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Influence of Body Odors and Gender on Perceived Genital Arousal

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Abstract Olfaction is often linked to mating behavior in non-humans. Additionally, studies in mating behavior have shown that women seem to be more affected by odor cues than men. However, the relationship between odor cues and sexual response—specifically, sexual arousal—has not been studied yet. The aim of this study was to evaluate the impact of the exposure to human body odors (from individuals of the opposite gender) on perceived genital arousal, while these were presented concomitantly to sexually explicit video clips. Eighty university students (40 women) rated their perceived genital arousal (perceived degree of erection/genital lubrication) in response to an audiovisual sexual stimulus, while simultaneously exposed to a body odor from an opposite-gender donor or no odor. Participants also rated each odor sample's (body odor and no odor) perceived pleasantness, intensity, and familiarity. Findings indicated that odor condition had an effect on women's (but not men's) perceived genital arousal, with women showing higher levels of perceived genital arousal in the no odor condition. Also, results showed that women rated body odors as less pleasant than no odor. Notwithstanding, the odor ratings do not seem to explain the association between body odor and perceived genital arousal. The current results support the hypothesis that women, rather than men, are sensitive to odors in the context of sexual response. The findings of this study have relevance for the understanding of human sexuality with respect to chemosensory communication.

Keywords Olfaction · Human body odors · Gender · Perceived genital arousal · Mating behavior

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Introduction

Across animal species, olfaction is known to play a key role in social communication and mating behavior (Wyatt, 2003). While human capacity for olfactory communication has been considered weak in relation to most mammals, it is well known that in many animal species (e.g., mice), social communication and mate choice are influenced by cues encoded by the Major Histocompatibility Complex (MHC, called Human Leucocyte Antigen, or HLA in humans), a gene cluster that constitutes the main factor in determining immunological individuality (e.g., Penn & Potts, 1998). Similarly to other species, humans are thought to partially base their choice of a partner on their genetic potential, exhibiting preferences for the odor of individuals who are dissimilar from themselves at genes coded in the HLA, thus striving for genetic variability and a more resistant immunity system (Havlicek & Roberts, 2009; Jacob, McClintock, Zelano, & Ober, 2002; Kromer

et al., 2016; Wedekind & Füri, 1997; Wedekind, Seebeck, Bettens, & Paepke, 1995). In line with this, the use of oral contraceptives seems to have a disruptive effect in mate choice, wherein women that use contraceptive pills often choose men with a similar HLA (Roberts, Gosling, Carter, & Petrie, 2008; Wedekind et al., 1995).

Interestingly, a gender effect regarding the importance of the different senses in mating behavior has also been documented in humans. More specifically, while men report visual cues as the most important sense in mating behavior (Havlicek et al., 2008), women judge odor cues as the most relevant ones in their partner choice, as well as in sexual arousal (Havlicek et al., 2008; Herz & Cahill, 1997), especially if the cues are perceived as more pleasant (Sodavari, Shahidi, Almadani, Moazedian, & Imani, 2014). Accordingly, when in the presence of a body odor from someone from the opposite gender, women who had experienced sexual intercourse with at least one partner, rated androstenone (found in higher concentrations in men than in women's apocrine secretions; Gower et al., 1994) as more pleasant than the ones who reported to never had experienced sexual intercourse, thus reinforcing the interconnection of body odors, hedonicity, and sexuality (Knaapila et al., 2012). Additionally, odors are known to induce emotions in the receiver (e.g., Herz, 2004; Semin & De Groot, 2013), with the odors perceived as more pleasant having a positive effect on attraction and mating behavior (Knaapila et al., 2012). A recent study with women compared the perceived similarity of body odors from unknown people to body odors of close relatives and partners, also evaluating how the body odors were perceived. The findings showed that the perceived similarity to a partner's odor correlated positively with the subjective ratings of the potential sexual interest in the odor's donor. Moreover, women evaluated the odors of individuals smelling similar to their partners as sexier and tenderer, more physically attractive, reliable, and as pertaining to someone who would be a better choice for father to their children (Sorokowska, Butovskaya, & Veselovskaya, 2015). These findings reinforce the role of olfactory cues in mating behavior, particularly for women (Herz & Inzlicht, 2002). On the other hand, previous research has shown that individuals suffering from anosmia present different social behaviors, including differences in sexual behavior, compared with individuals who have a normal sense of smell. More specifically, anosmic individuals showed a lack of sexual desire and a decreased frequency of sexual activity, half of that from individuals with a normal sense of smell (Croy, Negoias, Novakova, Landis, & Hummel, 2012).

