THE ROYAL SOCIETY

Human body odour, symmetry and attractiveness

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Several studies have found body and facial symmetry as well as attractiveness to be human mate choice criteria. These characteristics are presumed to signal developmental stability. Human body odour has been shown to influence female mate choice depending on the immune system, but the question of whether smell could signal general mate quality, as do other cues, was not addressed in previous studies. We compared ratings of body odour, attractiveness, and measurements of facial and body asymmetry of 16 male and 19 female subjects. Subjects wore a T-shirt for three consecutive nights under controlled conditions. Opposite-sex raters judged the odour of the T-shirts and another group evaluated portraits of the subjects for attractiveness. We measured seven bilateral traits of the subject's body to assess body asymmetry. Facial asymmetry was examined by distance measurements of portrait photographs. The results showed a significant positive correlation between facial attractiveness and sexiness of body odour for female subjects. We found positive relationships between body odour and attractiveness and negative ones between smell and body asymmetry for males only if female odour raters were in the most fertile phase of their menstrual cycle. The outcomes are discussed in the light of different male and female reproductive strategies.

Keywords: humans; body odour; fluctuating asymmetry; attractiveness; mate choice

1. INTRODUCTION

Recent studies on human body odour indicate the relevance of olfactory communication in various social situations. Apart from mother–child interactions and olfactory identification of relatives and partners (Hold & Schleidt 1977), the sense of smell apparently has important implications for human sexual behaviour (for a review see Schaal & Porter 1991). For example, several substances have been discovered in human excretions that act as sexual pheromones, such as male androstenes in sweat (for a review, see Gower & Ruparelia 1993) and female copulines in vaginal secretions (Michael *et al.* 1975).

Moreover, human female olfactory preferences seem to induce disassortative mating for components of the major histocompatibility complex (MHC) as in other mammals (Wedekind *et al.* 1995). Olfactory cues may thus be able to trigger an incest avoidance mechanism by reflecting parts of an individual's genetic equipment. In this study we focused on the question of whether human scent, apart from the above-mentioned functions, could signal mate condition like other cues in mate selection. Recent research has focused on the significance of developmental stability as such a mate-choice-relevant feature. Developmental stability describes an individual's ability to cope with genetic and environmental perturbations during development (see Møller & Swaddle 1997).

Fluctuating asymmetry, that is, small random deviations from perfect bilateral symmetry of morphological structures (Van Valen 1962), is presumed to indicate the developmental instability of an individual (e.g. Watson & Thornhill 1994). Low levels of fluctuating asymmetry are preferred in a potential mate in many species (see Møller & Thornhill 1998).

In humans, body and facial asymmetry are negatively associated with facial attractiveness (Gangestad *et al.* 1994; Grammer & Thornhill 1994), another confirmed mate choice criterion. Cross-cultural studies revealed that physical attractiveness plays an important role in human mate choice (Buss 1989). Although it appears to be a major criterion only for men, attractiveness of potential partners also rates highly among criteria used by females in choosing mates. Furthermore, Gangestad & Buss (1992) pointed out that attractiveness of the potential partner plays a major role in societies with higher parasite loads.

Each condition-sensitive mate choice criterion reflects the physical state of a possible mate with a certain error. Thus, the probability of selecting a truly high-quality mate will be improved when the choosing individual examines two or more sexual traits (Møller & Pomiankowski 1993). This should also be the case for signals of different modalities, that is, multichannel signals may well provide a better overall indication of mate condition than single-channel information. Fluctuating asymmetry and physical attractiveness both communicate the condition of developmental stability via the visual channel. We hypothesized that human body odour transmits information about an individual's developmental stability as an additional, redundant olfactory signal. Since olfactory and visual cues have different physiological roots, the signalling errors are likely to be uncorrelated. Thus, taking the information of both signals into account reduces the error and allows much more reliable mate choice decisions.

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Table 1. *Results of the t-test to examine deviations from zero of the mean asymmetry in the measured trait (directional asymmetry)*

trait	mean	s.d.	*t*	d.f.
wrist breadth	0.687	0.833	2.96*	60
hand breadth	0.935	1.536	3.06*	64
elbow width	0.793	1.282	2.89*	66
ear length	−0.500	1.507	1.68	66
ear breadth	0.319	1.108	1.27	68
ankle width	−1.560	2.100	3.88**	50
foot breadth	−0.507	2.197	1.41	66

*$p \leqslant 0.01$; **$p \leqslant 0.001$; two-tailed.

