A Psychological Scale for Body Odour Awareness

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Abstract

People differ in their awareness for odours surrounding them. Body odours are a special category because they are a medium for social communication. Body odours evoke approach and avoidance behaviours such as withdrawing from social interaction, and personal hygiene behaviours like washing or using fragranced products. So far it has remained unclear what the role of conscious awareness of body odours is in guiding social behaviour. Here, we present a new psychological scale on odour awareness, focusing specifically on body odours: the Body Odour Awareness Scale (BOAS). The scale was validated measuring body odour awareness in two dimensions (valence and source) over four domains: awareness for one's own body odours, both favourable and unfavourable, and awareness for other persons' body odours, both favourable and unfavourable. An explorative follow-up study suggested regional differences exist in body odour awareness, but these are not the same for every dimension of body odour awareness. Taken together, these results suggest the new BOAS is a useful tool to assess differences in awareness for body odours, and uncover the application potential for this new and validated scale.

Introduction

Environmental odours do not always attract attention yet display the power to affect human behaviour outside awareness. According to Stevenson (2010), odours serve three primary functions: ingestion related functions, e.g., in food; alarm us for environmental hazards; and social functions. The social function is closely linked to body odours that convey state or trait features of the person emitting them (De Groot et al., 2012; De Groot et al., 2018; Lübke & Pause, 2015; Semin & De Groot, 2013). Like many natural odours we encounter on in our environment, body odours are highly complex mixtures of many different molecules (Amann et al., 2014; De Groot, Croijmans & Smeets, 2021; Livermore & Laing, 1998).

Upon closer inspection, body odours seem to be a category on their own: like all odours they are perceived holistically, i.e. they are perceived as an indivisible whole. In addition their perceptual properties cannot be easily, if at all, predicted from the combination of compounds that make up the mixture (Livermore & Laing, 1998; McGee, 2020; Thomas-Danguin et al., 2014; James, 2020). The mixtures leading to body odours are composed of compounds from (at least) 10 different chemical classes (Amann et al., 2014), their ultimate holistic perceptual character tends to be dominated by sulphurous compounds and fatty acids. As a result, body odours may be dominated by the character of few compounds in the mixture. The smell of these, which are perceived as neutral to unpleasant by most people (McBurney, Levine, & Cavanaugh, 1976; Mitro, Gordon, Olsson & Lundström, 2012)[1], may afford avoidance behaviour in the form of moving away from a person, or engaging in personal hygiene behaviour such as showering and the use of perfumes. Yet, from a substantial body of chemosignaling literature we know body odours can also elicit responses that are not in line with the valence value of the (holistic) perception. Females exposed to the smell of sweat collected from donors in a happy state showed happy facial expressions (De Groot et al., 2015; De Groot et al., 2018) while the sweat odour itself was not evaluated as pleasant. Likewise, body odours not perceived as different based on self-report can invite subtly different responses in line with the emotional state the sender was in (fear, disgust; De Groot et al., 2012; De Groot, Semin & Smeets, 2014; De Groot et al., 2018; Lübke & Pause, 2015; Prehn, Ohrt, Sojka, Ferstl & Pause, 2006; Semin & De Groot, 2013). This suggests that body odours can be vehicles for social communication containing signals that do not seem to be

[1] Notable exceptions to this undesirability also exist, for example in the context of oneself, a romantic partner, or members of kin (Olsson, Barnard & Turri, 2006; Mahmut & Croy, 2019; Schafer et al., 2020; Perl, Mishor, Ravia, Ravreby, & Sobel, 2020).

picked up consciously, but are subject to implicit information-processing, thus going beyond the “mere” holistic perceptual quality of the odours.

Body odours may evoke dualistic or even contrasting reactions in perceivers, on the one hand inviting avoidance related to the negative holistic experience of the odour, while on the other hand inducing a smile which is more in line with an approach response. However, it seems too early to conclude explicit holistic perception and implicit effects linked to chemical signals are unrelated: For example, diseased, potentially contagious individuals’ body odours contain a signal that others can pick up and are aware of, so they can avoid the potential source of the disease (Shirasu & Touhara, 2011; Olsson et al., 2014; Gordon et al., 2015). This illustrates that these two functions of olfaction, social communication and avoidance of environmental hazards, sometimes overlap.

So far, we have not seen a systematic line of research to address the differences between conscious body odour perception and the implicit reactions evoked in an individual being exposed to chemical signals in the emitted mixture of compounds, which are less accessible to conscious perception. To further probe this relation, we introduce an instrument to uncover awareness for body odours. Body odour awareness is defined as the general tendency to which a person takes notice, acts upon, or is influenced by body odours in their environment, positive and negative, emanating from themselves or others. It is possible that awareness of body odour, attention to body odour, or a special interest in/or importance attached to body odours plays a role in how people react when smelling body odours. This can go in either direction: high awareness for body odours from either self or others may correlate to behaviours activated by holistic perception of body odour as unpleasant, leading to washing or masking by using fragranced products or perfume. High awareness may prepare a person to the social signal contained in body odour making the person more responsive to this message. Alternatively, being aware of a smell may invite deep processing of that smell, superseding the fast, implicit behavioural response (cf. Craik & Lockhart, 1972; Craik, 2010) to body odours. Before we further elaborate on this instrument, and what domains the instrument contains, we will first give an overview of prior research in the area of odour awareness.

Previous work on odour awareness has shown that there are individual differences in the importance people attribute to odours and the attention they allocate to them (e.g., Ayabe-Kanamura, Saito, Distel, Martinez-Gomez, & Hudson, 1998; Ferdenzi et al., 2013; Sorokowska et al., 2018). Research using the Odour Awareness Scale (OAS; Smeets et al., 2006), or parts of it, has shown that there are large individual differences (Dematte et al., 2011) and cultural and regional differences in odour awareness (Sorokovska et al. 2018; Seo et al., 2010; Ferdenzi. Mustonen, Tuorila & Schaal, 2008). Similarly, olfaction experts and novices differ in their awareness for environmental smells (Croijmans & Majid, 2016). Using other surveys on odour awareness has shown children's odour awareness and olfactory behaviour depend on their experience with odours in early life (Ferdenzi, Coureaud, Camos & Schaal, 2008; Novakova & Mrzilkova, 2016). In line with this, research has shown that odour awareness predicts olfactory related activities, for example it predicts trying novel types of flavours in food, in adults (Novakova, Valentova & Havlicek, 2014). Furthermore, odour awareness is related to certain aspects of odour cognition, such as memory for smells (Arshamian, Willander & Larsson, 2011). This shows that how people respond to odours across the three functional categories of smells introduced by Stevenson (2010) is different, potentially leading to different approach, avoidance, and social communication behaviours.

Differences in awareness for body odours are not straightforward to measure. Direct measures of olfactory functioning, such as perceptual sensitivity and identification ability for odours, appear to be only weakly correlated with odour awareness (Dal-Bo et al., 2021; Demattè et al., 2011; Novakova et al,. 2014; Smeets et al., 2006). This makes that odour sensitivity, as measured for example by intensity ratings or a threshold test, is not a good measure to estimate awareness for (body) odours. A validated questionnaire measuring odour awareness or the subjective attitude towards odours may offer a solution to this problem (cf., Han et al., 2020). However, general odour awareness, as for example the Odour Awareness Scale from Smeets et al. (2006), covers much more than body odours, and only briefly touches on some, mostly negative aspects of body odour. Similarly, the Body Odour Disgust Scale only covers how much of the strongly negative emotion *disgust* people experience from smelling body odours (Liuzza et al., 2017). This contrasts the finding that favourable body odour is named as one of the most important aspects in interpersonal relationships (Allen, Havlicek, Williams & Roberts, 2018; Ferdenzi, Rouby, & Bensafi, 2016; Croy, Bojanowski & Hummel, 2013; Mahmut & Croy, 2019; Mahmut, Stevenson, & Stephen, 2019; Herz & Cahil, 1997). Body odours also play an important, mostly positive role in kin relationships, and kin recognition (Croy, Frackowiak, Hummel & Sorokowska, 2017; Lübke et al., 2014).

Other efforts to study social odour awareness do not explicitly give attention to the important role that artificial additions such as fragrances have in body odours (e.g., Dal-Bo et al., 2021). The tendency to use fragrances to mask and alter body odour, to improve how we smell, may change our perception of body odours, and with it, could alter the communication (e.g., Lenochova et al., 2012; Croijmans, Beetsma, Aarts, Gortemaker, & Smeets, 2021; but see Cecchetto, Lancini, Bueti, Rumiati & Parma, 2019). Many people use at least one scented product every day, but using a dozen scented products is also not an exception – think of perfumes, deodorants, hand sanitizers, shower gels, shampoos, cremes, make-up, toilet sprays, scented candles, laundry detergent, fabric softener, etc. The act of applying specific substances (i.e. self-anointment behaviour) to alter how one smells is ancient (Drobnick, 2006; Prasad, Pratap, Neelima & Satyanrayanashastry, 2008), and employed in virtually every human culture in one form or another (Classen, Howes, & Synnott, 1994), This behaviour is also seen in other realms of the animal kingdom, for example in spider monkeys (Laska, Bauer & Salazar, 2007). But in humans, the behaviour is particularly prominent, with an associated billion dollar turnover for fragrance industries every year (Sabanoglu, 2020). This shows people act both as passive and active senders of their own body odours, and perceivers of body odours originating from others. The use of fragrance can be very effective in altering how others perceive or evaluate us.

In sum, the Body Odour Awareness Scale (BOAS) focuses on assessing awareness of body odours on the dimensions of source (self vs. others) and valence (positive vs. negative), considering both natural and artificial additions to the odour. The primary aim of this study was to develop a validated measure to assess individual differences in awareness for body odours. In the first study, two dimensions (positive vs. negative valence, own vs. other as a source, resulting in four domains) of the BOAS, were validated by means of a confirmatory factor analysis. In addition, internal consistency, test-retest reliability, and convergent and divergent validity were analysed to further establish the validity and reliability of the BOAS. As an extra measure of external validity we compared scores of men and women, since odour awareness is usually reported to be higher in women than in men (Smeets et al., 2006; Novakova et al., 2016; Doty & Cameron, 2009; Majid, Speed, Croijmans & Arshamian, 2018), and we expected the same pattern for body odour awareness.

As a secondary aim, we explored whether we could uncover differences between groups of people with diverse cultural backgrounds, when looking specifically at *body* odour awareness. To this end, data was collected from respondents living in the USA, the Netherlands, and India, to explore whether there are indications for cultural differences in body odour awareness as measured by the BOAS. This explorative study was inspired on a study by Sorokowska and colleagues (2018), that suggested individual level differences on odour awareness are more important than regional differences.

Methods Study 1

Questionnaire construction

Preliminary version. An initial questionnaire was developed in Dutch. The questionnaire was based on the dimensions *positive* and *negative body odour awareness*, paralleling the Odour Awareness Scale from Smeets and colleagues (2006). It is hypothesized that odour valence is the principal perceptual dimension odours are categorized on (Berglund, Berglund, Engen & Ekman, 1973; Yeshurun & Sobel, 2011), and there is scientific support that this primary dimension can be found across diverse cultures (Arshamian et al., preprint; Wnuk & Majid, 2014). Question development was based on the cognitive item-response theory, that hypothesizes that respondents go through several iterative steps when answering survey questions (Lietz, 2010; Tourangeau, Rips & Rasinski, 2000). Following this model, the positive/negative dimensions were divided into different indicators. Different indicators for positive and negative body odour awareness were formulated by brainstorming after reviewing the literature on body odours. This questionnaire, spanning 42 questions on positive and negative body odour awareness, was initially attested in 163 participants. Given the relatively disappointing results that suggested poor validity and reliability (see Supplementary materials for this version of the questionnaire), it was decided to re-develop this set of questions using a different domain structure.

