavioral changes, despite major changes in social needs and in odor emission and perception. Nine families with two children (8 pre-pubertal, aged 7–10, and 10 pubertal, aged 11–18) evaluated body odors of family members and unfamiliar individuals for pleasantness, intensity, and masculinity, and performed a recognition task. The hypothesized emergence of a parent–child mutual aversion for the odor of opposite-sex family members at puberty was not found, contradicting one of the few studies on the topic (Weisfeld et al., J. Exp. Child Psychol. 85:279-295, 2003). However, some developmental changes were observed, including reduced aversion for odor of the same-sex parent, and increased ability of adults, compared to children, to recognize odor of family members. Sex and personality (depressive and aggressive traits) also significantly influenced odor judgments. Further research with larger samples is needed to investigate the poorly explored issue of how olfactory perception of self and family members develops, and how it could correlate with normal reorganizations in social interactions at adolescence.

Key Words Body odor · Preferences · Kin recognition · Mate choice · Attachment · Axilla · Puberty · Personality

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Introduction

The extent to which human body odors influence interpersonal relationships generates considerable interest in western societies, within the scientific community and the general public. Although the function of social odors is well-documented in other animals (e.g., Brown and Macdonald, 1985; Wyatt, 2005), it has, until recently, been underestimated in humans, a species improperly considered to have a poor sense of smell (see Schaal and Porter, 1991). In the past few decades, however, research interest in the perception of social odors, notably in infant and adult populations, has increased considerably.

Mothers can discriminate the odor of their own child (e.g., Schaal et al., 1980; Kaitz et al., 1987), and infants recognize and prefer the body odor of their mother over that of another woman (e.g., Macfarlane, 1975). This maternal odor appears to guide infants toward the breast and to have a calming effect (Schaal et al., 1980; Doucet et al., 2007). In older children, a preference for maternal odor is present (e.g., Montagner, 1974), and the comforting effect of parental odors is reported by some children (Ferdenzi et al., 2008). Therefore, it has been hypothesized that body

odor is involved in the development of infant–mother attachment (Winberg and Porter, 1998), although such a mechanism still needs to be documented more rigorously. The feeling of security brought by affective bonds with the attachment figure is essential to a child's social and emotional development (Bowlby, 1988). Because familiar parental body odors contribute to create reassurance, they could have a significant contribution to attachment processes.

In adults, research has focused mainly on body-odor perception in the context of sexual-partner choice. Human odors convey information about factors involved in mate choice, such as a woman's fertility state (Singh and Bronstad, 2001), a man's personality (Havlicek et al., 2005), age, sex, and individual identity (Schleidt et al., 1981; Chen and Haviland-Jones, 1999; Olsson et al., 2006), and levels of genetic similarity (reviewed in Havlicek and Roberts, 2009). Disassortative preferences [i.e., oriented toward the odor of people having fewer alleles in common at the major histocompatibility complex (MHC)], have been reported in several studies (e.g., Wedekind et al., 1995; Thornhill et al., 2003; see Havlicek and Roberts, 2009, for a discussion). Such a tendency might have evolved in mammals, thus increasing resistance to pathogens by favoring MHC-heterozygosity in offspring and/or by avoiding general inbreeding (Potts et al., 1991; Penn et al., 2002). As body odors appear to be more genetically than environmentally determined (Roberts et al., 2005), and as there seems to be a familial component to body odor (Porter et al., 1986), it is likely that adult raters prefer odors of individuals who are genetically different, not only from themselves, but also from one or both of their parents (see also, Jacob et al., 2002).

In view of the studies on children and adults, we hypothesized that preference for odors of kin over non-kin change adaptively during development. Specifically, the preference for maternal body odor during infancy and childhood (serving attachment functions) may shift in sexually-mature adults toward a preference for body odors that differ from family odor, thus serving a mate-choice function. There is precedent for the idea that odor preferences can shift according to context. For example, the use of hormonal contraception (mimicking hormonal levels experienced during pregnancy) appears to disrupt adaptive disassortative preferences for a man's body odor (Wedekind et al., 1995) toward individuals who are more genetically similar to themselves (Roberts et al., 2008). This has been interpreted as an adaptive behavioral shift that normally would occur during pregnancy to promote kin interaction and elicit additional offspring care. Similarly, we suggest that olfactory perception of parental odors may shift around puberty because of major changes in reproductive physiology and social consequences (emergent sexual behavior, fluctuation in attachment to parents).