2. METHODS

We compared ratings of attractiveness and measurements of facial and body asymmetry with the evaluated quality of body odour of 19 female and 16 male subjects (mean age = 23.54, s.d. = 3.74). The participants were mainly students from the faculties of biology and psychology of the University of Vienna. Female subjects did not take oral contraceptives.

(a) *Measurement of body asymmetry*

To assess body asymmetry we measured seven bilateral traits of the subjects' bodies: hand breadth, wrist breadth, elbow width, ear length, ear breadth, ankle width and foot breadth. According to Livshits & Kobyliansky (1989), the summed fluctuating asymmetry of these traits shows considerable heritability. Measurement error was minimized by remeasuring each trait nine times. We used the mean of these repeated measurements as a basis for further calculations. According to Swaddle *et al.* (1994) accuracy of the asymmetry measurement was estimated by a three-way mixed model ANOVA. Between-individual variation in asymmetry was significantly and sufficiently higher than the estimated measurement error for each of the seven traits ($F_{34, 612}$ = between 8.60 and 45.77, $p < 0.001$).

The subsequent data analysis revealed that most examined traits showed directional asymmetry in our sample, that is the mean signed differences between left and right side deviated significantly from zero (table 1). Only the values for ear breadth, ear length and foot breadth fulfilled the criteria for fluctuating asymmetry. However, in most other studies on human fluctuating asymmetry, none of these seven measured traits showed directional asymmetry (e.g. Furlow *et al.* 1996). On the other hand, we have no reason to reject the possibility that the amount of directional asymmetry indeed might be higher in our investigated population. We therefore made the analysis both with an index solely of the three non-directional asymmetrical traits and with all seven characters.

Each asymmetry index was calculated as the mean of the relative differences between right and left side (that is $|r-1|$, divided by $0.5 \times (r+1)$), excluding two and seven cases of injured characters for the two different indices, respectively.

Subjects indicated their body heights and weights to control for effects of obesity on fluctuating asymmetry (Manning 1995). We used these data to calculate the corpulence index, that is (100×body weight in grams) divided by (body height in cm)^3. According to Knußmann (1988), this index is a more appropriate measure for separate-sex samples than the usual body mass index.

(b) *Measurement of facial asymmetry*

We recorded faces of the subjects with a video camera and digitized snapshots of these film sequences that showed the best upright position and neutral face expression of each person in 303 pixels×303 pixels size. By means of a computer program, the black-and-white portraits of the subjects were standardized to the same size and orientation. For the standardization the faces first were coded with 52 landmarks (source coordinates). In the second step the mean coordinates (destination coordinates) for all faces and the respective landmarks were calculated. In the third step the centre of gravity of the source coordinates was calculated for each face. Then the face was moved on the picture plane so that the centre of gravity of the face fell on the centre of gravity of the destination coordinates. Finally, each face was resized to 150% of its original size. Then the face was scaled down in one-pixel steps until the square sum of the difference between the source and destination coordinates reached a minimum (least squares method). After scaling, the face was rotated about the centre of gravity for 45°. Then the same method as above was applied for stepwise rotation. This results in size- and orientation-optimized pictures in relation to the centre of gravity of the face.

For the facial asymmetry analysis we used the method described by Grammer & Thornhill (1994). We manually set 12 landmarks on bilateral facial structures of each face that could be reliably identified. The program then connected these marks and computed the midpoints of the six resulting horizontal lines. Summing up the x-axis differences between the midpoints gives an index of horizontal asymmetry in the face. To assess reliability of this measurement, another person unfamiliar with the study's purpose set the landmarks in the portraits again.

The inter-correlation between the resulting two facial asymmetry indices was $r = 0.85$ at a significance level of 0.001.

(c) *Olfactory experiments*

As in previous studies (e.g. Hold & Schleidt 1977; Wedekind *et al.* 1995), body odour was collected by 'T-shirt experiments'. Each subject wore a T-shirt for three consecutive nights directly on the skin and had to follow a certain discipline during this time to avoid disturbing scents. The rules included refraining from (i) using deodorants and perfumed products, (ii) eating odour-producing food like garlic, onions, cabbage and asparagus, (iii) smoking cigarettes and drinking alcohol, (iv) sexual activity, and (v) avoiding pubs and discothèques because of the smoky air.