Revised version. The 32 items of the revised version of the questionnaire were based on the literature outlined in the introduction (see Table 1), again including a *valence* dimension (positive vs. negative). It was decided to add a *source* dimension of *own* vs. *other* body odours in the questionnaire, to follow the sender-perceiver model of social chemosignaling (De Groot, Semin & Smeets, 2014; Wyatt, 2010). Following this, indicators for body odour awareness were formulated during a brainstorm and back-and-forth between the authors, uncovering what aspects of body odours within the valence and source dimensions may be important to be aware of, given the functions of human olfaction (Stevenson, 2010). Indicators used to formulate questions on body odour awareness were: *positive body odours, negative body odours, public body odours, intimate body odours, artificial body odours, natural body odours, attractiveness,* and *familiar body odours*. These indicators were subsequently categorized into the 4 domains of body odour awareness: awareness for favourable own body odours (*Own-Positive*), awareness for unfavourable own body odours (*Own-Negative*), awareness for favourable body odours from others (*Other-Positive)*, and awareness for unfavourable body odours from others (*Other-Negative)*.

Table 1. The four domains of the Body Odour Awareness Scale with example situations where odours may occur.

		Source dimension	
		Own odour	Others' odour
Valence dimension	Negative	*Sweat smell after exercise*	*Smelling a stranger on the bus*
	Positive	*The smell of your hair after taking a shower*	*The smell of a romantic partner*

Questions were composed in Dutch. The first versions of the questions, aiming for 7 to 8 questions per dimension to trade-off between the length of the questionnaire and content validity, were created by the first author, and modified after rounds of suggestions and feedback from the other authors.

The Dutch version (See table A1 in the Appendix) was translated to English and then back translated to Dutch by an independent English/Dutch bilingual to check consistency across different versions. Any inconsistencies were resolved through discussion. The English version was once more checked by a native English speaker. See table 1 for the 32 item versions of the questionnaire in English.

Nine statements were reversely phrased (indicated with an ‘R’ in Table 2). Statements were answered using a 7-point Likert scale, with scale points labeled: “1 – completely disagree”, “2 mostly disagree”, “3 somewhat disagree”, “4 neither agree nor disagree”, “5 somewhat agree”, “6 mostly agree”, and “7 completely agree”.

Table 2: English items of the BOAS, listed according to their hypothesized domain. Note: item codes in **bold** remain in the questionnaire after validation.

hypothesized domain	Item code	Item content
Awareness for own favourable body odour (Own-Positive)	**BOAS1**	When I wear my favourite perfume or aftershave, I still smell it the entire day
	BOAS2R	I don't notice that my hands *smell* clean after washing them – I just *know* they are clean
	BOAS3	I still notice hours after I wash my hair that my hair smells clean
	BOAS4	I take care that I always smell pleasant
	BOAS5	I take care that I always smell neutral
	BOAS6	When I'm meeting someone, I make sure that I smell pleasant
	BOAS7	I regularly check if my clothing still smells nice
	BOAS8R	I don't really care how my deodorants or perfumes smell, as long as I don't smell like sweat
Awareness for own unfavourable body odour (Own-Negative)	**BOAS9**	I notice when my feet smell strong
	BOAS10	I notice when my clothing smells musty and unpleasant
	BOAS11	I immediately notice if I have bad breath
	BOAS12R	I don't really care if I notice that I smell (through my deodorant)
	BOAS13	I notice immediately if I smell like sweat
	BOAS14	When my hands smell like something (such as soap or food), I'm preoccupied with it constantly
	BOAS15R	I'm not bothered by how I smell when I am talking to someone
	BOAS16R	I don't care that people might smell something after I went to the toilet
Awareness for favourable body odours from others (Other-Positive	**BOAS17**	I recognize friends and family by how they smell
	BOAS18	I find it important that the people that I hang out with smell pleasant
	BOAS19R	I rarely notice if someone is wearing perfume
	BOAS20R	When I meet someone, I don't really care how they smell
	BOAS21	I notice when someone's hair smells nice
	BOAS22	I feel attracted to a stranger if that person is wearing a nice perfume or aftershave
	BOAS23	I feel attracted to strangers if their body odour is pleasant
	BOAS24	The smells of friends and family can really make me feel at ease
Awareness for unfavourable body odours from others (Other-Negative)	**BOAS25**	I notice when someone smells badly of sweat
	BOAS26R	If I see someone coming out of a toilet cubicle, I never choose another cubicle just because of the smell
	BOAS27	I notice immediately if someone has just had a cigarette/smoke
	BOAS28	If someone on public transport has a strong smell, I will keep my distance
	BOAS29	If a friend, my partner or a family member is ill, I notice this from how they smell
	BOAS30	I smell when someone just had a workout
	BOAS31R	I don't find it difficult to be intimate with someone who smells unpleasant
	BOAS32	I am offended when I smell that someone just farted

Questionnaire validation

Participants. Two-hundred participants were invited to participate in an online study via the platform Prolific. The survey was completed by 193 participants (*M* age = 30.2 years, range 18-69, *SD* = 8.5), of which 109 female (*M* age = 31.3 years, *SD* = 8.5) and 89 male (*M* age = 28.7 years, *SD* = 8.2). One-hundred-eight participants reported their native language was English, and the additional 85 participants reported to be fluent in English but were not English native speakers. See table A2 in the Appendix for a full overview of the country of residence of the participants. Participants had diverse educational backgrounds, with 5 participants (2.5% of the total) holding a doctorate degree, 54 (27.3%) indicating having followed some college, 14 (7.1%) completed a 2 year degree, 54 (27.8%) completed a 4 year degree, 38 indicated to have completed a professional degree, 23 (11.6%) completed high school as their highest finished education and 5 (2.5%) participants indicated not having finished high school. Since smoking and anosmia (i.e., the absence of one's sense of smell) may have an influence on odour awareness, participants indicated whether they smoked daily (*n* = 18, 9.3%), occasionally (*n* = 31, 16.1%), or never (*n* = 144, 74.6%). Five participants indicated their sense of smell was somewhat impaired (2.5%), and none of the participants reported a completely impaired sense of smell.

Other materials. It was expected body odour awareness is correlated to the broader construct of odour awareness, with a large size of the effect ($r > .5$; Cohen, 1988). To validate the BOAS, correlations with the Odour Awareness Scale (OAS; Smeets et al., 2006) were calculated. The OAS measures odour awareness with 31 questions over two dimensions, i.e., positive odour awareness and negative odour awareness. The reliability of the current administration of the OAS was operationalized by calculating internal consistency, with a McDonald's omega for the full scale (*M* = 3.59, *SD* = .50) of $\omega = .91$, for the positive scale (*M* = 3.77, *SD* = .57) $\omega = .84$, and for the negative scale (*M* = 3.52, *SD* = .52) of $\omega = .86$, indicating good internal consistency. To test construct validity by means of convergent validity, correlations between the different dimensions of the OAS and the different dimensions of the BOAS were calculated, with the expectation that the positive dimensions of the BOAS would correlate positively ($r > .5$) with the positive dimension of the OAS, and the negative dimensions of the BOAS would correlate positively with the negative dimension of the OAS.

Furthermore, divergent validity was assessed by calculating correlations of the BOAS to scores on a different construct that is theoretically unrelated (cf. Campbell & Fiske, 1959). Based on previous research (Croijmans et al. 2021), it was expected that body odour awareness is not correlated to self-esteem. To establish divergent validity as an indication of construct validity, the Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1979; Frank, De Raedt, Barbez, Rosseel, 2008) was added to the study. The RSES measures self-esteem using 10 questions over one single dimension. The internal consistency of the current administration of the RSES ($M = 2.84$, $SD = .53$) was $\omega = .91$, suggesting good reliability.

Procedure

Participants were invited through Prolific by means of a brief text invitation explaining the purpose and goal of the study. Participants were then again briefed about the study's content and duration, and gave their consent for participating voluntarily and using their (anonymous) data before starting the survey. The validation study was done in English. First, participants completed the 32 items of the BOAS, presented in a random order. Next, they completed the 31 questions of the OAS in the original order, and then the 10 questions of the RSES. Finally, participants completed 6 questions about their background (age, gender, education, smoking, anosmia, and native language). Participants were then invited for the follow-up study taking place one week after the initial study. To calculate test-retest reliability, 100 participants from the first sample were invited to take part in this follow-up study composed of only the BOAS. Ninety-seven participants (*M* age = 31.2 years, range 18-69, *SD* = 8.7), of which 53 female, completed the follow-up study.

Data analysis

The data analysis followed the steps suggested by Dima (2018), but with omitting the steps on item response theory since generation of the set of questions was already restricted to a smaller set of items: (1) item distributions and summary statistics, (2) scale structure using confirmatory factor analysis to test the expected four-domain structure, where model misfit is indicated by: a significant χ^2-goodness of fit test, root mean squared error-of-approximation (RMSEA) values for less than adequate fit ≥.08 or less than good fit ≥.06 (cf. Gruijters, Tybur, Ruijter, Massar, 2016), Tucker-Lewis index (TLI) and Comparative Fit index (CFI) ≤ .95, in addition to the items not loading with significant *z*-values at p =.01 on the specified factors, (3) test-retest reliability and internal consistency via classical test theory, (4) calculation and description of global scores, and (5) external validity in shape of convergent and divergent validity (cf. Campbell & Fiske, 1959) via calculation of the correlations with the OAS, and RSES, and a comparison of the scores in females and males. The method described by Campbell and Fiske (1959) suggests to include different measures of a related trait (in this case odour awareness) and of a different trait (in this case self-esteem), to establish validity. According do Campbell and Fiske (1959, p. 104) “Measures of the same [or related] traits should correlate higher with each other than they do with measures of different traits involving separate methods”. Thus, we expected higher correlations between the scores on the BOAS and OAS than between scores of the BOAS and RSES. More specifically, since body odour perception was previously found to be unaffected by perceiver self-esteem (Croijmans et al. 2021), there was a theoretical reason to hypothesize a weak (r <.2) correlation between the RSES and the domains of the BOAS. On the other hand, general odour awareness was hypothesized to be related to/predictive of awareness for body odours, thus a positive correlation ($r > .5$) between the overall scales and subscales of the BOAS and OAS would indicate convergent evidence for this relationship and thus, construct validity of the BOAS.

Since odour awareness is usually reported to be higher in women than in men (Sorokowska et al., 2018; Smeets et al., 2008; Doty & Cameron, 2009), we expected the same pattern for *body* odour awareness, as an additional test of the construct validity of the BOAS. To test this, men and women were compared on each domain of the BOAS and on the full scale.