Despite the increased scientific curiosity in human olfactory communication (e.g., Distel & Hudson, 2001), there is still limited research regarding the influence of body odors on human sexual response (Levin, 2004). The few existing studies have used artificial fragrances and not endogenous body odors to investigate such influence, showing an influence of men's fragrances on women's genital arousal during erotic fantasy (e.g., Graham, Janssen, & Sanders, 2000). Additionally, studies that have combined both fragrances and body odors concluded that fragrances extend beyond body odor masking effects and that people actually choose perfumes that interact well with their own body odor, resulting in an interaction between body odors and fragrances that produce individually specific odor mixtures (Lenochová et al., 2012).

In the present study, we investigated how human-produced chemosensory stimuli (body odors) presented as contextual information during the presentation of a sexually explicit video clip (i.e., audiovisual stimulation) influenced the perceived genital arousal. Audiovisual and olfactory cues were chosen as they have been suggested as important for perceived attractiveness and mate choice in both women and men (Herz & Inzlicht, 2002). Participants were shown a sexually explicit video clip and informed that throughout the video presentation they would be smelling a body odor collected from someone from the opposite gender. However, participants were randomly assigned either to a body odor condition (indeed a cotton pad from a donor from the opposite gender) or to a no odor condition (a cotton pad with no body odor). Since olfaction has been shown to influence human behavior (Stevenson, 2010), we expect to find differences in the participants perceived genital arousal depending on the odor condition (i.e., body odor or no odor). Moreover, given that the literature suggests a differentiated role of olfaction in mating behavior between women and men (e.g., Herz & Cahill, 1997; Herz & Inzlicht, 2002), we expect this effect to be modulated by the gender of the participant, with women's perceived genital arousal, rather than men's, to be more affected by the presence of body odor.

Method

Participants

A total of 89 heterosexual students from the University of Aveiro, Portugal, aged between 20 and 49 years ($M = 23.50$; $SD = 0.71$), volunteered to participate. We excluded nine participants for not fulfilling the inclusion criteria. Thus, the final sample consisted of 80 participants (40 women). Participants were randomly assigned either to the body odor condition (21 women [$M = 24.14$; $SD = 7.03$] and 19 men [$M = 22.16$; $SD = 3.24$]), or to the no odor condition (19 women [$M = 22.21$; $SD = 2.84$] and 21 men [$M = 23.52$; $SD = 4.29$]). See Table 1 for additional demographic information, noting that no significant difference between conditions was found for age, marital status, length of relationship, number of sexual partners, and hormonal contraception intake, $p > .05$.

When signing to enroll in the experiment, participants received detailed information about the experimental procedure, i.e., the task they would undergo, including that they would be watching sexually explicit video clips. It was furthermore explained that participants could interrupt or withdraw from the experiment at any moment. None of the participants have done so, and they all understood and agreed with the procedure beforehand.

Table 1 Sociodemographic characteristics

	Body odor condition ($N = 40$)		No odor condition ($N = 40$)	
	Women ($N = 21$)	Men ($N = 19$)	Women ($N = 19$)	Men ($N = 21$)
Age (years), $t(78) < 1$, ns				
M	24.14	22.16	22.21	23.52
SD	7.03	3.24	2.84	4.29
Range	18–49	18–28	18–29	19–37
Marital status (%), $\chi^2(2) = 2.05$, $p = .358$				
Single	90.5	94.7	94.7	100.0
Married or living together	9.5	0.0	0.0	0.0
Divorced	0.0	5.3	5.3	0.0
Length of relationship (months), $t(39) < 1$, ns				
M	40.67	41.45	41.06	39.25
SD	64.72	67.16	29.43	20.41
Range	3–324	1–53	2–96	3–72
Sexual partners (count), $t(74) < 1$, ns				
M	5.00	4.97	4.27	4.43
SD	6.25	6.25	4.99	5.08
Range	1–25	1–24	1–25	1–20
Hormonal contraception intake (percentage)				
Hormonal contraception	52.4	–	68.4	–
Natural	42.9	–	31.6	–
Unknown	4.8	–	–	–

Participants did not suffer from any mental, neurological, or metabolic diseases, had no diagnosed sexual dysfunctions, no olfaction or visual problems, and were medication free.

Body Odor Sampling

Body odor samples were collected from the armpit of six healthy university students (3 women), and the selection criterion of the sample was based on a demographic and health information survey, wherein the final donors were physically and mentally healthy, non-smokers and heterosexual (Martins et al., 2005). The body odor samples were collected using cotton pads placed in each armpit of the donor. Henceforth, each body odor donor provided a total of two samples (one sample from the right armpit and another from the left). The body odor donors were instructed to refrain from using odorant products (e.g., perfume and antiperspirant), from performing physically demanding activities (e.g., doing exercise), and to avoid a diet that would alter their natural body odor (e.g., they were instructed to avoid eating garlic and spicy food, as well as to avoid drinking coffee and alcoholic drinks). These procedures were required on the day before and on the day of the body odor collection (Havlicek & Lenochova, 2006).