To control for possible hormonally induced variation in body odour (Poran 1995), each woman had to start the T-shirt experiment between the eighth and the eleventh day of her menstrual cycle. This restraint made it necessary to conserve the odour of the worn T-shirts by deep-freezing.

The white T-shirts were prepared by washing them with non-perfumed soap powder; each T-shirt was then kept in two freezing bags after drying. Each subject received one T-shirt, a package of soap powder to wash his/her bedclothes before the experiment, a perfume-free washing bar (Neutrogena®) for personal hygiene once every morning and odourless liquid soap for hair cleaning. Subjects were informed about the experimental procedure and received a written explanation along with a list of the behavioural restrictions. We asked them after the experiment to report honestly possible violations of the rules, their moods during these days, and if they had restless nights. None of the reported minor disturbances had a significant effect on the odour evaluations.

Odour evaluations took place in four distinct rating sessions on different days at the same time of day. By presenting not more than ten T-shirts to a given group of raters we intended to avoid habituation of scent perception. Two groups of 15 and 11 male raters judged the odour of the ten and nine different T-shirts worn by female subjects, respectively. Twenty-one and 22 female raters judged the smell of the ten and six different T-shirts worn by male subjects, respectively. Raters have all been non-smokers. Female raters did not take oral contraceptives and reported the first date of their last menstrual bleeding and their mean cycle length to calculate day in cycle at the time of evaluation.

Before each odour evaluation a person unfamiliar with the experiment recoded the T-shirt numbers and put each frozen piece of clothing into a glass bottle. The filled containers were then heated to 38 °C for 30 min. Raters judged the T-shirt odour on a scale from one (lowest agreement) to seven (highest agreement) with regard to three adjectives: 'intense' as a control variable for odour perception and quantity, and 'pleasant' ('angenehm' in German) and 'sexy' ('erotisch' in German) as parameters of quality. After the judgement, we presented photographs of the subjects to the raters and asked them to indicate persons they knew. Such ratings were excluded from the data analysis. Hence, we received between nine and 22 valid judgements per worn T-shirt (mean = 15.17, s.d. = 4.13), of which we used the mean values as evaluations of each subject's odour.

According to Grammer (1993), female perception of the male pheromone androstenone changes with cycle phase. Therefore, we divided female raters into two groups of fertility phases (see Baker & Bellis 1995, p. 161): (i) least fertile, ranging from days 1 to 4 and 17 to 32 ($n = 26$) and (ii) most fertile, ranging from days 5 to 16 of the menstrual cycle ($n = 14$). Female raters were only classified as being in the most fertile phase if their reported mean cycle length did not exceed 32 days. Hence, three raters had to be excluded from this analysis. Generally, women in the most fertile phase of their menstrual cycle rated male body odour as more sexy than did women in the least fertile phase ($t = 2.31$, d.f. = 38, $p \leqslant 0.05$, two-tailed).

(d) *Attractiveness ratings*

The standardized portraits of the facial asymmetry analysis were printed out in black-and-white on a 300 dpi greyscale laser printer. Twenty-three male and 24 female students from the Economics Department, who were presumably unfamiliar with the evolutionary theories of beauty and symmetry, rated the portraits of opposite-sex subjects for facial attractiveness. They were asked on questionnaires to judge each subject's face with regard to the adjectives 'attractive' and 'sexy' on seven-point scales, again seven being the highest value.

3. RESULTS

Since all mean ratings and measurements were normally distributed, we used parametric statistical tests. Initial analysis of all collected data revealed no general sex differences for the subjects in this sample, except for sexiness of body odour. The smell of female subjects was judged significantly more sexy by men than the odour of male subjects by female raters ($t = -2.06$, d.f. = 28.68, $p < 0.05$, two-tailed).

Physical attractiveness and sexiness ratings of the portraits correlated highly positively both for female ($r = 0.99$, d.f. = 17, $p \leqslant 0.001$, two-tailed) and male subjects ($r = 0.95$, d.f. = 14, $p \leqslant 0.001$, two-tailed). Therefore, we combined these two variables to produce a mean value of facial attractiveness for further analysis.