Results Study 1

Item distribution and summary statistics

Data inspection per item suggested sufficient variation on each item, meaning that for most items, participants made use of all answer options, with the standard deviations suggesting that the data was spread around the mean enough to be able to do the statistical analyses (see Table 3). Inter-item correlations (see appendix Figure A1) suggested positive correlations $r >$ .20 (following Dima, 2018) between most items, with item 5 and item 14 being notable exceptions.

Table 3: Descriptive statistics per item. Note that items with an R in the label are reverse-coded..

item	mean	*SD*	min	max	skew	kurtosis	*SE*
BOAS1	3.17	1.69	1	7	-0.10	-0.96	0.12
BOAS2R	3.49	1.77	1	7	-0.36	-1.00	0.13
BOAS3	4.01	1.63	1	7	-0.60	-0.47	0.12
BOAS4	4.79	1.11	2	7	-0.74	0.21	0.08
BOAS5	3.49	1.37	1	7	-0.11	-0.55	0.10
BOAS6	5.14	0.98	3	7	-1.23	1.24	0.07
BOAS7	4.43	1.33	1	7	-1.05	1.10	0.10
BOAS8R	3.46	1.89	1	7	-0.28	-1.19	0.14
BOAS9	4.33	1.66	1	7	-0.96	0.01	0.12
BOAS10	5.06	0.94	1	7	-1.27	3.51	0.07
BOAS11	4.09	1.54	1	7	-0.64	-0.41	0.11
BOAS12R	4.96	1.15	1	7	-1.27	1.64	0.08
BOAS13	4.65	1.27	2	7	-0.91	0.24	0.09
BOAS14	2.92	1.72	1	7	0.03	-1.11	0.12
BOAS15R	4.59	1.54	1	7	-1.20	0.78	0.11
BOAS16R	4.32	1.68	1	7	-0.85	-0.29	0.12
BOAS17	3.13	1.73	1	7	-0.33	-0.95	0.12
BOAS18	4.06	1.34	1	7	-0.51	-0.11	0.10
BOAS19R	4.26	1.48	1	7	-0.91	0.13	0.11
BOAS20R	4.07	1.42	1	7	-0.57	-0.21	0.10
BOAS21	4.32	1.40	1	7	-1.14	1.37	0.10
BOAS22	3.95	1.35	1	7	-0.47	-0.14	0.10
BOAS23	3.74	1.52	1	7	-0.58	0.03	0.11
BOAS24	4.08	1.26	1	7	-0.52	0.27	0.09
BOAS25	5.13	1.08	1	7	-1.82	4.67	0.08
BOAS26R	4.01	1.79	1	7	-0.59	-0.66	0.13
BOAS27	5.28	1.12	1	7	-2.07	4.97	0.08
BOAS28	4.93	1.13	2	7	-1.15	1.19	0.08
BOAS29	2.21	1.71	1	7	0.38	-0.89	0.12
BOAS30	3.73	1.44	1	7	-0.59	-0.08	0.10
BOAS31R	4.29	1.88	1	7	-0.97	-0.22	0.14
BOAS32	3.47	1.82	1	7	-0.25	-0.91	0.13

Scale structure

The initial confirmatory factor analysis indicated somewhat mediocre model fit (following criteria from Dima, 2018; Gruijters et al., 2016), χ^2 (458) = 822, $p < .001$, RMSEA = .064 [.057 - .071], AIC = 21178, CFI = .72, TLI = .70. Factor loadings suggested items 5, 14, 26 and 31 might not fit the solution well, with z < 3.1, $p > .001$ (also see Appendix Table A3). Since item 5 is not necessarily about *positive* but about *neutral* body odour, removal of this item was supported by the item content, and further supported by the weak inter-item correlations of this item with other items in the scale (Appendix I, Figure A1); item 14's content appeared not necessarily about negative body odours, thus misfitting this specific domain; item 26 describes behaviour not necessarily related to smell alone, and can be interpreted somewhat ambiguously; and item 31 contained a double denial which could be somewhat difficult to interpret (see Table 2).

It was decided to remove these four items, and re-run the analysis (Table 4) to see if the model fit improved using the selected 28 items. The factor loadings of the second CFA suggested the factor structure was as hypothesized, with factor estimates for this model all non-zero, *z*s > 3.1, *p*s < .001, and the model fit indices slightly improved compared to the first CFA model, with fit indices being χ^2 (344) = 634, $p < .001$, RMSEA = .066 [.058 - .074], AIC = 18182, CFI = .76, TLI = .74.

Table 4: Factor Loadings for the second CFA of Study 1

				95% Confidence Interval			
Factor	Indicator	Estimate	SE	Lower	Upper	Z	p
Own-Positive	BOAS1	0.908	0.1213	0.670	1.146	7.48	< .001
	BOAS2	-0.741	0.1314	-0.999	-0.484	-5.64	< .001
	BOAS3	0.999	0.1147	0.775	1.224	8.71	< .001
	BOAS4	0.839	0.0727	0.697	0.982	11.54	< .001
	BOAS6	0.675	0.0664	0.545	0.805	10.17	< .001
	BOAS7	0.795	0.0931	0.612	0.977	8.54	< .001
	BOAS8	-0.497	0.1441	-0.780	-0.215	-3.45	< .001
Own-Negative	BOAS9	0.711	0.1247	0.467	0.955	5.70	< .001
	BOAS10	0.507	0.0682	0.373	0.641	7.43	< .001
	BOAS11	1.041	0.1055	0.834	1.248	9.87	< .001
	BOAS12	-0.429	0.0884	-0.603	-0.256	-4.85	< .001
	BOAS13	0.942	0.0857	0.774	1.110	11.00	< .001
	BOAS15	-0.583	0.1165	-0.811	-0.354	-5.00	< .001
	BOAS16	-0.420	0.1303	-0.676	-0.165	-3.23	0.001
Other-Positive	BOAS17	0.871	0.1309	0.614	1.127	6.65	< .001
	BOAS18	0.709	0.1011	0.510	0.907	7.01	< .001
	BOAS19	-0.486	0.1165	-0.714	-0.257	-4.17	< .001
	BOAS20	-0.592	0.1095	-0.807	-0.378	-5.41	< .001
	BOAS21	0.709	0.1049	0.504	0.915	6.76	< .001
	BOAS22	0.653	0.1114	0.434	0.871	5.86	< .001
	BOAS23	0.721	0.1244	0.477	0.965	5.79	< .001
	BOAS24	0.584	0.0985	0.390	0.777	5.92	< .001
Other-Negative	BOAS25	0.697	0.0897	0.522	0.873	7.77	< .001
	BOAS27	0.361	0.0930	0.179	0.543	3.88	< .001
	BOAS28	0.425	0.0939	0.241	0.609	4.52	< .001
	BOAS29	0.613	0.1447	0.329	0.896	4.23	< .001
	BOAS30	0.632	0.1190	0.398	0.865	5.31	< .001
	BOAS32	0.569	0.1518	0.271	0.866	3.75	< .001

Classic item response theory reliability

The remaining 28 items were entered into a reliability analysis. First, internal consistency was calculated per domain, and for the whole scale (Table 5).

Internal consistency of the four domains individually was mediocre (Table 5), but since none of the items improved the internal consistency considerably when removed, this mainly suggested that the relatively small set of items covered the whole domain of the construct (i.e., known also as the ‘internal consistency/content validity trade-off’). Internal consistency of the entire scale was satisfactory, with α = .86, ω = .87. No items were marked for removal, since no significant increase in McDonald’s omega was suggested, and items showed sufficient inter-item correlations and item-rest correlations ranging [.26-.64] (see Table 5).

Table 5: means and internal consistency values per domain and for the entire scale

	Number of items	Mean (SD)	Cronbach’s alfa	McDonald’s omega	Item-rest correlation range
Own-positive	7	5.1 (.94)	.73	.77	.27 - .59
Own-negative	7	5.6 (.82)	.66	.70	.25 - .59
Other-positive	8	5.0 (.80)	.68	.69	.21 - .49
Other-negative	6	5.1 (.76)	.52	.55	.17 - .41
Entire scale	28	5.2 (.66)	.86	.87	.23 - .66

To calculate test-retest reliability for the individual domains and the entire scale, the averages were calculated both for the initial administration as well as the second administration. Three measures of test-retest reliability were calculated: Typical error (i.e., the difference between initial and retest measure), change from mean (i.e., the statistical significance of the difference between measures), and correlation between test and retest measures (see Table 6).

Table 6: reliability statistics per domain and for the entire scale.

	Number of items (sample size *N*)	Typical error *M* (*SD*)	Change from mean *t* (*p*)	Retest correlation *r* (*p*)
Own-positive	7 (96)	-.06 (.53)	-1.0 (.298)	.847 (<.001)
Own-negative	7 (96)	.04 (.49)	.71 (.478)	.812 (<.001)
Other-positive	8 (96)	-.13 (.60)	-2.0 (.047)	.725 (<.001)
Other-negative	6 (96)	-.08 (.63)	-1.3 (.196)	.670 (<.001)
Entire scale	28 (96)	-.06 (.32)	-1.8 (.074)	.893 (<.001)

Table 7: descriptive and comparative statistics body odour awareness (BOAS), odour awareness, self-esteem and age, split by gender (women and men). Note: *indicates a statically significant difference between men and women, corrected for age, at p = .01 after correcting for multiple comparisons. ¹) age was compared using a t-test, other variables were compared using ANCOVA.

	Number of items (sample size *N*)	Full sample (N = 193) M (SD)	Women (N = 109) M (SD)	Men (N = 84) M (SD)	F-value (p-value)	Size of the effect η^2
Own-positive BOAS	7 (193)	5.1 (.94)	5.3 (.91)	4.8 (.91)	12.8 (<.001*)	.063
Own-negative BOAS	7 (193)	5.6 (.82)	5.8 (.75)	5.3 (.83)	12.9 (<.001*)	.063
Other-positive BOAS	8 (193)	5.0 (.80)	5.1 (.81)	4.8 (.77)	4.9 (.029)	.025
Other-negative BOAS	6 (193)	5.1 (.76)	5.2 (.71)	5.1 (.83)	1.2 (.283)	.006
Entire scale BOAS	28 (193)	5.2 (.66)	5.3 (.63)	5.0 (.66)	11.4 (<.001*)	.057
Positive Odour awareness	11 (193)	3.7 (.57)	3.7 (.54)	3.7 (.61)	1.1 (.293)	.006
Negative Odour awareness	21 (193)	3.5 (.52)	3.6 (.50)	3.4 (.53)	3.6 (.059)	.019
Odour awareness (entire scale)	32 (193)	3.6 (.50)	3.6 (.47)	3.5 (.53)	2.8 (.095)	.015
Self-esteem	10 (193)	2.8 (.53)	2.8 (.50)	2.9 (.57)	2.5 (.115)	.013
Age	-	30.2 (8.45) [18-69]	31.3 (8.5)	28.7 (8.2)	2.07 (.040)¹	.022

To further test the construct validity, the correlations between the domains and entire scale of the BOAS and a theoretically related construct, i.e., positive and negative (general) odour awareness, and a theoretically unrelated construct, i.e., self-esteem, were calculated (also see Appendix Table A4).

The correlations between different aspects of body odour awareness and positive and negative odour awareness were medium to high (r = [.45 – 77]), and all statistically significant (*p*s <.001), suggesting these two constructs were related without complete overlap, and in turn suggesting satisfactory convergent validity. As expected, there were no relationships between self-esteem and the different domains of body odour awareness (*r*s <.01, *p*s > .05) , suggesting satisfactory divergent validity.

