

Human Body Scents: Conscious Perceptions and Biological Effects

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Introduction

Compounds collected from the torso and axillary area of sleeping men can be distinguished based on the number of MHC alleles matching between the man and the woman choosing the scent she prefers. Compounds from breastfeeding women and their infants increase the sexual motivation of other women and change the timing of ovulation. Here we show that these human compounds, collected on cotton, frozen and thawed, were perceived as mild scents and rarely identified as coming from another human (9% of male compounds, 12% of female compounds). It was their pleasantness, rather than their familiarity, that was associated with MHC allele matches between the donor and the smeller. In contrast, neither liking nor disliking the mild scent of breastfeeding compounds, nor their detection or reported strength was associated with modulation of sexual motivation or ovulation.

Study 1. MHC alleles and choice of male body scents

When given a choice between three boxes with body scents on fabric and asked 'If you had to smell one of these odors all the time, which would you choose? And which would you avoid?' women chose those with scents of men with whom they shared some MHC alleles and avoided those with whom they shared none (detailed methods in Jacob *et al.*, 2002). Here we report how the women perceived this odor mixture of body scent, box and fabric, testing the hypothesis that emotional valence mediated choices, not familiarity, even though the compounds were more similar genetically.

Each woman rated 10 cardboard boxes containing a cotton t-shirt: six from male donors, one with chlorine bleach, one with clove oil and two untreated carrier controls. Women placed their nose and chin in the box's triangular opening and sniffed the contents, which included a tinfoil lining secured by scotch tape. Familiarity and intensity was rated from 0 (unfamiliar or undetectable) to 10 (very familiar or very intense). Pleasantness and spiciness were rated from -5 (unpleasant or bland) to +5 (very pleasant or spicy). In a series of counterbalanced rounds of two- and three-way choices among all donors, each woman chose her most and least preferred box, without knowing that they contained male body scents. No one man was chosen over the others (see Figure 1A).

Women typically reported detecting some scent (93% of the least and most preferred donors; $n = 98$ boxes), although they didn't typically associate it with a person (23%), but rather a thing or a place ($\chi^2 = 15.1$, $P \leq 0.0005$). This was equally true for all donors ($\chi^2 = 7.7$, $P \leq 0.65$; see Figure 1B). Indeed, only 9% of the worn t-shirts were associated with worn clothing or a human body odor, whereas the t-shirts boxes with Clorox or clove were readily identified as such.

The body scents were mild. They were reported to be half as intense as boxes with household odorants, less spicy and moderately more pleasant (Jacob *et al.*, 2002). Importantly, the worn t-shirts were less familiar than the household odorants or the clean t-shirts serving as carrier controls.

Overall, there was no one man that was most preferred or avoided. Rather, all but four women preferred the donor with HLA alleles

matching her paternal alleles and avoided those without any. This preference was predicted by the pleasantness of the scent, not its familiarity, intensity or spiciness (multiple regression coefficients: pleasantness (+0.23, $P \leq 0.03$); familiarity (-0.15, $P \leq 0.31$), intensity (-0.18, $P \leq 0.31$) and spiciness (+0.12, $P \leq 0.52$). Moreover, it was the least, not the most, preferred donors, which were associated with people (see Figure 1C; 39% of least preferred donors versus 7% of preferred donors, $\chi^2 = 15.0$, $P \leq 0.0005$). Thus preference for scents with MHC matches, which were experienced as more pleasant, was counteracted by their accurate identification as body scents.