Noticeable changes in the dynamics of social interactions related to puberty are, increasing distance from the parents, and closeness with opposite-sex peers (reviewed in Smetana et al., 2006). To our knowledge, only one study has investigated how social odors may be involved in these social changes. In that study, involving American families with children age 6–15 years, and by using pair-wise comparisons of body odors of a family member versus an unfamiliar control donor, Weisfeld et al. (2003) found a preference for the unfamiliar control donor over 1) the opposite-sex sibling (responses of all children) and the father (responses of adolescents only), and 2) the opposite-sex child (responses of parents). Although it is not known whether these results are related to a growing olfactory aversion between opposite-sex family members or to an inclination toward unfamiliar body odors, they are consistent with a possible involvement of body odors in inbreeding avoidance mechanisms.

The aim of this study was to investigate possible changes in the perception of kin body odor around puberty. Involving entire families, we investigated age-related changes in recognition and pleasantness, intensity, and masculinity evaluations of the body odor of parents, siblings, self, and unfamiliar individuals, as well as the impact of other potentially confounding variables (children's body self-esteem and temperament). To perform an absolute, rather than comparative, approach and to test the existence of aversions, we measured each sample's pleasantness by using rating scales rather than paired comparisons between a familiar and a control odor, such as those used by Weisfeld et al. (2003). We hypothesized that we would find further evidence of a bidirectional aversion (child–parent and parent–child) for the odor of opposite-sex individuals, in pubertal children only.

Materials and Methods

Participants Nine families, each with two children, took part in the experiment. The sample consisted of $N=9$ mothers (age, 39–52 yr), $N=7$ fathers (44–54 yr) and $N=18$ children (8 pre-pubertal, including 6 boys, age 7–10 yr, and 10 pubertal, including 7 boys, age 11–18). The children were reported as related biologically to both tested parents. Families were characterized by relatively high income and education level of the parents (>£50,000/year, degree/diploma), and of Caucasian origin. Age groups were completed following the children's answers to the Pubertal Development Scale (PDS; Petersen et al., 1988), the 7–10-yr-olds being classified almost exclusively in the pre-pubertal/early pubertal stages, and the 11–18-yr-olds in the mid-pubertal/late pubertal/post-pubertal stages. The families were recruited through press releases and word-of-mouth among

University of Liverpool staff. For their participation, they received £20 and a free family ticket to a local botanical garden. The study was approved by the Committee on Research Ethics of the University of Liverpool and complied with the Declaration of Helsinki guidelines on human experimentation.

Odor-Collection Procedure Instructions on how to collect body odors were given both in person (CF) and through use of an illustrated instruction sheet. The participants also received reminders by email shortly before each key step of the 5-day testing period. Participants were provided with 100% cotton t-shirts (Fruit of the Loom Inc., Bowling Green, KY, USA), previously washed with an unscented detergent (Surecare Sensitive™, Robert McBride Ltd, Manchester, UK). The t-shirts were worn for three consecutive nights, simultaneously by all family members. Starting 2 d before wearing the shirts, participants were asked to refrain from drinking alcohol and eating strong foods (e.g., curry, chili and other spices, garlic, onion, pepperoni, blue cheese, cabbage, asparagus; see Roberts et al., 2005). On the evening that odor collection started, before putting the t-shirt on, all participants were required to shower with a non-perfumed soap (Simple™, Accantia Health & Beauty Ltd, Solihull, UK) and were instructed not to use any scented products, such as antiperspirants, deodorants, perfumes, or colognes. Participants also were instructed to avoid sexual intercourse and odor contamination (from partner, cooking, other odorous clothes or pets) during the time they wore the t-shirt. No obvious contamination (by perfume, coffee, or tobacco, for example) was recorded by the experimenter (CF), who smelled every sample once. On the morning of each collection night, participants were instructed to store their t-shirt in a closed and identified zip-lock bag. Parents returned the samples of the whole family to the laboratory on the morning after the third collection night. No major infringement (food, smoking, drinking, etc.) to the instructions was noted, according to the answers of each participant to a questionnaire concerning their behaviors during the testing period. Each t-shirt was cut into four halves (from navel to collar and along the side seams), combined into two samples (front left + back right, and front right + back left), and stored at −80°C for a maximum length of 46 d. This procedure was used to duplicate the number of available samples while limiting possible side-related differences in odor quality (Ferdenzi et al., 2009). Previous studies showed that freezing for this length of time (and longer) does not influence body odor quality (Roberts et al., 2008; Lenochova et al., 2009).