Finally, as an additional test of the external validity, ANCOVAs were done to test the difference between men and women on the four domains of the BOAS and the entire scale (Table 7). Since there was an age difference between men and women (see Table 7), age was added as a covariate. Women reported higher odour awareness for their own body odours, both positive and negative, than men, p <.001. The difference between women and men for awareness of body odours of others was not significant after correcting for multiple comparisons. This finding suggests women are slightly more aware of body odours, but the effect sizes nevertheless suggest strong similarities between the two gender groups (see Appendix II for density distribution plots, plotting data for male and female participants side by side).

In summary, the 28 item version of the BOAS indicated content validity as tested by the confirmatory factor analysis: the factor structure proved to fit with the hypothesized 4-subscale structure. The test scores on the individual domains and the whole scale were further found to be reliable in time and internally consistent, suggesting good reliability. The correlation analyses showed high internal correlations between the different domains, as well as convergent validity as tested with the OAS, and divergent validity as tested by the RSES. The analysis showed that in this sample, men and women reported different scores, but only on the domain measuring awareness for own body odours. In agreement with other sources from the literature (e.g., Novakova et al., 2014), women reported on average higher awareness for their own body odour than men, but no such difference was found when looking at awareness for other's odours.

Thus, the Body Odour Awareness Scale was found to be valid and reliable. In a second study, we aimed to explore regional differences between groups of people (cf. Sorokowska et al., 2018). Based on access, we selected three convenience samples: English speaking participants from India, English speaking participants from the United States of America, and L2 English speaking Dutch participants from the Netherlands.

Study 2: Body odour awareness in different countries

Methods Study 2

Participants

The participant pool initially consisted of 241 participants, out of which 59 had to be excluded due to missing or incorrect nationality data, and two had to be excluded due to invalid open ended question answers (i.e., answers were apparently copy-pasted from other sources). There remained 180 participants (mean age 31.4 years, *SD* =10.5), of which 83 female (mean age 30.3 years, *SD* = 12.2), 97 male (mean age 32.3 years *SD* = 8.69). Of these, 47 participants lived in India (of which 11 females, *M* age = 33.1, *SD* age = 6.90). Participants from India were recruited through MTurk (https://www.mturk.com), by restricting the geographical location (based on IP address) where participants would see the study description and survey, and received $2.70 for their participation. Fifty-four participants lived in the United States (25 females, *M* age = 42.3 years, *SD* = 10.0), and were recruited through MTurk. As with the participants from India, location settings only allowed MTurk participants from the USA to see the task, and participants received $2.70 for their participation. For both samples, only "MTurk master workers" were recruited. MTurk Masters are people who have participated in multiple studies without previously having been excluded from studies for various reasons. Finally, 79 participants (47 females, *M* age = 23.5 years, *SD* = 3.22) were Dutch speaking students living in the Netherlands, were recruited via the University participant pool and received course study participation points.

Materials

The BOAS, as described in Study 1, was used. In addition, participants completed a number of general questions on their hygiene habits and how important smells and fragrances, including body odours, are during daily activities. The questions included questions on the importance of the different senses, including smell, during non-sexual and sexual activities, open-end questions on what (body) odours participants find pleasant and unpleasant, questions regarding hygiene and washing habits, and the use of fragranced personal care products. These questions fell beyond the scope of the current paper and are not analysed and reported on here, but are accessible in the data files.

Procedure

The data for this study were collected as part of a student's master thesis project on the relation between odour awareness and hygiene. The data were collected online, using Qualtrics survey software (https://www.qualtrics.com). Participants that were recruited via MTurk clicked on a link to the survey on Qualtrics. Other participants were recruited via university participant pool software and then proceeded to the survey. Participants were first asked whether they agreed to a digital informed consent form and started with the set of questions about hygiene standards. Participants then completed the 32 questions of the initial version of the BOAS in a randomized order. After this, they completed a number of questions about their background and other demographic information. All participants were tested in

English, and confirmed their ability to speak and understand English. The study took on average 15.7 minutes to complete.

The study was registered and approved at the institutional ethics board as a student's project using surveys without experimental manipulations.

Statistical analysis

As a first test of regional differences or similarities of the BOAS domains, the data for the 28 items that remained in the CFA solution described under Study 1, Table 4, were analysed by means of a CFA. It was hypothesized that if participants with different cultural backgrounds have similar body odour awareness, there would be good fit between this hypothesized domain structure and the data, as shown by goodness-of-fit indices RMSEA, TLI and a chi-squared test of fit. Next, to compare the different domains and overall scale between the different groups in detail, the BOAS subscale scores were calculated by averaging the scores over the questions in each domain. The different domains were analysed by means of 5 ANCOVAs, one for each domain and one for the full scale, with Group (3 levels: USA, India, Netherlands) as independent factor, average body odour awareness as dependent variable, and age and gender (added as dummy variable) as covariates. To correct for the family-wise error rate multiple testing is prone to, the alfa level was divided by the amount of tests (in this case 5, equivalent to a Bonferroni correction), amounting to a significance threshold of p = .01. Significant main effects were followed by Bonferroni corrected pairwise comparisons. Data analysis was performed in jamovi (The jamovi Project, 2021).

Results Study 2

The CFA did not show clear support for a cultural-independent domain structure. It must be stressed that the sample size was very diverse, and relatively small, and findings of the CFA should be interpreted with caution (Brown, 2006). Items loaded significantly on the respective factors (*z*-scores > 2.72, $p < .01$), but factor loadings for some items were relatively low (items 1, 8, 19, 21, 29 and 32, see Table 8). Model fit indices for the CFA also suggested less than adequate fit of the CFA solution with the data, χ^2 (344) = 1105, $p < .001$, RMSEA = .11 [.10 - .12], CFI = .53, TLI = .48. This suggested the structure may not hold in participants groups with diverse backgrounds.

Table 8: Factor Loadings for the CFA using between-country data of Study 2

				95% Confidence Interval			
Factor	**Indicator**	**Estimate**	**SE**	**Lower**	**Upper**	**Z**	**p**
Own Positive	BOAS1	0.463	0.1392	0.190	0.736	3.33	< .001
	BOAS2	-0.790	0.1475	-1.079	-0.501	-5.35	< .001
	BOAS3	0.912	0.1376	0.642	1.182	6.63	< .001
	BOAS4	0.655	0.0780	0.502	0.808	8.39	< .001
	BOAS6	0.613	0.0713	0.473	0.753	8.60	< .001
	BOAS7	0.730	0.1124	0.510	0.951	6.50	< .001
	BOAS8	-0.550	0.1442	-0.832	-0.267	-3.81	< .001
Own Negative	BOAS9	0.723	0.1022	0.522	0.923	7.07	< .001
	BOAS10	0.629	0.0858	0.461	0.798	7.34	< .001
	BOAS11	0.712	0.0996	0.517	0.908	7.15	< .001
	BOAS12	-0.704	0.1306	-0.960	-0.448	-5.39	< .001
	BOAS13	0.903	0.0952	0.716	1.090	9.48	< .001
	BOAS15	-0.820	0.1403	-1.096	-0.545	-5.85	< .001
	BOAS16	-0.734	0.1334	-0.996	-0.473	-5.51	< .001
Other Positive	BOAS17	0.711	0.1524	0.413	1.010	4.67	< .001
	BOAS18	0.751	0.1049	0.546	0.957	7.16	< .001
	BOAS19	-0.549	0.2022	-0.946	-0.153	-2.72	0.007
	BOAS20	-0.714	0.1427	-0.994	-0.435	-5.01	< .001
	BOAS21	0.475	0.0921	0.294	0.656	5.16	< .001
	BOAS22	0.646	0.1364	0.379	0.914	4.74	< .001
	BOAS23	0.547	0.1243	0.303	0.790	4.40	< .001
	BOAS24	0.684	0.1208	0.447	0.921	5.66	< .001
Other Negative	BOAS25	0.749	0.0784	0.596	0.903	9.55	< .001
	BOAS27	0.765	0.0915	0.586	0.944	8.36	< .001
	BOAS28	0.700	0.0859	0.531	0.868	8.14	< .001
	BOAS29	0.480	0.1548	0.177	0.784	3.10	0.002
	BOAS30	0.575	0.0886	0.402	0.749	6.49	< .001
	BOAS32	0.460	0.1456	0.175	0.746	3.16	0.002

Next, the groups were compared on the total BOAS scores (Figure 1) and the subscales (Figure 2). The assumption check for ANCOVA suggested that the assumption of equal variances was violated for the total scale (Levene's $F = 3.15$, $p = .045$), but since ANCOVA is relatively robust to violations of this assumption in case groups are equal and of reasonable size (Kohr & Games, 1974), it was decided to proceed with uncorrected analyses. For the entire scale, there was no main effect of group, *F* (2, 175) = .51, *p* = .603, η_p^2 = .006, no effect of age, *F* (1, 175) = 3.57, *p* =.060, η_p^2 = .020, but a significant effect for gender, *F* (1, 175) = 16.73, *p* < .001, η_p^2 = .087. Descriptive statistics showed women (*M* = 5.34, *SD* = .57) had higher overall body odour awareness than men (*M* = 4.96, *SD* = .63).

For the own-positive subscale, the pattern was similar, with no main effect of group, *F* (2, 175) = .51, *p* = .603, η_p^2 = .006, no effect of age *F* (1, 175) = .04, *p* =.842, η_p^2 < .001, but an effect of the covariate gender, *F* (1, 175) = 12.76, *p* < .001, η_p^2 = .068. Women had higher awareness for their own positive smells (*M* = 5.76, *SD* = .83) than men (*M* = 5.10, *SD* = .88).

For the own-negative subscale, there was a main effect of group, *F* (2, 175) = 10.11, *p* <.001, η_p^2 = .104, an effect of the covariate age, *F* (1, 175) = 7.58, *p* =.007, η_p^2 = .041, and an effect of the covariate gender, *F* (1, 175) = 19.84, *p* < .001, η_p^2 = .068. Descriptive statistics showed women had higher awareness for their own negative smells (*M* = 5.76, *SD* = .83) than men (*M* = 5.10, *SD* = .88), and a regression analysis showed an increase in awareness for own negative smells with age, *r* = .202, *p* = .004.

To follow up this significant main effect, Bonferroni corrected pairwise comparisons were performed. Participants from India (*M* = 4.84, *SD* = .90), reported less awareness than participants from the USA (*M* = 5.80, *SD* = .92), *p* <.001, Cohen's *d* = .76, and the Netherlands (*M* = 5.57, *SD* = .75), *p* < .001, Cohen's *d* = 1.14, with no difference between participants from the Netherlands and the USA, *p* = .092, Cohen's *d* = .39.

For the other-positive subscale, there were no significant effects, with no main effect of group, *F* (2, 175) = 2.21, *p* = .113, η_p^2 = .025, and no effects for the covariates gender, *F* (1, 175) = 3.03, *p* =.083, η_p^2 = .017, or age, *F* (1, 175) = 1.80, *p* =.182, η_p^2 = .010.