Study 2. Body scents from breastfeeding women and their infants

Compounds from the axillae and breasts of breastfeeding women increase sexual motivation (Spencer *et al.*, 2004) and alter the timing of ovulation and in other women (Jacob *et al.*, 2004). Are these effects mediated by the immediate olfactory experience reported by

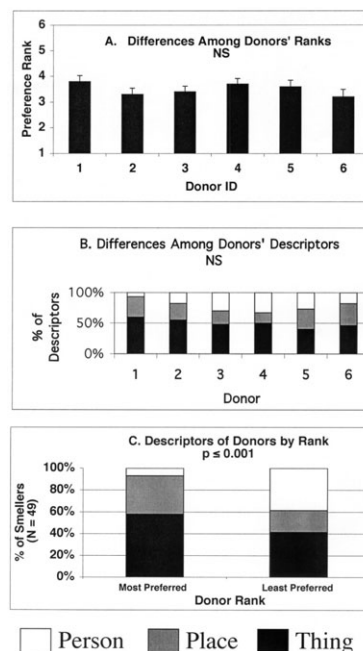


Figure 1 (A) Rank of each donor, averaged over all 49 women. (B) Odor categories were created *post hoc* to summarize the odor descriptors given in this study: person (white), place (grey) or thing (black). Within each category the frequencies of specific responses were: place (50% 'hospital' or 'clean room', 19% 'school', 13% 'home'); thing (53% 'soap' or 'clean clothes', 21% 'plastic' or 'rubber', 13% 'fragrance' or 'aftershave') and people (55% 'a person', 'brother', or 'church after a service' and 45% 'body odor' or 'dirty laundry').

the subject when the compounds were wiped above her upper lip, just under her nose?

During biweekly visits, each woman used latex gloves to wipe two cotton pads moistened with a carrier control of potassium phosphate buffered solution (control condition) directly under her nose or breastfeeding compounds collected on pads that had been worn next to the axillae and breasts of lactating women. These pad also likely contained compounds from their infants (e.g. saliva or skin cells). Subjects were asked: Did you smell anything? If yes, describe the smell (an open ended question). On a scale from not at all (0) to extremely (4): How strong is the smell? Do you like this smell? Do you dislike this smell? and Do you think this smell affects your mood? Thereby, we focused their attention on the odor qualities of the pads in both experimental conditions.

Women reported smelling an odor on only $52.8 \pm 3.8\%$ of their pads, with no difference between breastfeeding compound or control pads [pad type $F(1,45) = 1.24$, $P = 0.27$; cycle number $F(1,45) = 0.01$, $P = 0.92$; interaction $F(1,45) = 0.46$, $P = 0.50$]. Confirming that the odors were mild, women rated the odor strength at 0.81 ± 0.74 on the five-point scale [pad type $F(1, 45) = 0.64$; $P = 0.42$; cycle number $F(1,45) = 5.00$; $P = .03$; interaction $F(1,45) = 0.72$, $P = 0.39$]. Women had only a weak liking or disliking for both type of pads: like = 0.63 ± 0.67 on a five-point scale [pad type $F(1,45) = 0.003$, $P = 0.95$; cycle number $F(1,45) = 0.52$, $P = 0.48$; interaction $F(1,45) = 0.02$, $P = 0.90$]; dislike = 0.47 ± 0.63 on a five-point scale [pad type $F(1,45) = 1.08$, $P = 0.30$; cycle number $F(1,45) = 4.79$, $P = 0.03$; interaction $F(1,45) = 2.46$, $P = 0.12$]. Finally, women did not report that their mood was affected by the pads' odors ($.15 \pm 0.34$ on a five point scale [pad type $F(1,45) = 0.34$, $P = 0.56$; cycle number $F(1,45) = 0.47$, $P = 0.49$; interaction $F(1,45) = 1.07$, $P = 0.30$].