Personality Questionnaires Children completed the Body Esteem Scale for Adolescents and Adults (BESAA; Mendelson et al., 2001), that measures how they feel about their appearance and weight. Both parents evaluated the personality of their children by means of the Early Adolescent Temperament Questionnaire Revised (EATQ-R; Capaldi and Rothbart, 1992; Ellis and Rothbart, 2001). Only four dimensions were considered in the present study, either because they were related with some aspects of social interactions (Affiliation, 6 items; Aggression, 7 items) or because they were shown previously to be influential on odor perception (Depressive Mood, 5 items; Shyness, 5 items; Herberner et al., 1989; Pause et al., 1998).

Evaluation Procedure T-shirt halves were placed in zip-lock plastic bags (30×30 cm) and left at ambient temperature 2.5–3 hr before beginning the session. None of the participants reported nasal congestion or olfactory dysfunction. Participants were instructed to avoid wearing perfume on the testing day, and not to smoke or eat/drink in the 30 min preceding the session.

Perceptual Ratings of Familiar and Unfamiliar Individuals During the first olfactory task, participants rated all samples from the family (including their own t-shirt), the same number of unfamiliar samples, and a blank (unworn t-shirt). That is, 7–9 samples in total, according to whether the father took part or not. Unfamiliar samples were provided by members of other families and matched for sex and approximate age with the samples of the target family (age variation: 0.00±1.61 yr in children, 0.00± 3.70 yr in parents). Families were unacquainted with each other. Participants evaluated each sample in a random order, on 9-point scales, for *pleasantness* [ranging from −4 (not pleasant at all) to +4 (very pleasant)], *intensity*, and *masculinity* [ranging from 1 (not intense/masculine at all) to 9 (very intense/masculine)]. They were instructed to take 15-sec breaks between samples. Special care was given to the children to ensure that they understood the rating labels.

Recognition of Familiar vs. Unfamiliar Individuals The second olfactory task was a recognition task involving pairs of odors, i.e., a target sample (from a family member) and the paired control (unfamiliar). As an example, a child smelled his father's odor and the odor from an unknown man of approximately the same age and had to answer the question: "which one belongs to your dad?" Once samples of all family members were evaluated, separated by 15-sec breaks, the same task was repeated twice. In total, 9–12 pairs of samples (according to whether the father took part or not) were evaluated. Across the three repetitions, pairs and members of the pairs were presented in random order, with sample coding altered. The number of correct answers was computed for each target odor (from 0 to 3). To limit fatigue and odor adaptation, the two olfactory tasks were

separated by a break of several minutes and completion of the questionnaire.

Data Analysis Most variables were distributed normally (Kolmogorov-Smirnov tests, α=0.05) but, because of the small size of the sample and the nature of some variables (e.g., recognition scores, with a small number of categories), we used non-parametric statistics.

First, the ability to distinguish the odor of a family member from the odor of an unknown individual was tested with a *Chi-square* goodness-of-fit test. This test compares the observed distribution of participants falling into each score modality (0, 1, 2, or 3 correct answers over the 3 trials) and the distribution expected if participants answered by chance (e.g., 0, 9, 9, and 0 participants in the categories 0, 1, 2, and 3, respectively, if there were 18 participants in total, answering by chance would give 50% correct answers and thus a score of 1 or 2). An odor is recognized when the observed distribution is significantly different from the distribution expected by chance, because of a high number of participants having three correct answers (for example, 0, 3, 4, and 11 participants giving 0, 1, 2, and 3 correct answers, respectively). Note, that a significant difference between the distributions could also be because of a high number of participants having 0 correct answers (for example 11, 4, 3, and 0 participants giving 0, 1, 2, and 3 correct answers, respectively).

To test our main hypothesis, that an aversion for the odor of opposite-sex family members would appear with advancing puberty, we computed the differences between the pleasantness score of the odor of each family member minus the pleasantness score of the unfamiliar odor it was paired with. We used Mann-Whitney *U*-tests to compare pre-pubertal and pubertal children for this variable. As the number of girls was limited in this experiment, because of recruitment difficulties, we did not perform analyses on separate sexes, but considered olfactory evaluations between opposite-sex individuals and between same-sex individuals. Although pooling evaluations of female and male odors could have been problematic, it is acceptable here, as there was no significant difference of pleasantness between the odor of mothers and fathers, unknown adult females and males (Wilcoxon matched pairs tests), and girls and boys (Mann-Whitney *U*-tests on the rating of the mother and the father). Note, that an exploratory analysis of sex differences showed that girls rated the odor of their father (but not the unfamiliar man) as less pleasant than did boys (Mann-Whitney *U*-test, $P<0.05$).