Finally, for the other-negative subscale, there was no main effect of group, *F* (2, 175) = 1.73, *p* = .180, η_p^2 = .019, and no effect for the covariate age, *F* (1, 175) = 1.96, *p* =.163, η_p^2 = .011, but a significant effect for the covariate gender, *F* (1, 175) = 8.03, *p* =.005, η_p^2 = .044. Descriptive statistics showed women (*M* = 5.39, *SD* = .84) had higher awareness for other people's negative smells than men (*M* = 5.13, *SD* = .82).

These findings are not straightforward, and do not invite for clear-cut interpretations. In line with previous studies (Sorokowska et al., 2018), the findings show that there are differences in odour awareness, and the newly developed Body Odour Awareness Scale is sensitive enough to detect these differences. However, also in line with the previous studies, these differences are not large. This analysis suggests that the scale is relatively independent of cultural interpretations of the response scales used. If large differences, in one direction, would have been found, this could indicate that one of the groups interpreted the questionnaire in a different way. However, the current findings do not suggest this is the case. One finding that did appear from these results, is that women from these different countries report higher body odour awareness, in line with Study 1 (also see Appendix II).

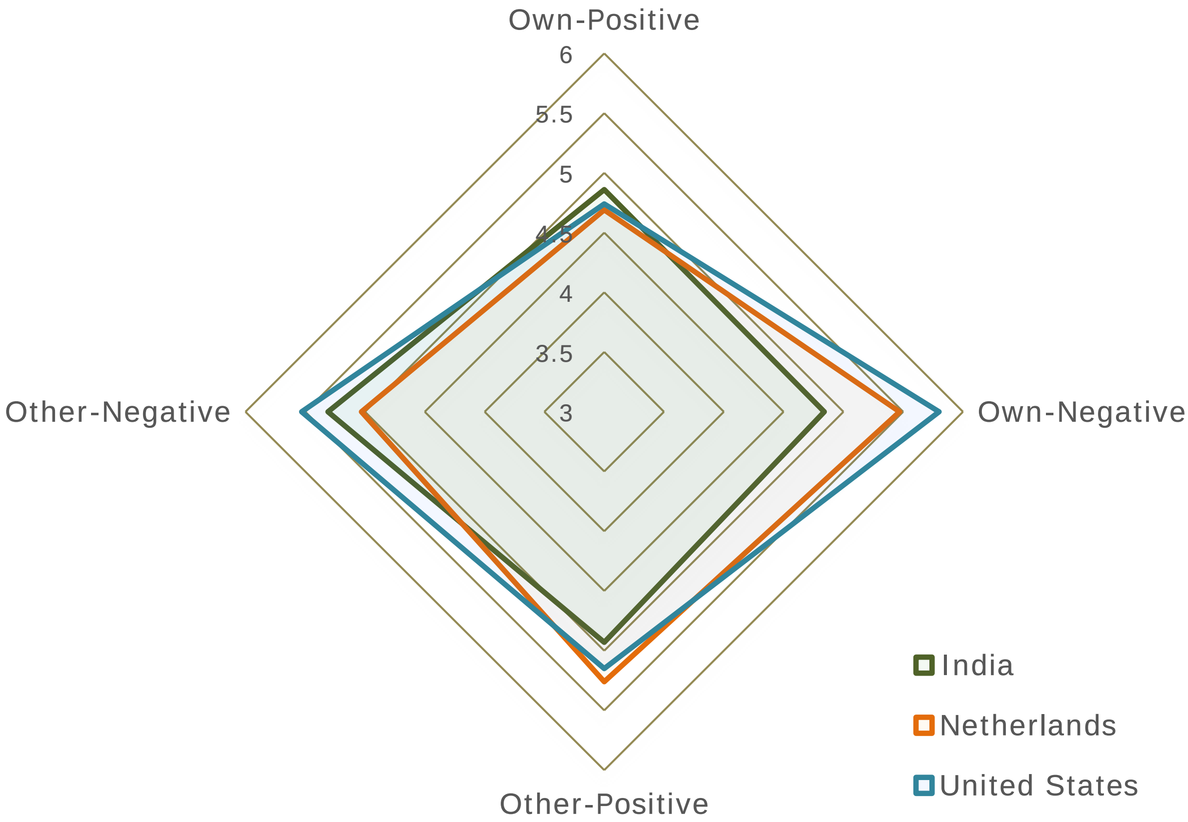

Figure 1: Comparison between different nationality groups per subscale of the BOAS. Displayed in the stacked spider chart are means for each nationality. Only the effect of nationality on the Own-Negative dimension is significant (as illustrated by an asterisks). Note that the scale is trimmed to 3-6 for clarity, but originally runs from 1-7.

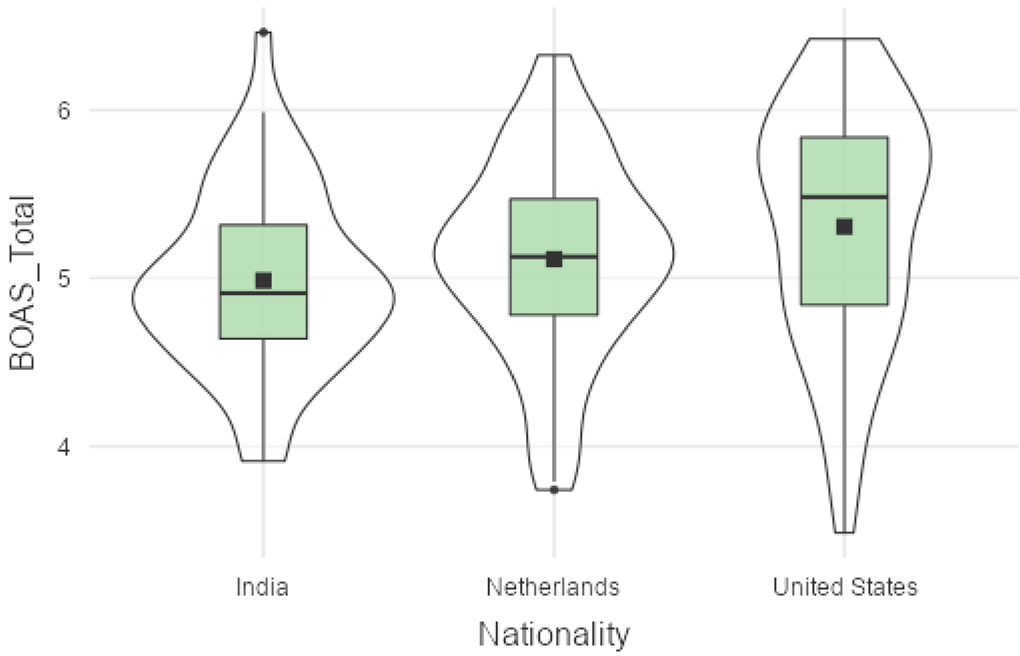

Figure 2: Box-violin plot of the overall scores on the BOAS split by nationality. The main effect of nationality is not statistically significant after correcting for age and gender (see text). Note: Means are plotted as solid squares, box-and-whiskers represent the median (solid midline), interquartile range (the box) and 95% confidence interval (whiskers). The 'violin' displays the mirrored distribution of the data.

Discussion

Body odours serve a number of social signalling functions, and people use fragrances to alter their body odour which may affect the impression that they have on others. Here we present the BOAS as a new questionnaire to measure people's awareness of these body odours. The BOAS showed good validity across several tests of validity, and satisfactory reliability. In a second, explorative study, small differences between cultural groups were found: people living in India showed less awareness for their *own unfavourable* body odours than people in the USA or in the Netherlands. Overall, body odour awareness for *favourable* body odours was found to be similar, both from the participants *themselves* as well as from *others*. These results should be interpreted with caution, since this study was exploratory in nature, and the factor analysis did not fully support the stability of the factor structure across different cultural groups. Differences between male and female participants were also found, across two studies, in diverse samples: women reported to be more aware for their own body odours than men.

The differences between women and men are in line with previous studies on (general) odour awareness (Smeets et al., 2006; Sorokowska et al., 2016; but see Novakova, Valentova, & Havlicek, 2014). However, the present studies build onto the literature in that the current findings zoom in on *body* odour awareness. The results further nuance previous studies by suggesting female and male participants report similar awareness for positive smells of *others*, and that differences exist in the awareness for *own* body odours, both positive and negative. We here show that this difference is also found in samples composed of different cultural groups. It is a remaining question whether there are innate gender differences that cause women to be more sensitive to smells (Brand & Millot, 2001; Majid, Speed, Croijmans & Arshamian, 2017; Novakova, Valentova, & Havlicek, 2014). The relationship between odour sensitivity and odour awareness is not direct (Novakova et al., 2014), but higher sensitivity for odours may indirectly drive odour awareness. Alternatively, this could be due to wide-spread cultural factors that cause women to be more involved in olfactory practices, such as wearing perfume and other fragranced personal care products (Ferdenzi et al., 2019; Ferdenzi, Coureaud, Camos & Schaal, 2008; Havlicek et al., 2008; Novakova, Valentova, & Havlicek, 2014). This higher involvement with fragrances could lead to increased olfactory sensitivity through experience (cf. Majid, Speed, Croijmans & Arshamian, 2017), which downstream could potentially result in higher body odour awareness. The findings here suggest the latter explanation, since only differences were found for *own* body odour; if an innate olfactory sensitivity effect would drive differences between men and women in odour awareness, differences on the other domains would be expected at the same time.

Body odours transmit social cues, and have communicative functions (Semin & De Groot, 2013; Gelstein et al., 2011; Stevenson, 2010; Schaal & Porter, 1991). However, it is unknown what the influence is of being highly aware of one's own or others' smell on social communication via olfaction (chemosignaling). Potentially, people that are highly aware of the smells in their environment may be less prone to implicit effects of body odours (e.g. through unconscious priming). On the other hand, some effects of chemosensory cues may be stronger with conscious awareness, for example conscious disease avoidance: it is advantageous for an individual to be able to avoid sick individuals to prevent potential contagion (e.g., Newman & Buesching, 2019; Olsson et al., 2014). At the same time it potentially improves fitness if a diseased individual's odour triggers caring/protective behaviour in kin or others (Newman & Buesching, 2019). Awareness could thus facilitate body odour evaluation or invite appropriate response behaviour. In addition, experience can induce structural changes in one's neurocognitive architecture: the olfactory cortex of perfumers operates in a more efficient way than that of perfume novices (Delon-Martin, Plailly, Fonlupt, Veyrac, & Royet, 2013; Plailly, Delon-Martin, & Royet, 2012), and brain activity of sommeliers smelling wine is different to that of average wine consumers (Banks et al., 2016; Castriota-Scanderberg et al., 2005; Pazart et al., 2014; Sreenivasan et al., 2017). Odour awareness is also related to how well people can identify (Demattè et al., 2011) and remember smells (Arshamian, Willander, & Larson, 2011), showing the impact of odour awareness on higher order cognitive functions. In contrast, other scholars have suggested odour awareness is not at all a prerequisite for behavioural effects of odours (e.g., Köster, Møller, & Mojet, 2014). With the BOAS, it becomes possible to investigate individual differences in body odour awareness and their effect on chemosignaling, in a straightforward and validated way.