On the day before the sampling, a kit for body odor collection was provided to each donor. The kit contained the following materials: a zip-bag with two cotton pads to be placed in each armpit on the day of the sampling, a medical adhesive tape to fixate the cotton pads, a non-perfumed and anti-allergic fluid soap (Lactacyd), a t-shirt (50% cotton, 50% polyester), and a towel (100% cotton). To ensure that both the t-shirt and the towel were properly clean and odorless, these materials were prewashed with an odorless detergent and water, as well as separately packed before being provided to the donors (Heckmann, Teichmann, Pause, & Plewig, 2003). On the day of the sampling, the donors were instructed to take a shower using the fluid soap and to use the provided towel to dry. Afterward, they should place the cotton pads on their armpits, using the medical adhesive tape, and then put on the provided t-shirt as a protective shell. They could use their own clothes if they were clean to avoid odors from previous days. The body odor donors were instructed to wear the cotton pads for a period of 4 h, while performing non-stressful assignments. After this period, the donors went to the laboratory, washed their hands, dried them in a provided towel and, in a private room, they removed the cotton pads from their armpits. A researcher would then check with the donors if they have complied with the provided instructions for the body odor collection. All donors verbally confirmed that they have followed the instructions and that they did not had problems during any stage of the odor collection process.

In order to select eligible odor samples for the main study, the cotton pads containing the body odors were subjectively evaluated by three volunteer students to select homogeneous odors. Body

odors were qualitatively evaluated by a small focus group ($n = 3$, 2 women) on intensity criteria, by selecting extreme odor samplings based on the subjective rating of the odors, i.e., samples that had a stronger smell or that did not contain any smell. No quantitative ratings were collected. The goal of this focus group was to select homogeneous odor samples for the main study and exclude potential outliers, with intensity being used as the criterion for this assessment. According to existing literature, the perception of olfactory stimuli is clearly distinct from that of visual and auditory stimuli, and its conscious percept is usually assessed in terms of perceived intensity and perceived pleasantness, which are usually highly correlated (e.g., Distel et al., 1999). We have opted for using *intensity* as the criterion for the pre-selection of the body odor samples to be used in the main study, particularly given that perceived intensity is assumed as the less ambiguous of these measures (e.g., Keller & Vosshall, 2016). Thus, the participants who smelled the odors were instructed to smell each of the 6 odors in a sequential way, from left to right, for 6 s, and asked to mentally judge (to avoid biases driven by other's perceptions) each body odor for intensity. After the completion of the body odors' line-up, participants were grouped and discussed the results from the individual task. More specifically, they were asked to discuss whether any of the body odors were distinctive in terms of intensity (the precise instruction was to "identify odors samples that had a stronger smell or that did not contain any smell"). Although the participants disagreed on the overall intensity of the presented body odors, which goes in line with the extensive literature showing highly idiosyncratic and variable perception in evaluating olfactory stimuli (e.g., Doty, 1975), they all agreed that no sample should be excluded as their qualitative assessment converged on pointing no sample as distinctive in terms of intensity. As a result, participants did not elect any of the body odors as outliers in terms of intensity and thus, no body odor samples were excluded.

Taking into account the results of the focus group, each of the six cotton pads with the eligible body odors samples were cut by a researcher in four equal parts, resulting in eight samples of body odor per donor (two samples from each armpit, each sample divided in four equal parts), thus resulting in a total of 48 body odor samples. Afterward, the samples were stored individually in zip-bags at −20 °C, to prevent bacterial degradation (Lenochová, Roberts, & Havlicek, 2009). The cotton pads with body odors remained frozen for a maximum period of 1 week and were thawed at the room temperature 1 h before the experiment. On the day of the study, a body odor sample was then placed inside a glass jar by a researcher using odorless plastic gloves to avoid contamination. Each body odor sample was used only once per participant.

In contrast, six odorless cotton pads were used for the participants allocated in the no odor condition. Similarly, each odorless cotton pad was cut into four equal pieces, providing a total of 48 odorless samples to be used as a control odor.