Finally, we tested the influence of personality variables by using a Principal Component Analysis performed on the Kendall tau correlation matrix. For higher intelligibility, only results for recognition and pleasantness were linked to personality dimensions (that is, average of the mother's and the father's evaluation on each personality dimension of the EATQ-R, and children evaluations on the body esteem scale BESAA).

Results

Recognition of Familiar vs. Unfamiliar Individuals

By Children When children were asked to distinguish the odor of self from the odor of an unfamiliar child on three occasions, their answers did not differ from chance levels ($\chi^2(3)=4.44$, $P>0.05$). They also answered at chance levels for the odors of their mother and sibling ($\chi^2(3)=5.00$ and 4.44, respectively, $P>0.05$), but not for their father ($\chi^2(3)=8.29$, $P<0.05$. However, this effect was not from more frequent right answers but from more frequent wrong answers).

By Adults Parents tended to recognize their own smell, compared to the odor of an unfamiliar donor, better than by chance ($\chi^2(3)=7.62$, $P=0.054$). Mothers recognized the odor of their child better than by chance ($\chi^2(3)=11.78$, $P<0.01$), whereas fathers did not ($\chi^2(3)=5.86$, $P>0.05$. Parents also identified the odor of their spouse at above-chance levels ($\chi^2(3)=8.71$, $P<0.05$).

Hedonic Ratings of Familiar vs. Unfamiliar Individuals

By Children Contrary to our expectations, analysis of the pleasantness difference, between the odor of familiar and unfamiliar adults, revealed no significant pubertal age-group difference for the ratings of opposite-sex adults (Fig. 1). However, a marginal difference for the ratings of same-sex adult was found (Mann-Whitney *U*-test, $P=0.074$). Pre-pubertal children preferred the odor of an unfamiliar same-sex adult (parent = −1.33±2.07 vs. unfamiliar = 0.33±3.39) whereas, pubertal children preferred the familiar adult (parent = 0.70±1.95 vs. unfamiliar = −0.50±1.96). No significant difference between pubertal age groups appeared for the intensity and masculinity ratings of the stimuli. Likewise, these groups did not differ for the pleasantness, intensity, or masculinity rating differences between self and an unfamiliar child, and between the sibling and an unfamiliar child.

By Parents The analysis of the pleasantness difference between the odors of own child, vs. an unfamiliar child, revealed no significant difference between pre-pubertal and pubertal odors, either when parents evaluated a child from the opposite sex (pre-pubertal children: own = −0.14±.69

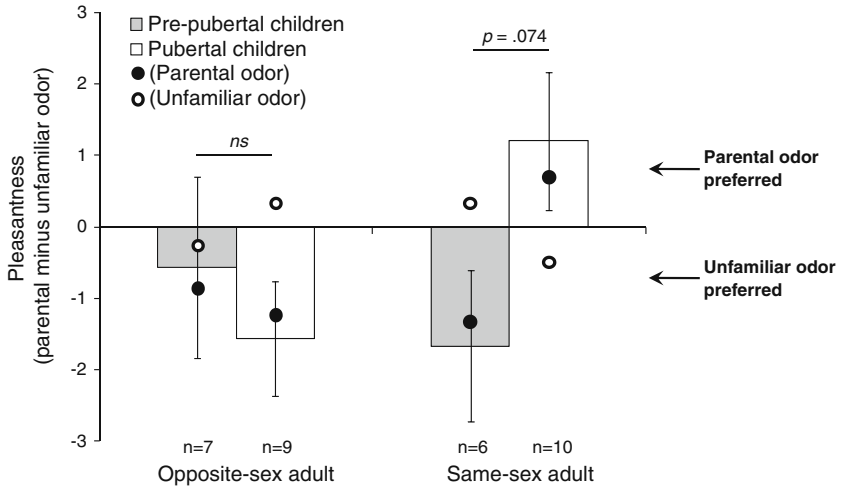

Fig. 1 Ratings by children of the body odors of familiar and unfamiliar adults. The *bars* represent the difference of pleasantness between the odors of familiar and unfamiliar adults (parent minus unfamiliar control adult, matched in sex and age), as a function of the age group of the rater (*grey* = pre-pubertal; *white* = pubertal), and for adults of the opposite and same sex as the rater (Mean ± SEM). A positive difference indicates that parental odor is preferred over unfamiliar odor. Age groups marginally differ (at $P<0.10$) on the rating of the same-sex adult (*ns*=not significant, $P>0.10$). The average ratings are also presented (*black circle*: odor of the parent; *white circle*: odor of the unfamiliar individual)

vs. unfamiliar = 0.29±1.80; pubertal children: own = 0.78± 1.48 vs. unfamiliar = −0.33±2.35) or the same sex as their own (pre-pubertal children: own = 1.33±1.63 vs. unfamiliar = −0.67±2.80; pubertal children: own = 0.00±1.33 vs. unfamiliar = 0.67±1.50). The body odors of children were evaluated positively, on average, and there was no aversion appearing at adolescence for the opposite-sex child (Fig. 2), under the conditions of the study.

