Body odor disgust sensitivity is associated with prejudice towards a fictive group of immigrants

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Abstract

Why are certain individuals persistent in opposing immigration? The behavioral immune system framework implies that a psychological mechanism, which adapted to detect and avoid pathogen threats, is also reflected in contemporary social attitudes. Moreover, prejudice towards outgroups might be partially driven by implicit pathogen concerns related to dissimilarity of these groups' hygiene and food preparation practices. Disgust, a universal core emotion supposedly evolved to avoid pathogen threats, as well as olfaction, both play a pivotal role in evoking disgust. In an online study (N = 800), we investigated whether individual differences in body odor disgust sensitivity (BODS) correlate with negative attitudes towards a fictive refugee group. The data analysis plan and hypotheses were preregistered. Results show that body odor disgust sensitivity is associated with xenophobia: BODS was positively associated with negative attitudes towards the fictive group. This relationship was partially mediated by perceived dissimilarities of the group in terms of hygiene and food preparation. Our finding suggests prejudice might be rooted in sensory mechanisms.

Keywords

olfaction, disgust, prejudice, behavioral immune system, xenophobia, body odor disgust sensitivity

Highlights

Higher ratings of body odor disgust sensitivity are related to more negative attitudes towards a fictive refugee group.

Negative attitudes towards the fictive refugee group are confidently related to general attitudes towards immigration.

Perceived group dissimilarity partially mediates the relationship between body odor disgust sensitivity and attitudes.

1. Introduction

Large-scale immigration has recently become a challenge for many western countries, with about a fourth of the world's contemporary migrants living in Europe and the United States (Pew Research Center, 2016). The influx of people into these countries is shaping the political landscape, with increasing support for parties and candidates opposing immigration. Researchers from political, but also psychological and biological sciences, have suggested mechanisms that might contribute to prejudice, which in turn may lead to opposing immigration.

The behavioral immune system framework (BIS; Schaller, 2006) suggests that prejudice - a generalized, often negative, attitude towards people belonging to a certain group - might arise from evolutionarily driven disease avoidance. The BIS is a set of psychological mechanisms presumably evolved to detect cues of pathogen threats, activate the appropriate affective and cognitive responses, and trigger the relevant avoidance behaviors (Schaller & Park, 2011). Disgust is a core universal emotion and is considered a defense mechanism that protects the body from contamination from potentially harmful substances (Curtis, Aunger, & Rabie, 2004). Disgust plays a central role in the BIS. It has been proposed that, similarly to the physical immune system, BIS can respond to a large set of cues, and is responsible for triggering disgust and prejudice towards people who might, for example, simply have a non-prototypical physical appearance (Schaller, 2011). In fact, BIS has been consistently related to xenophobia, opposition to immigrants, authoritarianism and social dominance (e.g. Faulkner, Schaller, Park & Duncan, 2004; Schaller & Park, 2011, Aarøe, Petersen & Arceneaux, 2017; see Terrizzi Jr, Shook, & McDaniel, 2013 for meta-analysis), but also moral judgment (Chapman, Kim, Susskind, & Anderson, 2009; Vicario, Kuran, Rogers, & Rafal, 2018).

Moreover, feelings of disgust have been consistently linked to the stigmatization of ethnic (Navarette & Fessler, 2006) and sexual minorities (Inbar, Pizarro, & Bloom, 2012).