Table 2. *Pearson correlations between the adjectives of odour evaluation*

(Correlations of female odour ($n = 19$, rated by males) are presented on the bottom left. Correlations of male odour ($n = 16$) are presented on the top right separately for female raters in the least fertile phase (first value) and most fertile phase (second value) of their menstrual cycle.)

	odour		
odour	intensity	pleasantness	sexiness
intensity	—	−0.36/0.12	0.06/0.42
pleasantness	0.04		0.75*/0.40
sexiness	0.19	0.64*	

*$p \leqslant 0.01$; two-tailed.

Ratings of male and female odour pleasantness and sexiness did not show such a strong agreement, as shown in table 2. The association between these two variables was not even significant for women in the most fertile cycle phase judging male body odour. Moreover, whereas female raters in the least fertile phase tended to find an intense odour more unpleasant, women in their most fertile phase rated more intense smells as rather sexier (table 2). To account for possible actual differences in the associations of pleasantness and sexiness of odour we used these two adjectives of quality separately in the further analysis. Generally, the ratings of odour pleasantness and sexiness given by women in their most and least fertile phases were negatively correlated, although not significantly (pleasantness: $r = -0.34$, n.s.; sexiness: $r = -0.37$, n.s.).

For female subjects, the corpulence index showed a significant negative correlation with both body asymmetry indices ($r = -0.59$ and $r = -0.63$, respectively, d.f. = 17, $p < 0.01$, two-tailed), attractiveness ($r = -0.55$, $p < 0.05$), and in tendency with sexiness of body odour ($r = -0.40$, n.s.). That means body symmetry increased with higher relative body mass, but facial attractiveness and sexiness of odour decreased. Male corpulence had only slight and non-significant influences on the variables of interest (for all variables: $r < 0.3$, n.s.).

(a) *Attractiveness, body and facial asymmetry*

As shown in table 3, the two different indices of body asymmetry were significantly and positively correlated with each other for both sexes. We found nearly no relationship between body asymmetry and facial attractiveness for female or male subjects (table 3).

Female facial asymmetry showed no significant correlation with facial attractiveness or body asymmetry, as presented in table 3. In tendency, the relation between facial asymmetry and attractiveness rather pointed in a theory-contradicting direction. That is, the more attractive the woman, the more asymmetrical her face. Male facial asymmetry, however, significantly decreased with increasing facial attractiveness (table 3). Moreover, the relation between facial and body asymmetry was positive, although not significant. Table 3 further shows

Table 3. *Zero-order (r_0) and partial correlations (r_P) between attractiveness, body asymmetry and facial asymmetry for female and male subjects controlled for effects of the corpulence index*

(Degrees of freedom are presented in parentheses.)

	female subjects						male subjects					
	attractiveness		BdA1		BdA2		attractiveness		BdA1		BdA2	
	$r_0(17)$	$r_P(16)$	$r_0(17)$	$r_P(16)$	$r_0(17)$	$r_P(16)$	$r_0(14)$	$r_P(13)$	$r_0(14)$	$r_P(13)$	$r_0(14)$	$r_P(13)$
BdA1[a]	0.27	−0.08	—	—	—	—	−0.09	−0.07	—	—	—	—
BdA2[b]	0.20	−0.21	0.75***	0.60**	—	—	0.04	0.05	0.76***	0.76***	—	—
FcA	0.14	0.33	−0.27	−0.17	−0.22	−0.09	−0.60*	−0.64*	0.33	0.33	0.30	0.31

[a] BdA1, body asymmetry measured as index of ear length, ear breadth and foot breadth.
[b] BdA2, body asymmetry measured as index of all measured traits.
FcA, facial asymmetry.
*$p \leqslant 0.05$; **$p \leqslant 0.01$; ***$p \leqslant 0.001$; two-tailed.

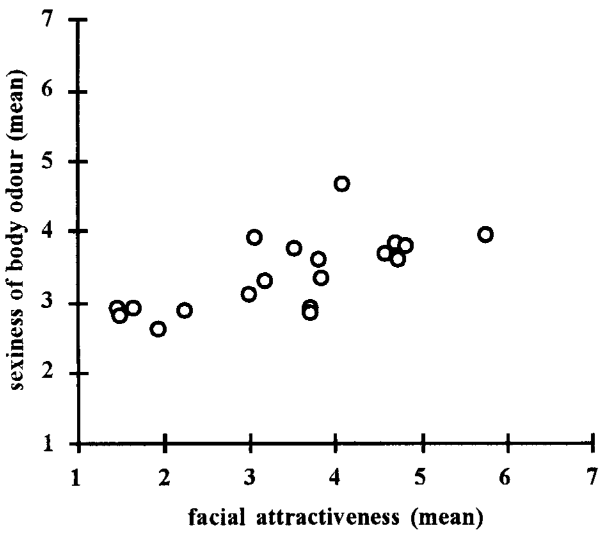

Figure 1. Relationship between facial attractiveness and sexiness of body odour for female subjects. The smell of women was rated by men as more sexy, the more attractive their faces.

that controlling for the corpulence index by partial correlation left the results for male subjects nearly unchanged, as expected.