Cultural differences are of further interest. People differ in what smells they like, how sensitive they are for certain smells, and how well they can describe smells, as a function of where they grow up and how involved they are with olfactory behaviour (Majid, 2020). It is difficult to draw strong conclusions from an explorative data collection, but the finding that people in India report to be less aware of their own unfavourable body odour could have different explanations. Following Sorokowska and colleagues (2018), there are a number of regional explanations possible, such as weather conditions (temperature and humidity), social economic status, or (extreme) city-population density. Expanding on the latter, if people are in closer proximity of each other, they may be more exposed to each other's body odours, which in turn may shape body odour awareness. Cultural salience of and rituals with smells may nevertheless be different between countries, for example following from differences in interpersonal distance, leading to differences in experience with body odours, and in turn shaping awareness (cf. Ferdenzi et al., 2013). Extending this hypothesis could be that own body odours are less important in cultures that favour the community rather than the individual in a society, i.e., collectivistic vs. individualistic cultures (Hofstede, 1980; Darwish & Huber, 2003). Here we show a glimpse of what differences may exist in body odour awareness, but also that differences are not necessarily large and rather specific. Additionally, since the dimensional structure of the BOAS was not fully supported by the CFA, strong conclusions should be avoided. Future studies may nevertheless investigate what underlies cultural differences in body odour awareness using the BOAS, tested in large and diverse samples.

Another potential use of the BOAS is to investigate how (body) odour awareness may be related to human self-anointment behaviour, i.e., the use of fragranced personal care products. Personal care marketing has traditionally focused on gendered marketing (Powers, 2019). However, a more refined way of advertising products based on how they smell may be more effective when considering a distinction between body odour awareness, instead of gender. The results here show that while there are differences between women and men, there is also a large overlap: the within group variation was much larger than between group variation. Or in other words: men with the highest body odour awareness, even on the domain of odour awareness where the biggest differences were found (own-negative body odours), were much more aware of their own smell than women with the lowest body odour awareness (see Appendix II for a visual exploration of this). Stepping away from a traditional gendered marketing perspective, instead focusing on individual differences in odour appreciation, in turn could improve consumer satisfaction and company revenue.

In conclusion, measuring body odour awareness with the BOAS has the potential to uncover inter-individual differences in how people are aware of body odours. The Body Odour Awareness Scale extends the diverse studies that employed the Odour Awareness Scale by focusing specifically on body odour. The validation study strongly suggests the construct of body odour awareness encompassing both positive and negative body odours, from both a sender (i.e., one’s own body odour) as well as from a perceiver (i.e., someone else’s body odour) perspective, and that this is a different construct than general odour awareness. In addition, the BOAS considers the ancient practice of applying fragrances as critical part of the composition of body odours. One potential use of the BOAS could be to link body odour awareness to fragrance use and consumer choice, in different cultures.

Author contributions: IC, MS and GD conceptualized the idea for this project. IC drafted the first version of the questionnaire and received critical input from MS and GD. IC collected, analysed and interpreted the data for study 1. IC and NM collected data for study 2, where NM pre-processed the data and analysed the data as part of her master thesis, and IC analysed the data as reported in the current manuscript. NM and IC interpreted the results for study 2. IC drafted the first version of this manuscript, and MS and GD gave critical feedback and suggestions, and revised the manuscript. All authors approved of the final version of the manuscript.

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Appendix I

Table A2: Dutch version of the BOAS. Items with code printed in bold remain in the validated version of the BOAS.

Item code	Item content
BOAS1	Als ik mijn favouriete parfum/aftershave op heb ruik ik dat de hele dag
BOAS2R	Ik merk het niet dat mijn handen schoon ruiken na het wassen – ik *weet* gewoon dat ze schoon zijn
BOAS3	Ik merk nog tot uren na het haren wassen dat mijn haar schoon ruikt
BOAS4	Ik let erop dat ik altijd lekker ruik
BOAS5	Ik let erop dat ik altijd neutraal ruik
BOAS6	Als ik met iemand heb afgesproken zorg ik dat ik aangenaam ruik
BOAS7	Ik ruik regelmatig of mijn kleding nog fris ruikt
BOAS8R	Mij maakt het niet echt uit hoe mijn deodourant of parfum ruikt, als ik maar niet naar zweet ruik
BOAS9	Het valt me op wanneer mijn voeten sterk ruiken
BOAS10	Ik merk het als mijn kleding muf en onaangenaam ruikt
BOAS11	Ik merk meteen wanneer ik een slechte adem heb
BOAS12R	Wanneer ik merk dat ik mezelf ruik (door mijn deodourant heen) dan stoort me dat niet of nauwelijks
BOAS13	Ik merk het gelijk als ik naar zweet ruik
BOAS14	Als mijn handen naar iets ruiken (bijvoorbeeld zeep of etenswaren), dan ben ik daar de hele tijd mee bezig
BOAS15R	Ik ben niet met mijn lichaamsgeur bezig als ik met iemand praat
BOAS16R	Het kan mij niet schelen dat mensen iets zouden kunnen ruiken nadat ik naar het toilet ben geweest
BOAS17	ik herken bekenden en familieleden aan hun geur
BOAS18	ik vind het belangrijk dat de mensen met wie ik omga aangenaam ruiken
BOAS19R	Ik merk het amper wanneer iemand parfum draagt
BOAS20R	als ik iemand ontmoet maakt het me niet uit hoe deze persoon ruikt
BOAS21	Ik merk wanneer iemands haar lekker ruikt
BOAS22	ik voel me aangetrokken tot een vreemde als diegene een lekkere parfum of aftershave draagt
BOAS23	Ik voel me aangetrokken tot vreemden met een aangename lichaamsgeur
BOAS24	De geuren van vrienden en familieleden maken dat ik me echt op mijn gemak voel
BOAS25	Ik merk het als iemand onplezierig ruikt naar zweet
BOAS26R	Als ik iemand uit het toilet zie komen, dan kies ik nooit een ander hokje vanwege de geur
BOAS27	ik merk het direct op wanneer iemand net gerookt heeft
BOAS28	Als iemand in het openbaar vervoer een sterke geur heeft, houd ik afstand
BOAS29	als een vriend, partner of familielid ziek is, dan merk ik dat aan zijn of haar geur
BOAS30	ik ruik het als iemand heeft gesport
BOAS31R	Ik vind het niet moeilijk om intiem te zijn met iemand die onaangenaam ruikt
BOAS32	Ik ben beledigd als ik ruik dat iemand zojuist een scheet heeft gelaten

Table A2: country of residence of the participants in Study 1

Country of residence	**N**
United Kingdom	84
United States	9
Belgium	4
Israel	3
Poland	8
Italy	17
Australia	4
Sweden	4
Netherlands	5
Greece	9
Spain	4
Japan	2
Estonia	4
Slovenia	4
Germany	3
Norway	1
Hungary	8
Canada	1
New Zealand	1
Portugal	13
Mexico	2
Latvia	1
Ireland	3
France	2

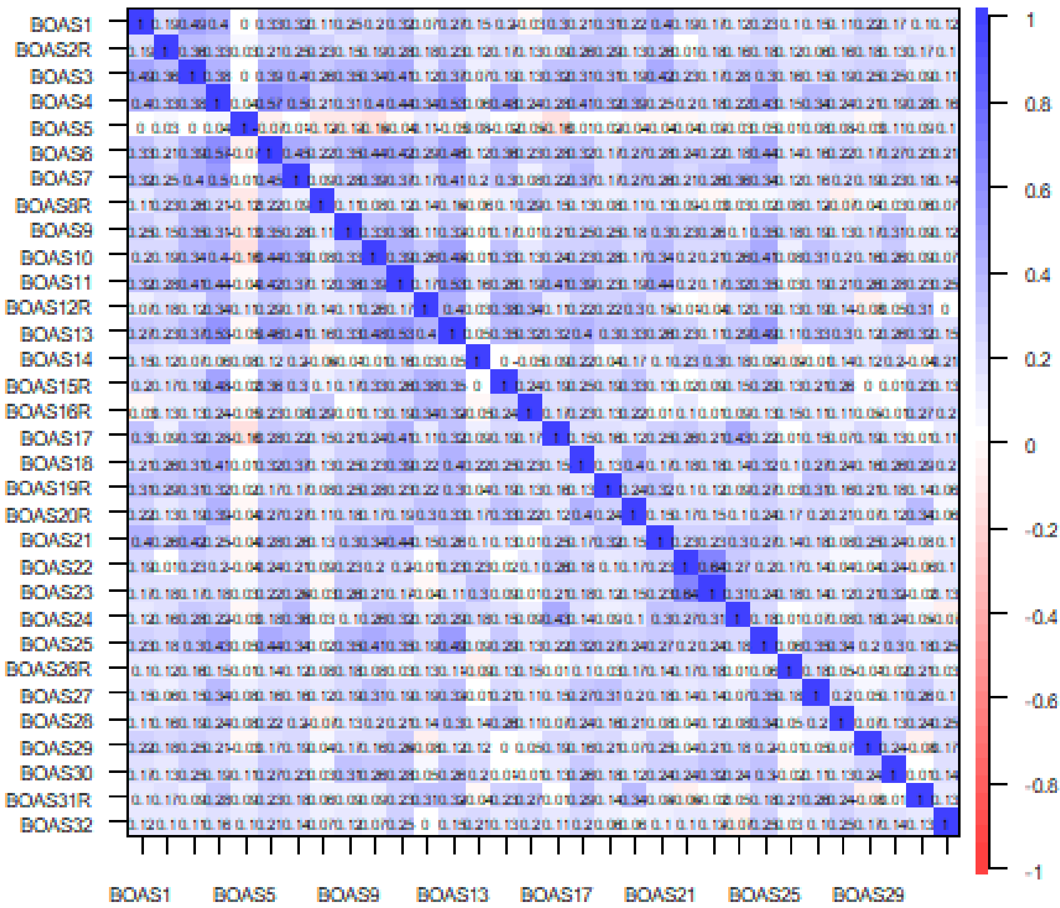

Figure A1: correlations between items. Darker colors indicate stronger correlations.