Thus far, BIS sensitivity has mainly been assessed by using the Perceived Vulnerability to Disease scale (PVD, Duncan, Schaller & Park, 2009), the Three Domains of Disgust Scale (TDDS, Tybur, Lieberman & Griskevicius, 2009) and the Disgust Scale-Revised (DS-R, Olatunji et al., 2007). We recently developed a new scale assessing body odor disgust sensitivity (BODS, Liuzza et al., 2017a; Liuzza, Olofsson, Sabiniewicz, & Sorokowska, 2017b). The BODS scale consists of scenarios depicting six different body odors (upper body sweat, feet sweat, breath, gas, urine and feces) selected for their relevance in pathogen processes (Shirasu & Touhara, 2011) and their universal capability to evoke disgust (Curtis & Biran, 2001; Culpepper, Havlíček, Leongómez & Roberts, 2018). What distinguishes BODS from other assessments of disgust and contamination sensitivity, is that BODS focuses on body odors. From a theoretical point of view, disgust towards body odors should be a critical function of the BIS; indeed, it has been argued that the principal function of olfaction is to detect pathogen threats (Stevenson, 2009) especially when these pathogens are signaled by body odors (Olsson et al., 2014). Moreover, individuals born without a sense of smell report enhanced social insecurity and problems in social relationships with other people; their problems are related to the inability to perceive their own, as well as the other person's body odor (Croy, Negoias, Novakova, Landis, & Hummel, 2012), which further strengthens the assumption of a link between olfaction and social interactions. Importantly, although body odors are regulated by social norms (Largey and Watson, 1972), BODS does not involve moral and social judgments, but instead focuses on pure, universal sensory disgust triggers (Curtis and Biran, 2001). A previous validation study showed that BODS uniquely predicts disgust reactions to armpit sweat odors (Liuzza et al., 2017b). Moreover, consistent with previous research on BIS and social conservatism, we recently found that the BODS is

related to right-wing authoritarianism (RWA), even when adjusting for the association between RWA and other BIS measures (Liuzza et al., 2018).

There are at least two likely mediators of the relationship between prejudice and disease avoidance; firstly, there is the historical consideration that contact with unfamiliar groups has led to epidemics (e.g. Oldstone, 2009). Secondly, the belief that our own cultural hygiene and food preparation practices are better suited to avoid diseases can contribute to preferring limited contact with outgroups (Schaller, 2011). In this paper we address the question whether olfactory disgust plays a role in xenophobia (negative attitudes towards, and dislike of people from countries other than one's own). We also addressed whether this relationship is mediated by perceived dissimilarity of food and sanitary habits and a general opposition to immigration. We preregistered our hypotheses and planned analyses, used the BODS as a suitable sensory BIS measure, as well as Bayesian statistics in order to evaluate how likely our hypotheses are, given the data.

1.1 Hypotheses

We assessed the following hypotheses.

1.1.1 Body odor disgust will predict negative attitudes towards a fictive Central African outgroup – the Drashneean refugees (Hypothesis 1)

1.1.2 The Drashneean refugees will be perceived as dissimilar in terms of food, hygiene and sanitary practices (Hypothesis 2)

1.1.3 Perception of dissimilar practices will mediate the relationship between BODS and negative attitudes towards Drashneeans (Hypothesis 3)

1.1.4 Negative attitudes towards Drashneeans will be correlated with general attitudes towards immigration (Hypothesis 4)

1.1.5 BODS will predict general negative attitudes towards immigration (Hypothesis 5)

2. Material and methods

2.1 Preregistration

Prior to data analysis, we preregistered the planned approach and hypotheses on the Open Science Framework (OSF). The data, as well as all materials used in the study, are available online at https://osf.io/fsbna/.

2.2 Participants

Data were collected with Amazon Mechanical Turk (MTurk) via a web interface from Qualtrics, between the 28th of August 2017 and the 2nd of September 2017. We recruited only US participants with a prior approval rate of 85%, who had taken part in no less than 50, and no more than 1000 surveys. The lower limit served to provide an estimate of participants' reliability, while the upper limit aimed at excluding over-experienced MTurk workers. We performed a power analysis using the *pwr* R package (Champely, 2018) and planned a sample of n = 800 to assume a power of 80% to detect an effect as small as r = 0.1. Of 816 respondents participating in the study, we excluded 11 participants who did not complete the survey. Of the remaining 805, 444 were females (mean age = 37.81, SD = 11.62).

2.3 Measurements

Beside the measures listed below, we collected demographic information about age, gender and education, which we used as covariates of no theoretical interest in our models.