(b) *Female subjects*

We found remarkable positive correlations between facial attractiveness and quality of body odour for female subjects (table 4). This effect was most pronounced and reached significance for body odour sexiness, that is, the more attractive the face of a women, the more sexy her smell (figure 1).

Both indices of body asymmetry showed considerable, although non-significant, negative correlations with pleasantness of female body odour when effects of corpulence were kept constant (table 4). Body odour sexiness exhibited this relationship only with the body asymmetry index of non-directional traits. Note that this correlation reaches significance if treated one-tailed ($p = 0.03$), as appropriate according to our hypothesis.

(c) *Male subjects*

Controlling for corpulence left the associations between male odour, attractiveness and asymmetry nearly unchanged, so we refrain here from presenting the partial correlations. As the left part of table 5 shows, women in the least fertile phase rated male body odour less pleasant the more attractive the men's faces. This negative tendency can be seen also for sexiness of body odour. Likewise, the relation between quality of scent judged by 'least fertile' women and body and facial asymmetry was rather positive, although none of these correlations reached significance (table 5).

On the other hand, if evaluated by women in the most fertile phase, sexiness of male body odour correlated positively with facial attractiveness (right part of table 5). Moreover, odour sexiness correlated significantly negatively with the body asymmetry index solely of three traits. Male facial asymmetry shows the same negative, although non-significant pattern, with both quality variables of odour rated by 'most fertile' women, as shown in table 5. In other words, women in the most fertile phase of their menstrual cycle tend to prefer the odour of physically attractive and symmetrical men.

The correlation coefficients between sexiness of odour and physical attractiveness of men rated by most and least fertile women differed significantly from another ($t_s = -2.25$, $p < 0.05$). Likewise, we found significant differences for the correlation coefficients of odour pleasantness and facial asymmetry between most and least fertile phase women ($t_s = 2.13$, $p < 0.05$) and for the coefficients of odour sexiness and facial asymmetry ($t_s = 2.05$, $p < 0.05$).

4. DISCUSSION

Despite small sample sizes this study supports the hypothesis that human scent signals individual developmental stability. Before we discuss this outcome in more detail, we will argue about some of the detected side results.

First, Manning (1995) reported a positive association of body asymmetry and body weight for women. However, in our sample, female subjects with higher relative body mass showed significantly lower asymmetry. Adipose tissue is important for maintaining the fertility status of a woman, since it stores oestrogen (Frisch 1975). Therefore, we would expect fluctuating asymmetry to decrease with increasing body mass. However, fluctuating asymmetry may vary

Table 4. Zero-order (r_0) *and partial correlations* (r_P) *between body odour and attractiveness, body asymmetry and facial asymmetry for female subjects* ($n = 19$), *controlled for effects of the corpulence index*

(Degrees of freedom are presented in parentheses.)

	attractiveness		BdAl[a]		BdAl[b]		FcA	
	$r_0(17)$	$r_P(16)$	$r_0(17)$	$r_P(16)$	$r_0(17)$	$r_P(16)$	$r_0(17)$	$r_P(16)$
pleasantness	0.45	0.37	−0.13	−0.38	−0.11	−0.37	−0.02	0.06
sexiness	0.70**	0.62*	−0.08	−0.44	0.16	−0.14	0.04	0.15

[a] BdAl, body asymmetry measured as index of ear length, ear breadth and foot breadth.
[b] BdA2, body asymmetry measured as index of all measured traits.
FcA, facial asymmetry.
*$p \leqslant 0.01$; **$p \leqslant 0.001$; two-tailed.

