**Interdisciplinary challenges for elucidating human olfactory attractiveness**

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**SUPPLEMENTARY METHODS**

This article presents data from an experiment divided in two studies (1 and 2, detailed below). Study 1 is part of a larger study aiming at creating a database of facial and vocal stimuli (GEFAV [1]) and at comparing facial, vocal and olfactory attractiveness in the same individuals (unpublished): only a small fraction of the data related to olfactory attractiveness is presented here, whereas Study 2 was used in its entirety for the present article. Both protocols have been approved by the Committee on Research Ethics of the Faculty of Psychology and Education Sciences at the University of Geneva.

**Participants**

In both studies, participants were heterosexual, of European descent, and non-smokers, and were aged between 18 and 36 years old. They were recruited through notice posting and word-of-mouth, mostly among university students. Those who provided body odour samples are called “donors” and those who rated the odours are designated as “raters”. All participants provided written informed consent and received cash or course credits for their participation.

*Study 1 (main study).* 79 participants, including 39 men and 40 women were involved as donors. Among the women, 22 were using hormonal contraception (“pill users”) and 18 were not (“non-pill users”): for the latter, body odour collection was performed during the estimated follicular phase of their menstrual cycle (see estimation procedure in [2]). Raters, about half of which being also odour donors, were 38 men and 55 women including 29 pill users and 26 non-pill users among which 12 were estimated in the fertile phase of their menstrual cycle.

*Study 2 (follow-up descriptive study).* Due to time constraints for the evaluation session, a subset of Study 1 donors was selected to obtain 32 donors in total (16 men and 16 women, including 8 fertile non-pill users and 8 pill users). Selection was performed with the aim to reduce the sample size while keeping a good representation of the range of attractiveness: therefore, roughly every other sample was retained on the distribution of male and female attractiveness separately (attractiveness here being the average of short- and long-term attractiveness ratings, see Procedure below). Raters were 16 men and 17 women, including 9 non-pill users (1 fertile) and 8 pill users, and were independent of odour donors. Note that due to limited sample size, the factor “pill use” was not considered in the data analysis.

**Procedure**

*Body odour collection.* Donors had to follow strict behavioural guidelines from 2 days before and during the 6-day sampling procedure. Especially, strong foods, alcohol, cigarette smoke and the use of perfumed cosmetics were to be avoided. Participants had to use a non-perfumed shower gel (Alterra® parfümfrei, Rossmann) and a non-perfumed deodorant (Mum® sensitive care, Doetsch Grether AG) that we provided. They had to wear a cotton t-shirt (Sunshirts.ch) for 6 consecutive nights and in the mornings, they had to gently rub their face, neck and scalp with a 20x20cm cotton cloth, thereby providing a composite sample of these areas of the head. The instruction sheet was illustrated with 6 different photographs of a person performing the head odour collection. T-shirts and cloths were previously washed in the laboratory with a non-perfumed washing powder (Omo® Sensitive, Unilever). During the day, the t-shirt and the cloth were kept in two separated zip-lock bags, under the participant’s pillow. On the 6th morning, the bags containing the samples had to be dropped before noon in a dedicated box in the laboratory, and were subsequently cut (axillary area separated from the rest of the t-shirt), wrapped in aluminium foil, placed in a ziplock bag and stored at -28°C. There was no major infringement of the instructions to report according to a questionnaire on the participants’ behaviours during the testing period. In addition, the length of index and ring fingers of the participants’ right hand was measured to the nearest 0.1 mm using Vernier callipers, directly on fingers (see details of the procedure in [3]).

*Odour rating.* The samples were left 2 hours at room temperature before the testing sessions started. After the ratings of Study 1, the samples were frozen again, and re-used in the rating session of Study 2. Although refreezing is usually avoided (because of the samples instability due to their biological nature), no major change in body odour samples perceived quality has been reported with repeated thawing [4]; moreover, all samples received exactly the same treatment which makes it possible to compare them. Gender-separate sessions were organized, namely one testing day for donors of each sex who evaluated all opposite-sex samples. They took place in a well-ventilated room with 8 individual boxes and computers. The samples were presented in 250 ml open glass jars wrapped and covered with aluminium. Head samples were evaluated before axillary samples that were intuitively thought to be more intense (although ratings showed that it was not the case), and individual samples were presented in random order within these two categories. All samples were placed on a central table and participants picked the sample they were instructed to evaluate via an E-Prime interface.

In Study 1, raters evaluated the olfactory samples of 20 opposite-sex donors (i.e., 40 stimuli) during a single 1-hour session. Each odour sample was evaluated by minimum 18 and maximum 30 opposite-sex raters. Ratings on continuous visual analogue scales (recoded from 0 to 100 later on) were collected for short-term attractiveness (“For a short-term relationship, could you personally be attracted to this man / woman?”) and long-term attractiveness (“For a long-term relationship, could you personally be attracted to this man / woman?”). Note that ratings of pleasantness, masculinity for male samples, femininity for female samples, and trustworthiness were also collected but are not presented here. In Study 2, raters evaluated the olfactory samples of 16 opposite-sex donors (i.e., 32 stimuli) during a single 1-hour session. They had to evaluate the attractiveness and intensity of the samples using the same continuous scales as in Study 1, and to describe them using a list of 22 descriptors, with the Check-All-That-Apply method, i.e., by choosing the most appropriate terms in the list. The descriptive terms were compiled from different sources [5,6] reporting descriptions of body odours by experts (perfumers), trained raters and untrained evaluators with their own personal vocabulary. The final list was chosen to cover a wide spectrum of positive and negative qualities while remaining easy to use by untrained raters (Table S1).