2.3.1 Body Odor Disgust Sensitivity scale (BODS, Liuzza et al. 2017a)

BODS is a 12-item scale which measures disgust sensitivity to body odors. Items refer to six types of body odors (feces, upper body sweat, feet, urine, gas and breath) appearing both in an internal (e.g. "You are alone at home and notice that your feet smell strongly") and external (e.g. "You are sitting next to a stranger and notice that their feet smell strongly") contexts. Participants rated the extent to which each scenario elicits disgust on a Likert type of scale ranging from 1 (not disgusting at all) to 5 (extremely disgusting).

2.3.2 Measures of explicit xenophobia

In order to assess explicit xenophobia, we adapted a scenario from Faulkner et al. (2004). Participants were introduced to a fictive outgroup from Central Africa, the Drashneean refugees: "Imagine the following scenario: There is a country in Central Africa, which for the purposes of this study we will refer to as Dhrashnee, that has been experiencing a great deal of civil unrest in recent years. As a result of these conditions, many people from this country are trying to leave. A large number of these refugees are seeking to immigrate to the United States of America." Then, they were asked to rate 6 items related to the following: (1) their overall attitudes towards Drashneeans, (2) how much they agree that Drashneeans could bring health-related problems and (3) criminality into the country if they were allowed to immigrate, and to what degree they perceive Drashneeans as similar (or dissimilar) to themselves in terms of (4) food, (5) hygiene, and (6) sanitary practices. The answers were given on a 10-point scale (ranging from *strongly disagree* to *strongly agree* for Questions 1 - 3, and from *Not at all similar* to *Highly similar* for Questions 4-6). Additionally, we used a feeling Thermometer (Esses, Haddock, & Zanna, 1993). The feeling Thermometer was

assessed through a visual analogue scale (VAS) where participants were asked to respond by using a sliding scale that ranged from 0 to 100. High numbers on the scale indicate favorable attitudes towards Drashneeans, 50 indicate neutral attitude, and the low numbers indicate more unfavorable attitudes. Answers to Questions 1, 2 and 3 were standardized and collapsed to form an index of attitudes towards the outgroup members along with the feeling Thermometer. Questions 4-6 were used as a manipulation check to test whether the outgroup was perceived as more dissimilar than similar, as well as, a mediator in Hypothesis 3.

2.3.3 Other: Self-reported political orientation and Attitudes towards immigration

For exploratory purposes we collected additional information about participants' political ideology: 1) Participants rated how liberal they are on a 1-7 scale (1 - *extremely liberal*; 7 - *extremely conservative*), 2) they also filled in a 6 item questionnaire about attitudes to immigration in general (Faulkner et al., 2004) in which their rated the degree to which they agree to statements about immigration (on a scale from 1 - *Strongly disagree* to 7 -*Strongly agree*, some items being reverse-coded such that higher score indicated opposition towards immigration).

2.4 Missing data

As stated in the preregistration file, we only included participants who completed the entire survey (n = 805, 98.6% of the observations). Due to an error when launching the survey, 38 of these participants did not respond to the general attitudes towards immigration questions. Data from these participants was therefore used only in the analyses which did not include the general attitudes to immigration variable. We did not plan to exclude participants based on any other criteria. The large sample should provide enough protection against noisy, influential observations.

2.5 Data analysis

All analyses have been performed in R (R core Team, 2018, version 3.4.4) and R Studio (RStudio Team, 2015).

2.5.1 Unidimensionality and internal consistency of the scales used in the study

We conducted Confirmatory Factor Analyses through the *lavaan* R package (Rosseel, 2012) on each of our measures in order to ascertain that the assumed dimensionality for each scale led to a good fit of the data. As stated in the preregistration, we aimed to achieve an acceptable level of internal consistency (Cronbach's $\alpha > 0.6$) as well as an acceptable goodness of fit for assumptions of unidimensionality: (SRMR <= 0.08, RMSEA <= 0.08, TLI >= 0.90, CFI >= 0.90; Hu & Bentler, 1999)[1].