Table A3: Factor Loadings for the initial CFA

				95% Confidence Interval			
Factor	**Indicator**	**Estimate**	**SE**	**Lower**	**Upper**	**z**	***p***
	BOAS1	0.9081	0.1213	0.6704	1.1458	7.488	< .001
	BOAS2	-0.7425	0.1314	-1.0000	-0.4850	-5.652	< .001
	BOAS3	0.9975	0.1146	0.7728	1.2221	8.701	< .001
own-positive	BOAS4	0.8381	0.0727	0.6956	0.9806	11.525	< .001
	BOAS5	-0.0319	0.1074	-0.2423	0.1785	-0.297	0.766
	BOAS6	0.6751	0.0663	0.5451	0.8051	10.178	< .001
	BOAS7	0.7961	0.0930	0.6139	0.9784	8.561	< .001
	BOAS8	-0.4964	0.1441	-0.7789	-0.2139	-3.444	< .001
	BOAS9	0.7105	0.1240	0.4674	0.9536	5.728	< .001
	BOAS10	0.4980	0.0683	0.3642	0.6318	7.296	< .001
	BOAS11	1.0406	0.1051	0.8346	1.2466	9.902	< .001
own-negative	BOAS12	-0.4227	0.0884	-0.5959	-0.2496	-4.784	< .001
	BOAS13	0.9319	0.0859	0.7635	1.1002	10.848	< .001
	BOAS14	0.3157	0.1356	0.0498	0.5816	2.327	0.020
	BOAS15	-0.5792	0.1161	-0.8068	-0.3517	-4.990	< .001
	BOAS16	-0.4152	0.1299	-0.6697	-0.1607	-3.197	0.001
	BOAS17	0.8683	0.1310	0.6114	1.1251	6.626	< .001
	BOAS18	0.7156	0.1009	0.5178	0.9134	7.090	< .001
	BOAS19	-0.4838	0.1163	-0.7117	-0.2559	-4.160	< .001
other-positive	BOAS20	-0.6026	0.1091	-0.8163	-0.3888	-5.524	< .001
	BOAS21	0.7077	0.1048	0.5022	0.9132	6.750	< .001
	BOAS22	0.6458	0.1112	0.4278	0.8639	5.805	< .001
	BOAS23	0.7089	0.1241	0.4656	0.9522	5.712	< .001
	BOAS24	0.5805	0.0988	0.3869	0.7740	5.877	< .001
	BOAS25	0.6821	0.0880	0.5096	0.8546	7.749	< .001
	BOAS26	-0.2249	0.1520	-0.5228	0.0731	-1.479	0.139
	BOAS27	0.3856	0.0923	0.2046	0.5665	4.177	< .001
other-negative	BOAS28	0.4326	0.0933	0.2497	0.6156	4.635	< .001
	BOAS29	0.5678	0.1439	0.2857	0.8498	3.946	< .001
	BOAS30	0.5978	0.1188	0.3650	0.8305	5.033	< .001
	BOAS31	-0.4270	0.1592	-0.7391	-0.1149	-2.682	0.007
	BOAS32	0.5779	0.1510	0.2820	0.8739	3.828	< .001

Note. 'Maximum likelihood' extraction method was used in combination with a 'oblimin' rotation. Item loadings <.3 are suppressed.

Table A4: Pearson's correlations (*r*) between the different domains (Self-Positive, Self-Negative, Other-Positive, Other-Negative) of the BOAS and theoretically related (general odour awareness as measured by the OAS) and unrelated (self-esteem, as measured by the Rosenberg Self-Esteem Scale (RSES) constructs.

		1 BOAS_SelfPos	**2 BOAS_SN**	**3 BOAS_OP**	**4 BOAS_ON**	**5 BOAS_AVE**	**6 OAS_Pos**	**7 OAS_Neg**	**8 OAS_Ave**
2 BOAS_SelfNeg	*r*	0.558	—						
	p	< .001	—						
3 BOAS_OtherPos	*r*	0.601	0.553	—					
	p	< .001	< .001	—					
4 BOAS_OtherNeg	*r*	0.407	0.416	0.470	—				
	p	< .001	< .001	< .001	—				
5 BOAS_Average	*r*	0.833	0.798	0.844	0.681	—			
	p	< .001	< .001	< .001	< .001	—			
6 OAS_Positive	*r*	0.548	0.493	0.703	0.446	0.699	—		
	p	< .001	< .001	< .001	< .001	< .001	—		
7 OAS_Negative	*r*	0.559	0.555	0.649	0.584	0.737	0.754	—	
	p	< .001	< .001	< .001	< .001	< .001	< .001	—	
8 OAS_average	*r*	0.590	0.565	0.712	0.566	0.768	0.901	0.964	—
	p	< .001	< .001	< .001	< .001	< .001	< .001	< .001	—
9 RSES_average	*r*	0.075	0.063	0.045	0.058	0.076	0.208	0.073	0.132
	p	0.301	0.382	0.534	0.422	0.294	0.004	0.313	0.067

Appendix II

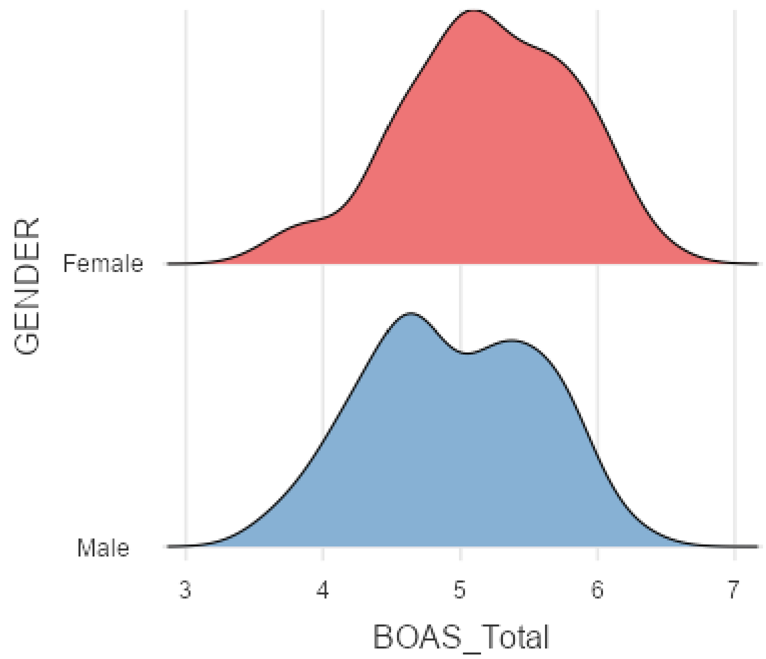

Figure AII.1: Density plots for scores on the BOAS full scale, split by gender, from Study 1 (see main manuscript). A t-test for the difference between male and female participants shows: t (191) = 3.47, *p* < .001, *Cohen's d* = .50.

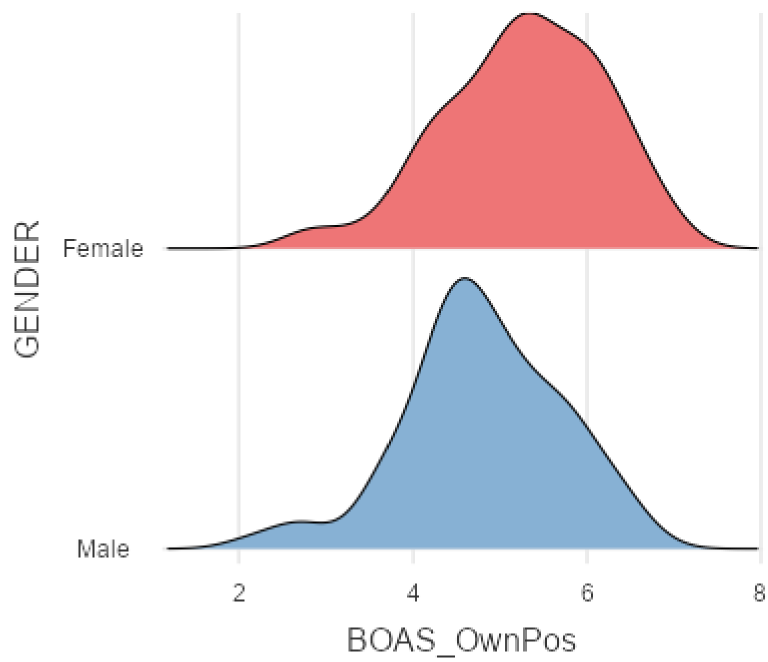

Figure AII.2: Density plots for scores on the awareness for own-positive smells domain of the BOAS, split by gender, data from Study 1 (see main Manuscript). A t-test for the difference between male and female participants shows: t (178) = 3.57, *p* < .001, *Cohen's d* = .52.

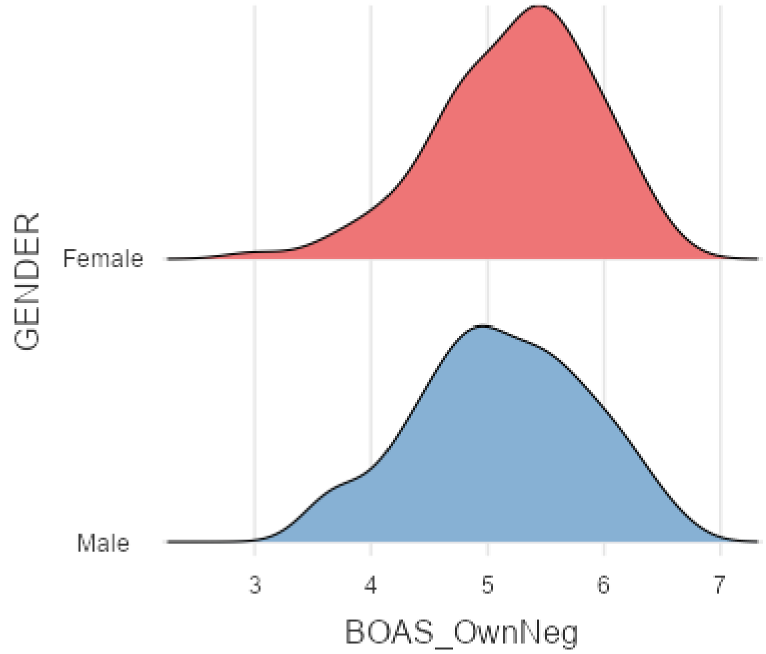

Figure AII.3: Density plots for scores on the awareness for own-negative smells domain of the BOAS, split by gender, data from Study 1 (see main Manuscript). A t-test for the difference between male and female participants shows: t (191) = 3.84, *p* < .001, *Cohen's d* = .56.

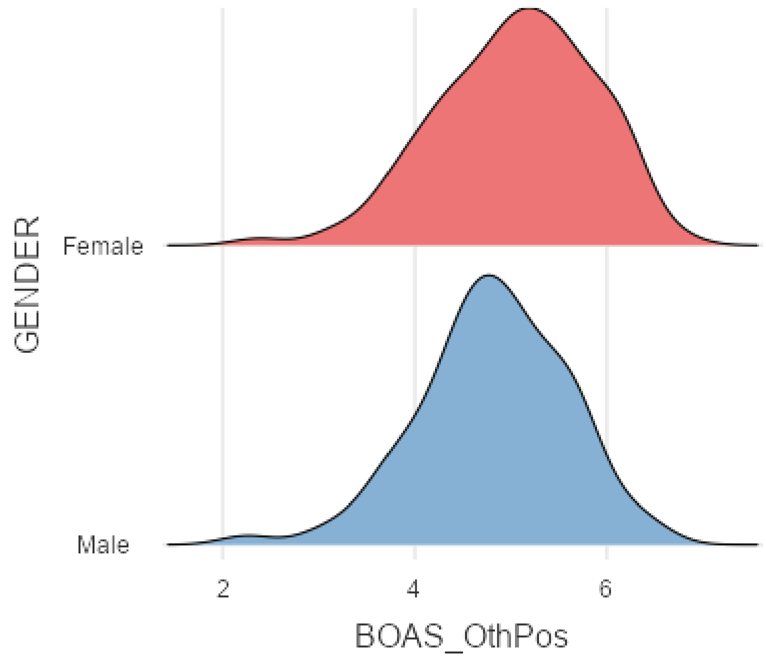

Figure AII.4: Density plots for scores on the awareness for other-positive smells domain of the BOAS, split by gender, data from Study 1 (see main Manuscript). A t-test for the difference between male and female participants shows: t (191) = 2.05, *p* = .042, *Cohen's d* = .30.