Procedure

Participants were randomly assigned to one of two conditions: body odor or no odor condition. They were exposed to the odor while viewing an audiovisual presentation (a 3 min sexually explicit video clip) involving a man and a woman during oral and vaginal/penile sexual intercourse. When participants signed for the experiment, they were informed that they should refrain from eating certain food-types (e.g., garlic), drinking coffee, or use any products that could interfere with their ability to smell on the testing day. The task was run in a private room of the laboratory. Before starting the video clip, the researcher instructed the participants in the different conditions that the odor they would smell belonged to someone from the opposite gender (i.e., women were instructed they would smell the odor of a man and men were instructed they would smell an odor from a woman), independently of being exposed to a body odor or to no odor. This means that even in the no odor condition, participants received the same instruction. Then, participants were asked to pick the wide-mouth glass jar with the odor sample inside with their dominant hand and to start smelling it from the moment the video started playing until its end. Moreover, participants were instructed to breathe through their noses and asked to initiate the video presentation after being left alone in the room and ready to start the task. The video clip was presented on a computer screen (HP-L1710, 17 in.), and all participants used headphones to increase privacy and to avoid external noises that could interfere with the task. When the task finished, participants answered a questionnaire aimed at evaluating their perceived genital arousal and their perception of the odor's pleasantness, intensity, and familiarity. After the completion of the task, they opened the door signaling that the task was finished. Informed consent was obtained from all the participants included in the study.

Measures

Sexual arousal was evaluated using a self-report specific-gender question regarding the level of perceived degree of genital arousal (e.g., Suschinsky & Lalumiere, 2012). Men's evaluated their perceived degree of erection and women evaluated their perceived degree of vaginal lubrication on a seven-point Likert scale varying from (1) very low to (7) very high sexual arousal.

The perception of the odor characteristics was evaluated using a subjective rating scale addressing pleasantness, intensity, and familiarity of the odor, using a nine-point Likert scale, varying from (1) not pleasant at all to (9) extremely pleasant in the case of pleasantness evaluation; (1) not intense at all to (9) extremely intense in the case of intensity; and lastly (1) not familiar at all to (9) extremely familiar in the case of familiarity.

Design and Data Analyses

We performed separate one-way ANOVAs for women and men to examine the effects of odor condition in (1) perceived

genital arousal and (2) subjective ratings attributed to odors (intensity, pleasantness, and familiarity). In addition, a post hoc regression analysis (Enter method assessing the effects of odor ratings on perceived genital arousal) was conducted for women as a means to clarify the findings found in the first level of analyses.

Results

Odor Effects by Gender

Women

Since no significant differences were found in odor ratings between women who were taking or not taking hormonal contraception either in the body odor condition (intensity, $t[18] = -.24$, $p = .816$; pleasantness, $t[18] = .08$, $p = .938$; familiarity, $t[18] = .60$, $p = .555$) and in the no odor condition (intensity, $t[17] = -1.51$, $p = .151$; pleasantness, $t[17] = -.35$, $p = .658$; familiarity, $t[17] = -.62$, $p = .543$), hormonal contraception intake was not included as a variable in this study.

Results revealed a statistically significant effect of odor (body odor or no odor) on the perceived genital response of women ($F[1, 38] = 17.39$, $p < .001$, $\eta_p^2 = .314$). Pairwise comparisons showed that women's perceived genital response was significantly higher in the no odor condition ($M = 4.53$; SD = .46), compared to the body odor condition ($M = 1.86$; SD = .44) (see Table 2).

Regarding the odor ratings, results have shown statistically significant differences between the two odor conditions in intensity ($F[1, 38] = 11.04$, $p = .002$, $\eta_p^2 = .225$), pleasantness ($F[1, 38] = 10.60$, $p = .002$, $\eta_p^2 = .218$), and familiarity ($F[1, 38] = 5.06$, $p = .030$, $\eta_p^2 = .118$). Pairwise comparisons showed that women perceived body odors as more intense, less pleasant and more familiar than no odor (see Table 2 for detailed descriptive statistics).

Because body odors were rated as less pleasant than the no odor condition, and in light of the unexpected findings on the effects of odors in perceived genital arousal (with women reporting less perceived arousal in the body odor condition), we conducted an ANCOVA analysis, adding the subjective odor ratings (pleasantness, intensity, and familiarity) as a covariate. By doing this, we aimed to test whether the subjective appraisal of the odors—rather than the odor condition—would modulate perceived genital arousal in women. Findings revealed that after controlling for the separate effects of pleasantness, intensity, and familiarity on the perceived genital arousal of women, the results remained statistically significant ($F[1, 35] = 14.75$, $p < .001$, $\eta_p^2 = .297$), showing a higher perceived genital response in the no odor condition ($M = 4.71$; SD = .53) in relation to the body odor condition ($M = 1.67$; SD = .50).

Men

For men, results did not reveal a statistically significant effect of odor (body odor or no odor) on the perceived genital response ($F[1, 38] = 0.00$, $p = .961$, $\eta_p^2 = .000$). Pairwise comparisons showed that men's perceived genital response did not statistically differ between the no odor condition ($M = 3.62$; SD = .56) and the body odor condition ($M = 3.58$; SD = .59) (see Table 2).