2.5.2 Confirmatory analyses

We used Bayesian approach for parameter estimation and hypothesis testing (i.e., the Bayes factor) as implemented in the bayesian regression models in Stan (*brms*) package (Bürkner, 2016) to test our hypotheses. Bayes factor is a ratio comparing the likelihood of the data under the null and alternative hypotheses, therefore provides information about both (see e.g. Jarosz & Wiley, 2014 for more details). We report Bayes factor (BF) results using Jeffreys terminology (see Jarosz & Wiley, 2014). BF_{10} represents evidence for the alternative hypothesis (as compared to the null) while BF_{01} corresponds to evidence for the null (as compared to alternative hypothesis). Additionally, we report the 95% posterior credible intervals, which represent a range of probable values for the posterior parameter estimates.

[1] Root Mean Square of Approximation (**RMSEA**), Standardized Root Mean Residual (**SRMR**), Tucker-Lewis Index (**TLI**), Comparative Fit Index (**CFI**)

Since we used a fictive outgroup, about which participants had only a minimum of information, we refer to any negative attitudes towards the Drashneeans as xenophobic attitudes or prejudice. For the multiple regressions (Table 1, models 1 to 5), we used a preregistered prior of a normal distribution centered on 0, with a standard deviation on 0.25. This prior was inspired by a meta-analytical effect of the relationship between BIS measures and social conservatism (Terrizzi et al., 2013). We used education, gender and age as demographic covariates, that were not of theoretical interest. All variables were standardized prior to testing the models to ease the interpretation of results.

Prior to checking if dissimilarity mediates the relationship between BODS and negative attitudes towards Drashneeans (xenophobia), we checked if our data fulfills the requirements for mediation, namely, whether perceived dissimilarity was related to BODS and xenophobic attitudes (Table 1, models 3A-3B,). The mediation was checked using the *mediation* package in R (Tingley, Yamamoto, Hirose, Keele & Imai, 2014; Table 1, model 3C).

Hypothesis	Model	Model notation
Hypothesis 1	model 1	`Xenophobia ~ BODS + Gender + Age + Education`
Hypothesis 2	model 2	`Dissimilarity ~ Gender + Age + Education`
Hypothesis 3	model 3A: *mediation path*	`Dissimilarity ~ BODS + Gender + Age + Education`
	model 3B *direct path*	`Xenophobia ~ Dissimilarity + Gender + Age + Education`
	model 3C *indirect path*	`Xenophobia ~ Dissimilarity + BODS + Gender + Age + Education`
Hypothesis 4	model 4	`GeneralAttitude ~ Xenophobia + Gender + Age + Education`
Hypothesis 5	model 5	`GeneralAttitude ~ BODS + Gender + Age + Education`

Table 1. **Models corresponding to each hypothesis.** Details of regression models built to test our five hypotheses. Models are described in Wilkinson notation. Names used in the models

correspond to the following variables: negative attitudes towards Drashneeans (Xenophobia), perceived dissimilarity of food, hygiene and sanitary practices of the Dreashneeans (Dissimilarity), Body odor disgust sensitivity (BODS), general negative attitudes towards immigration (GeneralAttitude), gender, age and education.

2.5.3 Second prediction: Confirming the theoretical model with SEM

Additionally, we planned to perform a Structural Equation Modeling (SEM) analysis in order to test our theoretical model explaining the relationships hypothesizes earlier (all paths in Fig. 1.). We performed a maximum likelihood (ML) based SEM (as implemented in the *lavaan* package; Rosseel, 2012). The model (Fig. 1.), as well as the use of the *lavaan* package has been preregistered. However, after completing the preregistration, we discovered a bayesian equivalent of the analysis (implemented in the *blavaan* package; Merkle and Rosseel, 2016) and decided to run a parallel bayesian SEM analysis to include in Supplementary materials. We set the same priors as the ones set for the *brms* regression analyses (normal distribution with a mean = 0 and SD = 0.25). The SEM analyses were performed on raw scores, except for Xenophobic attitudes index and the feeling Thermometer. More detailed results from both SEM analyses can be found in the Supplementary materials.