Link with Personality Variables The factor analysis on the personality and pleasantness/recognition data are presented in Table 1. Six factors had eigen values higher than 1.00 and were, therefore, considered for interpretation. The first factor, explaining 18% of the variance, is interpretable in terms of the link between the level of the child's depressive mood and his/her ability to recognize the odor of his/her mother. Aggression and body esteem were negatively

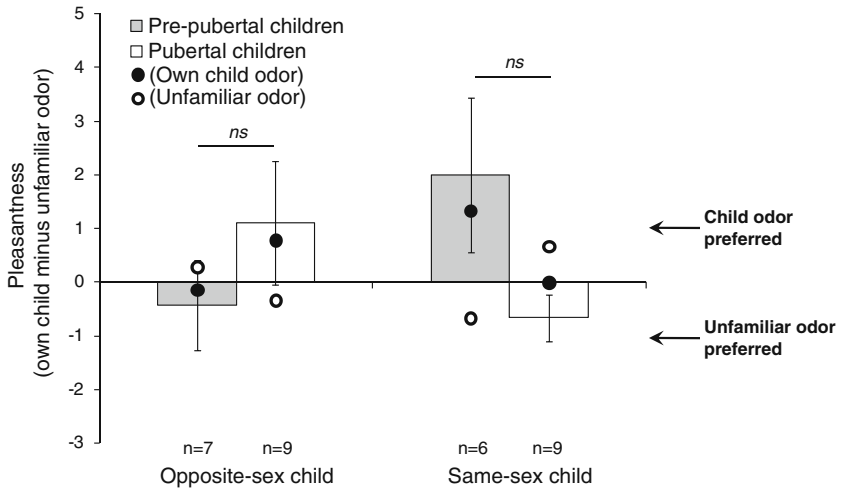

Fig. 2 Ratings by parents of the body odors of familiar and unfamiliar children. The *bars* represent the difference of pleasantness between the odors of familiar and unfamiliar children (own child minus unfamiliar control child, matched in sex and age), as a function of the age group of the rated child (*grey* = pre-pubertal; *white* = pubertal), and for children of the opposite and the same sex as the adult rater (Mean ± SEM). A positive difference indicates that the odor of a parent's child's is preferred over that of an unfamiliar one. Age group differences were not significant (*ns* = not significant, $P>0.10$). The average ratings are presented (*black circle*: odor of the own child; *white circle*: odor of the unfamiliar child)

Table 1 Results of the Principal Component Analysis on the personality variables (Affiliation, Aggression, Depressive Mood and Shyness dimensions of the EATQ-R questionnaire, and the BESAA body esteem score) and the olfactory evaluations of the children (pleasantness and recognition of the odor of self, the mother, the father and the sibling), based on the Kendall tau correlation matrix. Only loadings superior to 0.50 on Factors F1 to F6 are visible

	F1	F2	F3	F4	F5	F6
Depressive Mood	0.66					
Recognition—Mother	0.92					
Pleasantness—Self		0.77				
Pleasantness—Mother		−0.82				
Recognition—Father		0.64	−0.55			
Recognition—Self			0.64			
Recognition—Sibling			−0.81			
Body Esteem				−0.58		
Aggression				−0.50		
Pleasantness—Sibling				0.91		
Pleasantness—Father					0.91	
Affiliation						0.73
Shyness						−0.81
Explained variance	18%	16%	12%	11%	9%	8%
Eigenvalue	2.30	2.05	1.57	1.47	1.22	1.01
Total explained variance	74%					

linked to pleasantness of the sibling's odor, as shown by the fourth factor (11% of the variance). The sixth factor shows that affiliation and shyness are inversely correlated. Finally, and of minor interest to our questions, the second and third factors represent the inverse relationship firstly, between the pleasantness of the odors of self and of mother, and secondly, between the ability to recognize the odor of self from the odor of father and sibling.