When the pads were reported to have a scent, control pads were described as like wet cotton (see Figure 2) as well as a food, chemical or commercial fragrance. Pads with breastfeeding compounds were significantly more likely to be described as having a body odor or

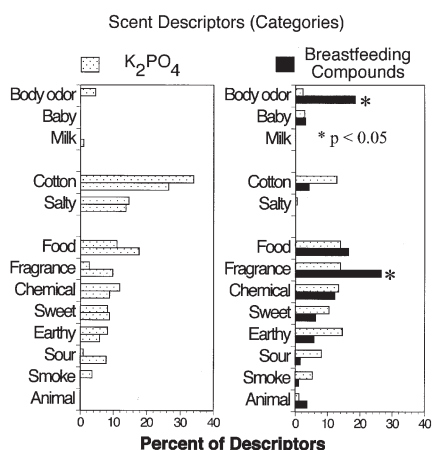


Figure 2 Descriptors for control pads (open bars), and breastfeeding compound pads (solid bars). Examples of specific descriptors within each summary category are: animal: skunk, pig, leather, musky; baby: baby, baby oil, baby shampoo, baby powder; body odor: body odor, body part (feet), person (grandmother), fleshy; chemical: chemical, chlorine, cleaning products ('Clorox', wax), alcohol (beer) hospital (antiseptic), paper, metal, plastic, 'Walmart'; commercial fragrance: commercial products (dryer sheets, 'Mountain Fresh'), cosmetics (perfume, soap), floral (honeysuckle), fragrant; wet cotton: cotton, wet cotton, water (wet, rain, humid); earthy: plants (grass, trees), dirt (musty, dusty) old, stale; food: food, fruits (strawberry), vegetables (cucumber) meat (chicken etc.), coffee, mint; milk: milk, milky; salty: salt, salty; sour: sour (tangy, vinegar), rotten (rancid, ripe, foul, etc.) pungent, sharp; smoke: smoke (bar smell, ash, exhaust); sweet: sweet, sugary, syrupy.

fragrance, although they too were described as food or a chemical. None the less, none of these differences in olfactory quality accounted for the functional effects of breastfeeding compounds on menstrual cycle length, or sexual desire (Jacob *et al.*, 2004; Spencer *et al.*, 2004).

General discussion

These studies of male and female human scents, collected on cotton, reveal that they are mild and rarely described as having a human odor (9% of male compounds and 12% of female compounds). Rather, both are described as smelling like a hospital, cloth, food, commercial fragrances or chemical odors. The low perceived strength and infrequent identification as human odors were similar in both studies despite different testing conditions: male scents were presented on a t-shirt in an enclosed cardboard box lined with tinfoil covered by tape, and subjects rated them six times in a single 30 min testing session. Women's scents on cotton pads were held with latex gloves and wiped under the nose daily for 2 months and rated 16 times. Most remarkable were the marked individual differences in perception of scents (e.g. range 0–00% reported).

Further work is needed to study perception of the full range of human scents and odors. The male compounds were collected while sleeping, and therefore are not representative of all male body odors. Likewise, the women were breastfeeding their infants. Importantly, in both studies, the compounds were on fabric and had been frozen and thawed, which can reduce odor unless rehydrated (G. Preti, personal communication, 2002).

Pleasantness of the human scent was associated with a woman's preference for it, based on having MHC alleles that matched her own. This suggests that matching MHC alleles affects emotional more than cognitive processing of these scents. In the case of breastfeeding compounds, the effect of breastfeeding compounds on timing of ovulation or women's sexual motivation was not associated with liking or disliking neither the mild scent of breastfeeding compounds, nor their detection or reported strength. The role of implicit olfactory properties and associations remain to be tested, as well as olfactory thresholds.

Further work is needed to elucidate the olfactory experience of human scents as they are experienced in different contexts. Some human compounds are experienced as conscious odors, e.g. recognized verbally and explicitly as odors with verbal descriptors. Other compounds have an odor, yet these olfactory properties are not required for them to function as pheromones, modulating hormonal and motivational states. Finally, it is useful to recognize the category of vasana (McClintock, 2001, 2002). These are compounds that present in such low concentrations that they are not consciously recognized as an odor, but nonetheless modulate hormonal and psychological states. The data here indicate that matching MHC alleles affect the pleasantness of a perceived odor. In contrast, breastfeeding compounds may be either pheromones or vasanas, as they affect ovulation and sexual motivation independently of the odor qualities measured in these studies.

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