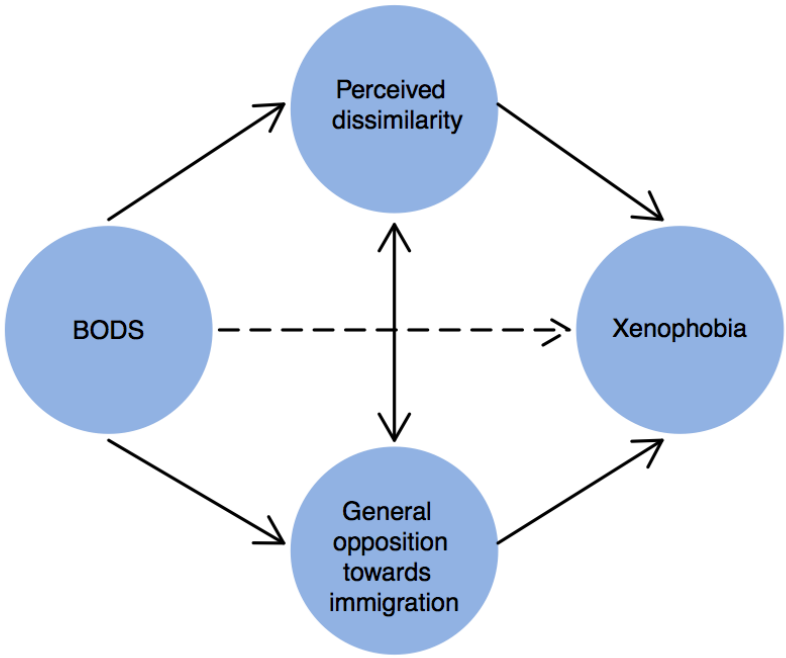

Fig. 1. Preregistered theoretical model of the relationship between latent variables: body odor disgust sensitivity (BODS), negative attitudes towards the fictive outgroup (xenophobia), perceived dissimilarity in terms of food, hygiene and sanitary practices and general opposition towards immigration.

3. Results

3.1 Unidimensionality and internal consistency of the scales used in the study

All scales reached acceptable to perfect fit with a unidimensional model as well as desired internal consistency (Cronbach's α 's > 0.84). To maintain the assumptions, the scales needed to be reduced in some cases: failure to achieve the thresholds led to further inspections of our items which, in two cases, determined the removal of the most problematic items in terms of reliability or unidimensionality. This is what occurred with the measures of explicit xenophobia and the BODS' items. In the first case, modeling the residual covariance between

the reverse-coded items and between the straight-coded items led to acceptable fit. In the case of the BODS, an inspection of the modification indexes led to the removal of six items, which led to an acceptable fit for the remaining six items (see the Supplementary Materials).

Descriptive statistics for scores on the four scales are in Table 2. The xenophobia scale was standardized prior to performing dimensionality and consistency checks, therefore it has a mean of 0.

	mean estimate (SD)
Xenophobia (questions)	5.11 (2.26)
Xenophobia (thermometer)	41.36 (24.05)
BODS	3.21 (0.84)
Perceived dissimilarity	6.35 (2.23)
General opposition towards immigration	3.26 (1.39)

Table 2. Descriptive statistics for scores on the four scales. The mean and standard deviation (SD) values for each scale. For Xenophobia, we provide mean and Sd of the questions and the feeling thermometer separately. The variables correspond to choices among the following ranges of values: Xenophobia 1 - 10 (questions) and 0 - 100 (for the feeling thermometer), BODS: 1 - 5, Perceived dissimilarity: 1 - 10, General opposition to immigration: 1 - 7.

3.2 Body odor disgust sensitivity is associated with xenophobic attitudes to an unfamiliar outgroup

BODS confidently predicted the level of xenophobic attitudes towards the unfamiliar outgroup (Fig. 2.). As expected (Hypothesis 1), higher BODS was related to more negative

attitudes towards the Dhrashneean refugees (mean posterior estimate = 0.19, 95% posterior credibility intervals (PCI) = [0.13, 0.24]. Although the strength of the relationship was not very strong, we found decisive evidence against the null hypothesis (BF_{10} > 1000).