Discussion

Developmental Effects The main aim of this study was to investigate the possibility of a pubertal shift in preferences for family body odors, characterized by the development of a mutual aversion between opposite-sex children and parents. The rationale for such a hypothesis is the transition from child–parent attachment to mate-choice necessity, both mechanisms potentially involving body-odor perception and evaluation. Initial results by Weisfeld et al. (2003) suggested such a phenomenon. However, here we did not find any such shift in children or parents. Specifically, no aversion occurred in parents who gave positive ratings of the odors of children. The only developmental difference that we found was a marginally significant effect on children's perception of odor of the same-sex parent. Pre-pubertal children tended to display an aversion for odor of the same-sex parent (the unfamiliar adult was rated more positively), while pubertal children rated the same-sex parent more positively than the unfamiliar adult, with overall ratings less negative than those of pre-pubertal children. As same-sex pairs were mostly boy–father (11 vs. only 5 girl-mother pairs), a possible explanation to this effect could be that perceptions become less negative after puberty, because of a specific reduction in sensitivity to major odorous compounds of male axillary sweat (androstenone and androstadienone: Dorries et al., 1989; Hummel et al., 2005) by boys. Adolescent males' greater tolerance for androstenes, and other unpleasant odorants with less biological significance (Chopra et al., 2008), is believed to be caused by pubertal changes in the levels of gonadal steroids. Our study also revealed that, whereas parents, who might have developed this ability through years of experience, recognized the odors of self, of their child (mothers only), and of their spouse, children (pre-pubertal and pubertal) were unable to recognize their own odor or the odors of other family members. Furthermore, in contrast to the results of another study (Weisfeld et al., 2003), children tended to pick out the odor of the unfamiliar man as being the odor of their father. This intriguing result needs further investigation.

In summary, these results suggest that there may be modifications in social odor perception at adolescence, but that these seem related to general phenomena (e.g., global sensitivity changes, experiential factors) rather than to specific aversions to opposite-sex family members. However, our limited sample size precludes a firm conclusion that such aversions do not exist. Further research with larger samples is needed to test developmental shifts in the perception of familiar body odor on each sex separately.

Sex Differences Although sex could not be taken into account in the present study, because of the small sample of girls, a preliminary analysis revealed that girls rated the odor of their father (but not those of an

unfamiliar adult male) as more unpleasant than boys did. Many studies have documented sex differences in social olfaction and reported a significant advantage for females. Females appear to be more sensitive than males to volatile chemicals present in axillary secretions, namely androstenone and androstadienone, at least from puberty onwards (Dorries et al., 1989; Hummel et al., 2005). Female sensitivity seems to be particularly focused on odors with social significance (Lundström et al., 2006), and even more so during the fertile period of the menstrual cycle (Doty et al., 1981; Grillo et al., 2001; Ferdenzi et al., 2009). In addition, females rely on body odors during social interactions related to partner choice significantly more often than do males (Herz and Inzlicht, 2002; Havlicek et al., 2008). Females also recognize the odor of familiar individuals more readily than do males (Schleidt et al., 1981), which was also true for adults in the present study; mothers significantly recognized the odor of their child, whereas fathers did not. This male–female difference is probably linked to a greater physical proximity between mothers and offspring, particularly in child care (Geary, 1998) and through adolescence (Smetana et al., 2006). Because of this female advantage in social olfaction, and because of differential changes in olfactory sensitivities in adolescent boys and girls (see above), sex is a factor to be considered in future research on the function of social odors during human development.

Personality and Body Odor Perception In the present study, the depressive trait of a child's temperament was positively related to its ability to recognize its mother's odor. Although previous studies found no link between personality and perception of the body-related compound androstadienone (Filsinger et al., 1987), our results corroborate studies that have shown that neuroticism in adults (depression loads heavily on the neuroticism dimension; Eysenck, 1990) is associated with higher olfactory sensitivity and better identification abilities, perhaps because of higher emotional activation (Pause et al., 1998; Chen and Dalton, 2005). Biologically significant odors, such as mother's odor, might thus be more salient to children with depressive tendencies than to others. We also found that the pleasantness of a sibling's odor was negatively linked to personality traits such as aggression. To interpret this particular link, it would be useful to determine if aggression is linked with higher levels of sibling rivalry, which could be linked to more negative evaluation of a sibling's odor. The roles of odors in the interactive behavior of siblings (Porter and Moore, 1981; Weisfeld et al., 2003) has been even less studied than odors in child–parent interactions, and is deserving of greater attention.

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