Regarding the ratings of the odors, results revealed no statistically significant effect for intensity ($F[1, 38] = 0.12$, $p = .734$, $\eta_p^2 = .003$), pleasantness ($F[1, 38] = 0.06$, $p = .802$, $\eta_p^2 = .002$), and familiarity ($F[1, 38] = 2.34$, $p = .134$, $\eta_p^2 = .050$), as a function of the odor condition. Men perceived both conditions as being similarly intense, pleasant, and familiar (see Table 2, for detailed descriptive statistics).

Relationship Between Odor Perception and Perceived Genital Arousal in Women

In light of the previous findings showing an effect of the odor condition in women's perceived genital arousal and odor ratings, we conducted a regression analysis (Enter method) to evaluate the role of odor perception in perceived genital arousal. A multiple regression analysis, with all predictors entered in a single step, was performed for each odor condition, using STATA 14.0. All odor ratings (intensity, pleasantness, and familiarity) were chosen as predictor variables and perceived genital arousal as a criterion variable. In accordance, and in order to provide an index regarding multicollinearity, we compared the variance inflation factor (VIF) value for each of the predictor variables, using the following cut-off values as reference: 10, 5, and 3.3 (see O'Brien, 2007). Findings revealed that using the most conservative cut-off points (3.3; Cenfetelli & Bassellier, 2009) all the predictors obtained VIF values below the cut-off, ensuring non-multicollinearity: Women obtained a mean of VIF of 1.41 in the body odor condition (intensity 1.64; familiarity 1.20; and pleasantness 1.40) and of 1.16 in the no odor condition (intensity 1.24; familiarity 1.19; and pleasantness 1.01).

The regression analysis showed a non-significant model ($F[3, 17] = .151$, $p = .928$) for women in the body odor condition, accounting for .02% of perceived genital arousal's variance ($R^2 = .026$). According to the standardized regression coefficients analysis, intensity ($\beta = -.026$, $p = .917$), pleasantness ($\beta = -.151$, $p = .644$), and familiarity ($\beta = .078$, $p = .701$) were not predictors of perceived genital arousal for women in the body odor condition.

A similar result was found for women in the no odor condition, in which a regression analysis showed a non-significant model ($F[3, 15] = .824$, $p = .501$) accounting for 14% of perceived genital arousal's variance ($R^2 = .141$). According to the standardized regression coefficients analysis, intensity ($\beta = .496$, $p = .140$), pleasantness ($\beta = .191$, $p = .596$), and familiarity ($\beta = -.159$, $p = .611$)

Table 2 Descriptive statistics of subjective odor ratings (intensity, pleasantness, familiarity) and perceived genital arousal for women and men, including one-way ANOVA results and significance level

			Body odor condition *M* (SD)	No odor condition *M* (SD)	One-way ANOVA	*p*
Women	Subjective odor ratings	Intensity	5.33 ± 2.35	3.11 ± 1.82	$F(1, 38) = 11.04$	.002
		Pleasantness	3.62 ± 1.66	5.26 ± 1.52	$F(1, 38) = 10.60$	.002
		Familiarity	4.67 ± 2.46	3.11 ± 1.85	$F(1, 38) = 5.06$	.030
	Perceived genital arousal		1.86 ± 0.44	4.53 ± 0.46	$F(1, 38) = 17.39$	<.001
Men	Subjective odor ratings	Intensity	5.26 ± 1.82	5.05 ± 2.13	$F(1, 38) = 0.12$	.734
		Pleasantness	5.84 ± 1.74	5.71 ± 1.45	$F(1, 38) = 0.06$	.802
		Familiarity	5.00 ± 1.67	4.05 ± 2.20	$F(1, 38) = 2.34$	.134
	Perceived genital arousal		3.58 ± 0.59	3.62 ± 0.56	$F(1, 38) = 0.00$	.961

were not predictors of perceived genital arousal for women in the no odor condition.

Discussion

The present study investigated the impact of smelling opposite-sex body odors versus no odor while viewing sexually explicit video clips on perceived genital arousal in women and men. The results showed that the odor stimuli had a significant impact on the perceived genital arousal in women, but not in men. However, and contrarily to our hypothesis, our findings showed that the exposure to a body odor resulted in lower perceived genital arousal, compared to the exposure to no odor. Importantly, this effect does not seem to be influenced by odor ratings of pleasantness, intensity, and familiarity in women.