Table 5. *Pearson correlations between body odour and attractiveness, body asymmetry and facial asymmetry for male subjects* ($n = 16$), *evaluated by women in their least and most fertile phase of menstrual cycle*

	male odour rated by least fertile women ($n = 26$)		male odour rated by most fertile women ($n = 14$)	
	pleasant	sexy	pleasant	sexy
attractiveness	−0.55*	−0.41	0.09	0.48
BdA1[a]	−0.07	0.18	−0.14	−0.50*
BdA2[b]	0.16	0.36	−0.18	−0.19
FcA	0.44	0.35	−0.41	−0.47

[a] BdAl, body asymmetry measured as index of ear length, ear breadth and foot breadth.
[b] BdA2, body asymmetry measured as index of all measured traits.
FcA, facial asymmetry.
*$p \leqslant 0.05$; two-tailed.

with the oestrogen status of women, as suggested by Manning *et al.* (1996). Since we did not control for menstrual cycle phase at the time of the asymmetry measurements, our results on corpulence and asymmetry for women might be confounded by this variable.

Second, although facial asymmetry showed a clear negative relation to facial attractiveness in male subjects as predicted by theory and previous findings (Grammer & Thornhill 1994), this was not the case in our women's sample. Additionally, female facial asymmetry did not point in the same direction as the respective body asymmetry indices. These outcomes were not significant and may lead to different results in bigger samples. However, Gangestad *et al.* (1994) and Thornhill & Gangestad (1994) reported significant negative correlations for facial attractiveness and (body) asymmetry only for male subjects and not for females. Hence, in future research we should consider possible actual sex differences in fluctuating asymmetry due to hormonal variation during the female menstrual cycle that may differentially influence facial and body asymmetry.

Third, the lack of significance for most results of body asymmetry may be due to our small sample size and consequently weak statistical power. Moreover, unlike previous research, we found a lot of measured traits to be directionally asymmetrical in our population. Such effects probably confound small samples much more than bigger ones. Several studies have found significant negative associations between body asymmetry and attractiveness (see Møller & Thornhill 1998), at least for male subjects. And in accordance with our findings, Gangestad & Thornhill (1998) report a significant negative correlation between male body asymmetry and odour attractiveness if rated by high-fertility risk women.

Fourth, for most of our results on body odour only one of the quality variables, pleasantness or sexiness, is significant. We assume that sexiness of odour is a more powerful indicator for olfactory perceptions relevant to mate choice, since probably not every pleasant smell (such as lemon) has sexual associations. Interestingly, women in the least fertile phase seem to distinguish least between these variables as compared to 'most fertile' female raters and male raters (table 2).

Concerning our initial hypotheses we can conclude that human scent indeed transmits information relevant to mate choice. Body odour seems to be a condition-dependent trait of mate value and therefore can be viewed as a redundant signal.

However, whereas men clearly seem to favour developmental homeostasis in potential mates, this feature presumably plays a more complex role in female mate choice. According to the theory of parental investment (Trivers 1972), female choice should favour mates that provide material benefits, protection and care to ensure offspring survival. On the other hand, chosen males ought as well to contribute heritable qualities to the progeny. Some evidence suggests that these qualities do not necessarily go together. The more attractive and symmetrical men (with presumably high developmental stability) may have the opportunity to raise their reproductive success by multiple mating rather than by paternal investment. Accordingly, Gangestad & Thornhill (1997) found attractive and symmetrical men to have more in-pair and extra-pair sexual relationships.

Female strategy has to make a compromise between the needs of material and genetic benefits in selecting a mate. The best solution could be a conditional one, which is to search primarily for a reliable long-term investing partner and thereafter to optimize genetic equipment of the offspring by copulations with physically attractive men. In this regard, a study by Baker (1997, p. 171) indicates that some women in the later stage of reproductive ontogeny show an increased tendency for 'shopping around for genes' by extra-pair copulations. Olfactory signals, and differential responsiveness to these, may be the major cues triggering such a behaviour, as our study suggests.

Around the time of ovulation women perceive the male pheromone androstenone as less aversive compared to other cycle phases (Grammer 1993). Considering this effect it seems possible that androstenone is responsible for the observed female odour preferences in the present study. Metabolic pathways suggest a relationship between α-androstenes and testosterone (Gower & Ruparelia 1994). It is presumed that only individuals with high immunocompetence can afford the immune-suppressing effect of a high testosterone level (Folstad & Karter 1992). Immunocompetence may in turn be promoted by high developmental stability (Grammer & Thornhill 1994).

Undoubtedly, these suggested hypotheses are in need of further clarification and different methodological approaches.

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