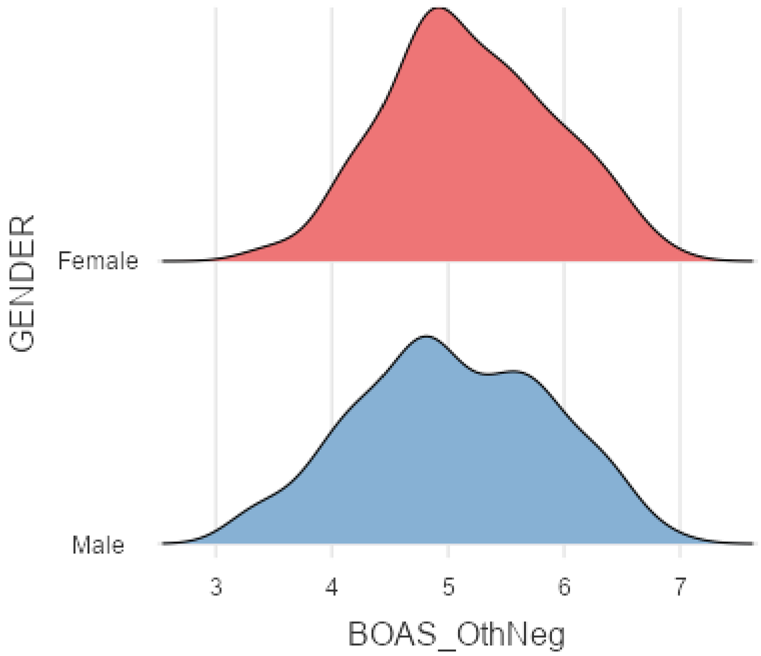

Figure AII.5: Density plots for scores on the awareness for other-negative smells domain of the BOAS, split by gender, data from Study 1 (see main Manuscript). A t-test for the difference between male and female participants shows: t (191) = 1.29, *p* = .200, *Cohen's d* = .19.

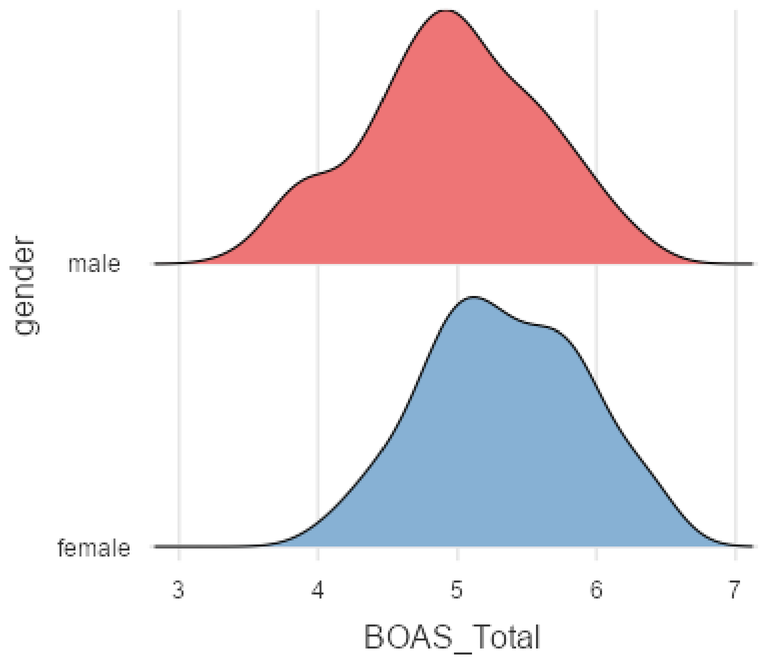

Figure AII.6: Density plots for scores on the awareness for the entire scale of the BOAS, split by gender, data from Study 2 (see main Manuscript). A t-test for the difference between male and female participants shows: t (178) = 4.19, *p* < .001, *Cohen's d* = .63.

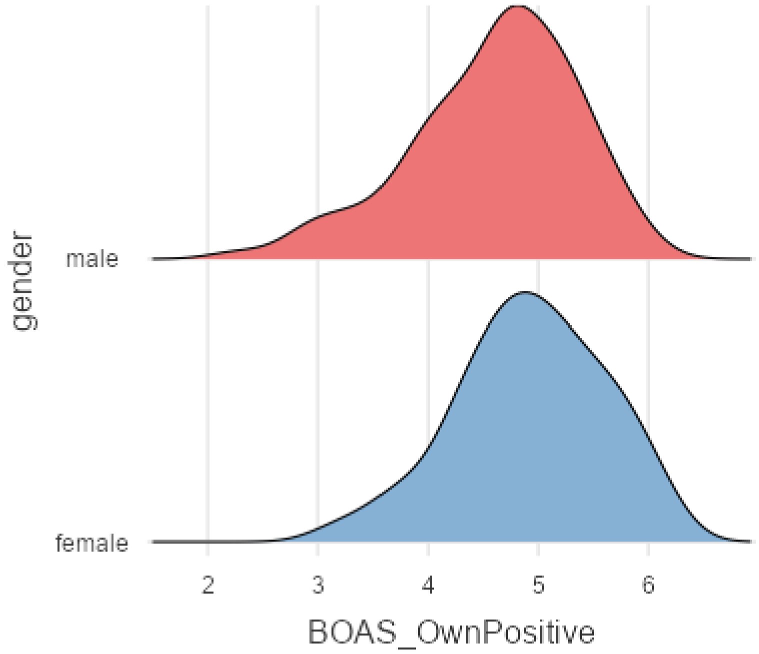

Figure AII.7: Density plots for scores on the awareness for own-positive smells domain of the BOAS, split by gender, data from Study 2 (see main Manuscript). A t-test for the difference between male and female participants shows: t (178) = 3.02, p = .003, *Cohen's d* = .45.

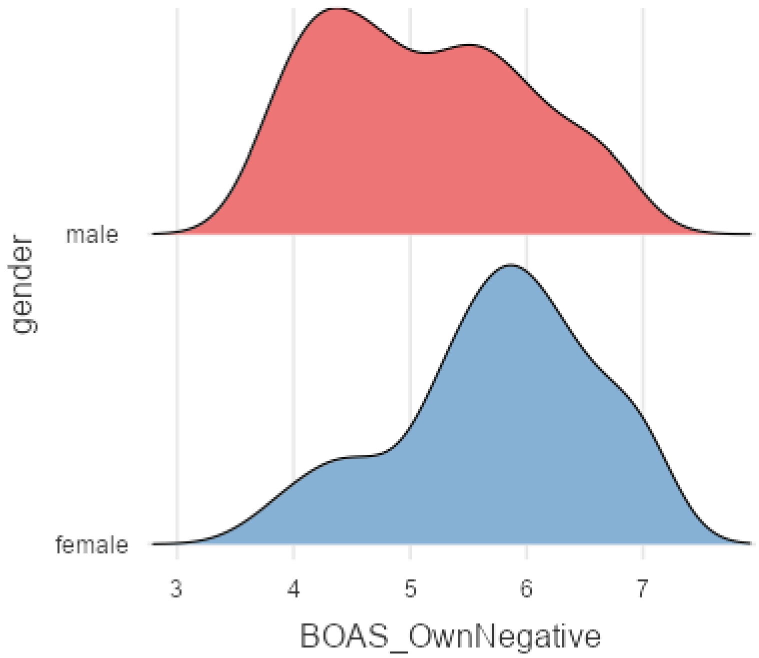

Figure AII.8: Density plots for scores on the awareness for own-negative smells domain of the BOAS, split by gender, data from Study 2 (see main Manuscript). A t-test for the difference between male and female participants shows: t (178) = 5.13, p < .001, *Cohen's d* = .77.

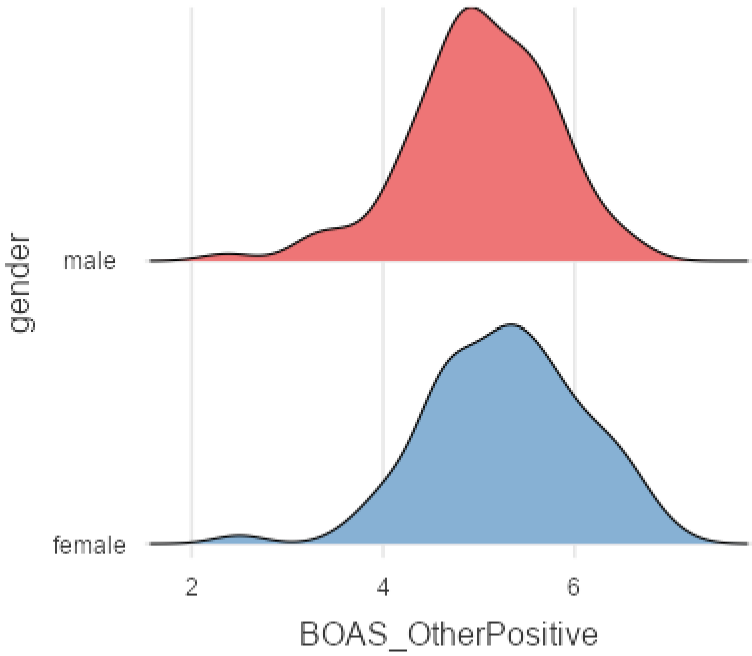

Figure AII.9: Density plots for scores on the awareness for other-positive smells domain of the BOAS, split by gender, data from Study 2 (see main Manuscript). A t-test for the difference between male and female participants shows: t (178) = 2.33, *p* = .021, *Cohen's d* = .35.

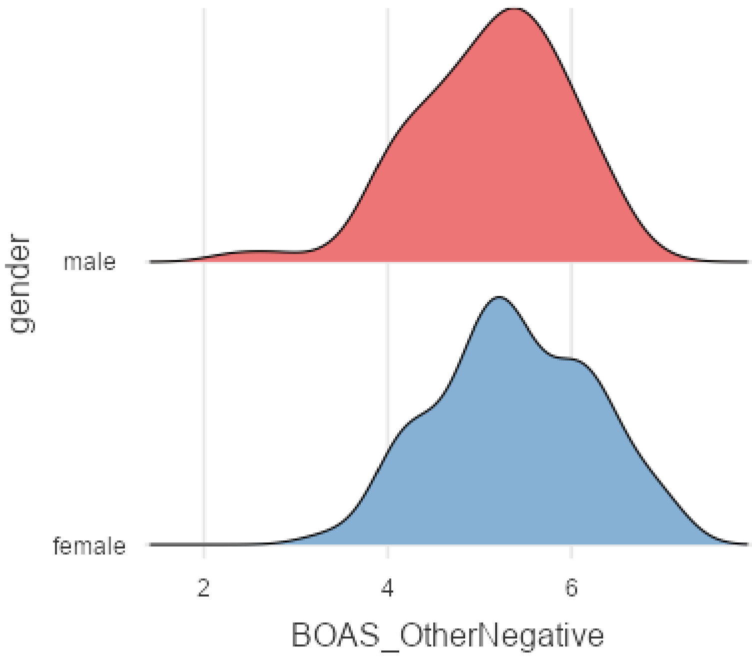

Figure AII.10: Density plots for scores on the awareness for other-negative smells domain of the BOAS, split by gender, data from Study 2 (see main Manuscript). A t-test for the difference between male and female participants shows: t (178) = 2.07, *p* = .040, *Cohen's d* = .31.