**Data analysis**

Data were analysed using Statistica v.12. Significance level was set at p<.05.

*Study 1 (main study).* Opposite-sex ratings were averaged for each odour sample (mean of 18 to 30 raters; ratings were missing when no odour was perceived). After checking that the variables were normally distributed (Kolmogorov-Smirnov tests), Pearson correlations were computed between 2D:4D ratio and mean ratings of attractiveness (short-term and long-term separately). Note that short- and long-term attractiveness were highly correlated (axilla: r=0.96, N=79, p<0.0001; head: r=0.97, N=77, p<0.0001).

*Study 2 (follow-up descriptive study).* The descriptive data was analysed as follows. First, the frequency of each descriptor was computed, for each donor sex separately, as the number of times this descriptor was chosen for that particular odour source (e.g., “floral” has been ticked 56 times for all female head samples together, and 41 times for all male head samples together; see absolute frequencies in Table S1) relative to the maximum number of times a descriptor can theoretically be chosen (16 donors × 16 raters = 256 times for women’s odours and 16 donors × 17 raters = 272 times for men’s odours, which results in a percentage of occurrence of the term “floral” of 22% in female samples and of 15% in male samples). To compare male and female samples, and head and axillary samples, differences of percentages were computed and highlighted when superior to 5% and 10% difference in Figure 1. Second, two principal components analyses (PCA) were conducted, on head and axillary samples separately, using the raw number of times each descriptor has been chosen for each individual odour sample. The first two factors that explained near half of the variance have been considered for interpretation (see Figure 2), and variables (descriptors) as well as cases (male and female donors) have been represented on this bi-dimensional space. Third, to analyse the ratings, opposite-sex responses were averaged for each odour sample (mean of 14 to 17 raters; ratings were missing when no odour was perceived). After checking that the variables were normally distributed (Kolmogorov-Smirnov tests), paired-sample t-tests were conducted to compare head and axillary odour attractiveness and intensity, and Pearson correlations were computed between attractiveness of odours sampled from the head and the axilla.

**SUPPLEMENTARY TABLE**

**Table S1.** List of 22 descriptors used to describe body odours, in English and in French, which was the language of the experiment. *A priori* valence of the terms is indicated, as well as their source (a: Wedekind et al 2007 in *Evolutionary Psychology* [5]; b: Troccaz et al 2015 in *Microbiome* [6]), and their absolute frequency for each sample category (female and male axillary and head odours).



**SUPPLEMENTARY FIGURE**

**Figure S1.** Correlation graphs between 2D:4D ratio and mean ratings of attractiveness (short-term and long-term separately) for **(a)** axillary odour and **(b)** head odour, in female (left) and male donors (right). Pearson rs with Ns in subscript, and p-values are provided on the graphs. One man and one woman received extremely low attractiveness ratings of their axillary odour (outliers, i.e., rating lower than the mean minus 3 standard deviations; dots within brackets on the graphs): results without these outliers are reported within brackets.



**REFERENCES**

1. Ferdenzi C, Delplanque S, Mehu-Blantar I, Da Paz Cabral KM, Domingos Felicio M, Sander D. 2015 The Geneva Faces and Voices (GEFAV) database. Behav. Res. Methods 47, 1110–1121. (doi:10.3758/s13428-014-0545-0)

2. Ferdenzi C, Schaal B, Roberts SC. 2009 Human axillary odor: are there side-related perceptual differences? Chem. Senses 34, 565–571. (doi:10.1093/chemse/bjp037)

3. Ferdenzi C, Lemaitre J-F, Leongomez JD, Roberts SC. 2011 Digit ratio (2D:4D) predicts facial, but not voice or body odour, attractiveness in men. Proc. R. Soc. B Biol. Sci. 278, 3551–3557. (doi:10.1098/rspb.2011.0544)

4. Lenochova P, Roberts SC, Havlicek J. 2009 Methods of human body odor sampling: the effect of freezing. Chem. Senses 34, 127–138. (doi:10.1093/chemse/bjn067)

5. Wedekind C, Escher S, Van de Waal M, Frei E. 2007 The major histocompatibility complex and perfumers’ descriptions of human body odors. Evol. Psychol. 5, 330–343. (doi:10.1177/147470490700500206)

6. Troccaz M, Gaïa N, Beccucci S, Schrenzel J, Cayeux I, Starkenmann C, Lazarevic V. 2015 Mapping axillary microbiota responsible for body odours using a culture-independent approach. Microbiome 3, 3. (doi:10.1186/s40168-014-0064-3)