Although body odors seem to play a significant role in human mate choice (Lübke & Pause, 2015) by, for example, being linked to physical attractiveness (Franzoi & Herzog, 1987), our results suggest that their influence on human's sexual responses—more specifically, in the perceived genital arousal component—seems to depend on the gender of the participant, with women (but not men) being affected by the presence of the body odors. Indeed, a previous study showed that women rated olfaction as the most influential sense in women's mating behavior (Herz & Cahill, 1997), which goes partially in line with the results of our study, showing that women report different perceptions of genital arousal depending on the odor condition. However, this influence was not predicted by the women's perception of odors (odor ratings). So, even though women have pointed olfaction as the most influential sense in their mating behavior, with unpleasant odors hampering the interest in sexual intercourse (Herz & Cahill, 1997), body odors, rather than the perception of the odors, seemed to have decreased the perceived genital arousal in women. Such finding suggests that the mechanism behind the relationship between body odors and sexual arousal may be linked to some odor component rather than to the subjective appraisal of the odor. While this assumption deserves appropriate testing, it is worth noting that a recent study indicated that women—but not men—were more likely to want children when in partnership with a HLA (class I) dissimilar partner (Kromer et al., 2016). Although speculative, this could explain the current findings; the body odor samples collected from men may have contained similar HLA, eventually reducing women's perceived genital arousal. In this case, the results would be influenced by the gene clusters present at the HLA level that may have been perceived as less favorable by women (Havlicek & Roberts, 2009; Jacob et al., 2002; Wedekind & Füri, 1997; Wedekind et al., 1995). Also, it has been reported that women tend to outperform men, at least for some tested odorants, in different odor tests such as absolute threshold, discrimination, and identification tests (Doty & Cameron, 2009). This gender difference[1] could help explain why women were more sensitive to body odors than men, and why they modulated their subjective sexual response as a function of the odor condition. Indeed, women may have been better at detecting odors. On the other hand, this finding also conforms to previous data showing that men evaluate visual sexual cues as more influential than other sensory cues (including olfaction) in relation to women (Havlicek et al., 2008; Herz & Cahill, 1997).

Another alternative explanation for the current unexpected findings relates to the role of culture. Cultural differences in odor perception and categorization are also reported in the literature (e.g., Chrea et al., 2004). Because most studies on body odors and/or sexuality are conducted in countries other than south European countries, a cultural bias must be considered. In fact, laboratory studies on human sexuality conducted in Portugal have been showing distinct patterns of human sexual response that may be culturally specific (cf. Carvalho et al., 2013). Cross-cultural studies should be performed to understand the replicability of the results and the role of culture in this context. Also, besides measuring the subjective perceptions of genital arousal, several components of sexual response could be measured (e.g.,

[1] It should be recognized that there is very little research supporting the notion that higher olfactory acuity affects women's sexual experiences differently (Bendas, 2016).

physiological genital arousal), since it is possible that body odors may have an effect depending on the sexual component that is being measured.

This study presents a preliminary paradigm to test the influence of body odors on perceived genital arousal. Due to its preliminary nature, several limitations must be addressed. First, despite the strong variability on how subjective sexual responses are assessed, the single item used in the present study to evaluate perceived genital arousal might not be capturing the full concept of subjective sexual arousal, which often includes markers of affective states. A more comprehensive assessment of subjective and objective sexual response should be included in future research. Also, it is worth noting that menstrual cycle was not accounted in the current design, and only hormonal contraception intake was controlled and included in the participants' description. Although findings from studies on the role of menstrual cycle on sexual response have not been conclusive (cf. Bossio, Suschinsky, Puts, & Chivers, 2014), there is a large body of research suggesting an association between the menstrual cycle phases and appraisals of attractiveness (e.g., Jones et al., 2008).

As a development of this research, several methodological arrangements should be considered: (1) different odor combinations should be tested, such as the usage of odors that are and are not congruent with the sexual partner preferences. This will enable to test if our results regarding perceived genital arousal are indeed related with mating behavior in heterosexual individuals, since sexual orientation results in different brain processing of odors (Savic, Berglund, & Lindström, 2005; Berglund, Lindström, & Savic, 2006); (2) besides body odors and no odor conditions, a third odor stimulus of some type (e.g., a common odor) should be considered as the results from this study only show the influence of body odors and no odor on the perceived genital response (Graham, Sanders, Milhausen, & McBride, 2004); (3) consider a within-subjects design study to investigate differences in the perceived genital arousal responses; (4) to further explore the influence of odors' pleasantness in human's sexual response, future research should also perform a pre-selection of the odor stimuli according to their pleasantness in order to determine whether the pattern of results follows that from the present experiment; (5) finally, replicating this study with different sexual orientations, as well as considering other components of human sexual response, should be of interest.

In conclusion, findings on the effects of body odors in perceived genital arousal suggest the existence of gender-specific effects, with women's perceived genital arousal being modulated by the presence of body odors, while this was not the case for men. This suggests that different processes may intervene in the relationship between body odors and human sexual response, depending on the gender. Despite preliminary, the present findings open new venues of research in the context of mating behavior and chemosensory communication, adding to the literature on human sexuality.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

Bendas, J. (2016). *Odor threshold relates to sexual pleasure*. Poster presented at the meeting of European Chemoreception Research Organization, Athens, Greece.

Berglund, H., Lindström, P., & Savic, I. (2006). Brain response to putative pheromones in lesbian women. *Proceedings of the National Academy of Sciences, 103*(21), 8269–8274.

Bossio, J. A., Suschinsky, K. D., Puts, D. A., & Chivers, M. L. (2014). Does menstrual cycle phase influence the gender specificity of heterosexual women's genital and subjective sexual arousal? *Archives of Sexual Behavior, 43*(5), 941–952.

Carvalho, J., Gomes, A. Q., Laja, P., Oliveira, C., Vilarinho, S., Janssen, E., & Nobre, P. (2013). Gender differences in sexual arousal and affective responses to erotica: The effects of type of film and fantasy instructions. *Archives of Sexual Behavior, 42*(6), 1011–1019.

Cenfetelli, R., & Bassellier, G. (2009). Interpretation of formative measurement in information systems research. *MIS Quarterly, 33*(4), 689–708.

Chrea, C., Valentin, D., Sulmont-Rossé, C., Mai, H. L., Nguyen, D. H., & Abdi, H. (2004). Culture and odor categorization: Agreement between cultures depends upon the odors. *Food Quality and Preference, 15*(7), 669–679.

Croy, I., Negoias, S., Novakova, L., Landis, B. N., & Hummel, T. (2012). Learning about the functions of the olfactory system from people without a sense of smell. *PLoS ONE, 7*(3), e33365–e33365.

Distel, H., Ayabe-Kanamura, S., Martínez-Gomez, M., Schicker, I., Kobayakawa, T., Saito, S., & Hudson, R. (1999). Perception of everyday odors—Correlation between intensity, familiarity and strength of hedonic judgement. *Chemical Senses, 24*(2), 191–199. https://doi.org/10.1093/chemse/24.2.191.

Distel, H., & Hudson, R. (2001). Judgement of odor intensity is influenced by subjects' knowledge of the odor source. *Chemical Senses, 26*(3), 247–251.

Doty, R. L. (1975). An examination of relationships between the pleasantness, intensity, and concentration of 10 odorous stimuli. *Perception and Psychophysics, 17,* 492–496.

Doty, R. L., & Cameron, E. L. (2009). Sex differences and reproductive hormone influences on human odor perception. *Physiology & Behavior, 97*(2), 213–228.

Franzoi, S. L., & Herzog, M. E. (1987). Judging physical attractiveness what body aspects do we use? *Personality and Social Psychology Bulletin, 13*(1), 19–33.

Gower, D. B., Holland, K. T., Mallet, A. I., Rennie, P. J., & Watkins, W. J. (1994). Comparison of 16-androstene steroid concentrations in sterile apocrine sweat and axillary secretions: Interconversions of 16-androstenes by the axillary microflora—a mechanism for axillary odour production

in man? *Journal of Steroid Biochemistry and Molecular Biology, 48*(4), 409–418.
Graham, C. A., Janssen, E., & Sanders, S. A. (2000). Effects of fragrance on female sexual arousal and mood across the menstrual cycle. *Psychophysiology, 37*(1), 76–84.
Graham, C. A., Sanders, S. A., Milhausen, R. R., & McBride, K. R. (2004). Turning on and turning off: A focus group study of the factors that affect women's sexual arousal. *Archives of Sexual Behavior, 33*(6), 527–538.
Havlicek, J., & Lenochova, P. (2006). The effect of meat consumption on body odor attractiveness. *Chemical Senses, 31,* 747–752.
Havlicek, J., & Roberts, S. C. (2009). MHC-correlated mate choice in humans: A review. *Psychoneuroendocrinology, 34*(4), 497–512.
Havlicek, J., Saxton, T. K., Roberts, S. C., Jozifkova, E., Lhota, S., Valentova, J., & Flegr, J. (2008). He sees, she smells? Male and female reports of sensory reliance in mate choice and non-mate choice contexts. *Personality and Individual Differences, 45*(6), 565–570.
Heckmann, M., Teichmann, B., Pause, B. M., & Plewig, G. (2003). Amelioration of body odor after intracutaneous axillary injection of botulinum toxin A. *Archives of Dermatology, 139,* 57–59.
Herz, R. S. (2004). A naturalistic analysis of autobiographical memories triggered by olfactory visual and auditory stimuli. *Chemical Senses, 29*(3), 217–224.
Herz, R. S., & Cahill, E. D. (1997). Differential use of sensory information in sexual behavior as a function of gender. *Human Nature, 8*(3), 275–286.
Herz, R. S., & Inzlicht, M. (2002). Sex differences in response to physical and social factors involved in human mate selection: The importance of smell for women. *Evolution and Human Behavior, 23*(5), 359–364.
Jacob, S., McClintock, M. K., Zelano, B., & Ober, C. (2002). Paternally inherited HLA alleles are associated with women's choice of male odor. *Nature Genetics, 30*(2), 175–179.
Jones, B. C., DeBruine, L. M., Perrett, D. I., Little, A. C., Feinberg, D. R., & Smith, M. J. L. (2008). Effects of menstrual cycle phase on face preferences. *Archives of Sexual Behavior, 37*(1), 78–84.
Keller, A., & Vosshall, L. B. (2016). Olfactory perception of chemically diverse molecules. *BMC Neuroscience, 17,* 55. https://doi.org/10.1186/s12868-016-0287-2.
Knaapila, A., Tuorila, H., Vuoksimaa, E., Keskitalo-Vuokko, K., Rose, R. J., Kaprio, J., & Silventoinen, K. (2012). Pleasantness of the odor of androstenone as a function of sexual intercourse experience in women and men. *Archives of Sexual Behavior, 41*(6), 1403–1408.
Kromer, J., Hummel, T., Pietrowski, D., Giani, A. S., Sauter, J., Ehninger, G., … Croy, I. (2016). Influence of HLA on human partnership and sexual satisfaction. *Scientific Reports, 6,* 32550. https://doi.org/10.1038/srep32550.
Lenochová, P., Roberts, S. C., & Havlicek, J. (2009). Methods of human body odor sampling: The effect of freezing. *Chemical Senses, 34*(2), 127–138.
Lenochová, P., Vohnoutova, P., Roberts, S. C., Oberzaucher, E., Grammer, K., & Havlíček, J. (2012). Psychology of fragrance use: Perception of individual odor and perfume blends reveals a mechanism for idiosyncratic effects on fragrance choice. *PLoS ONE, 7*(3), e33810. https://doi.org/10.1371/journal.pone.0033810.
Levin, R. (2004). Smells and tastes—their putative influence on sexual activity in humans. *Sexual and Relationship Therapy, 19*(4), 451–462.
Lübke, K. T., & Pause, B. M. (2015). Always follow your nose: The functional significance of social chemosignals in human reproduction and survival. *Hormones and Behavior, 68,* 134–144.
Martins, Y., Preti, G., Crabtree, C. R., Runyan, T., Vainius, A. A., & Wysocki, C. J. (2005). Preference for human body odors is influenced by gender and sexual orientation. *Psychological Science, 16*(9), 694–701.
O'Brien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity, 41,* 673–690.
Penn, D., & Potts, W. (1998). How do major histocompatibility complex genes influence odor and mating preferences. *Advances in Immunology, 69,* 411–436.
Roberts, S. C., Gosling, L. M., Carter, V., & Petrie, M. (2008). MHC-correlated odour preferences in humans and the use of oral contraceptives. *Proceedings of the Royal Society of London B: Biological Sciences, 275*(1652), 2715–2722.
Savic, I., Berglund, H., & Lindström, P. (2005). Brain response to putative pheromones in homosexual men. *Proceedings of the National Academy of Sciences of the United States of America, 102*(20), 7356–7361.
Semin, G. R., & De Groot, J. H. (2013). The chemical bases of human sociality. *Trends in Cognitive Sciences, 17*(9), 427–429.
Sodavari, M., Shahidi, M. A., Almadani, S. A. H., Moazedian, A., & Imani, M. S. (2014). The role of pleasant and unpleasant odors in the individual and social attractiveness. *Journal of Educational and Management Studies, 4*(2), 311–315.
Sorokowska, A., Butovskaya, M., & Veselovskaya, E. (2015). Partner's body odor versus relatives' body odor: A comparison of female associations. *Polish Psychological Bulletin, 46*(2), 209–213.
Stevenson, R. J. (2010). An initial evaluation of the functions of human olfaction. *Chemical Senses, 35*(1), 3–20.
Suschinsky, K. D., & Lalumiere, M. L. (2012). Is sexual concordance related to awareness of physiological states? *Archives of Sexual Behavior, 41*(1), 199–208.
Wedekind, C., & Füri, S. (1997). Body odour preferences in men and women: Do they aim for specific MHC combinations or simply heterozygosity? *Proceedings of the Royal Society of London B: Biological Sciences, 264*(1387), 1471–1479.
Wedekind, C., Seebeck, T., Bettens, F., & Paepke, A. J. (1995). MHC-dependent mate preferences in humans. *Proceedings of the Royal Society of London B: Biological Sciences, 260*(1359), 245–249.
Wyatt, T. D. (2003). *Pheromones and animal behaviour: Communication by smell and taste*. Cambridge: Cambridge University Press.