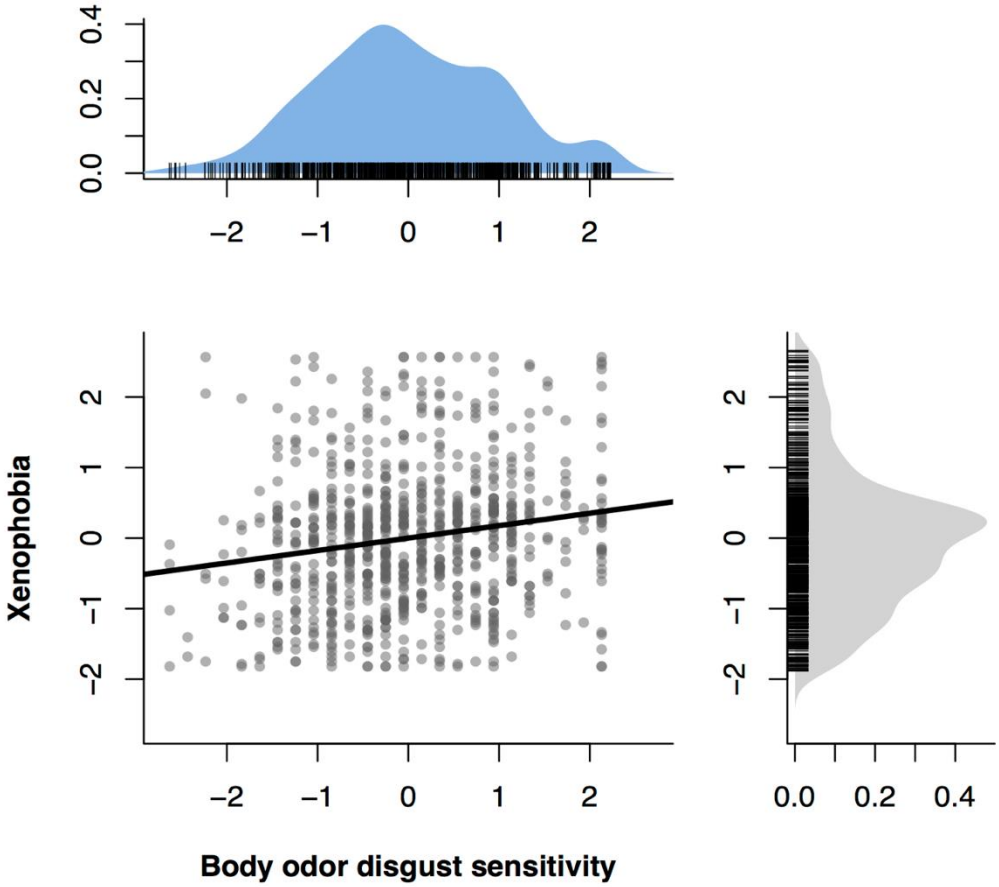

Fig. 2. Relationship between body odor disgust sensitivity (BODS) and negative attitudes towards the fictive outgroup (Xenophobia). The distributions of both variables are depicted above (BODS) and right (Xenophobia) of the scatterplot. The density of the data is additionally illustrated by the intensity of the color of each data point.

3.3 Dhrashneean refugees are perceived as dissimilar in terms of food preparation, hygiene and sanitary practices.

We found that the 95% PCI ranged from 6.19 and 6.50 and there was decisive evidence in favor of the hypothesis that the perception of dissimilarity in terms of was above the midpoint ($BF_{10} > 1000$).

3.4 Perceived dissimilarity mediates the relationship between BODS and xenophobic attitudes towards an unfamiliar group

In order to test if the BODS-xenophobia relationship was mediated by perceived dissimilarity of the Dhrashneean refugees (Hypothesis 3) we first checked the prerequisites for mediation namely, whether perceived dissimilarity is related to both BODS and xenophobic attitudes. Dissimilarity confidently predicted the xenophobic attitudes (mean posterior estimate = 0.45, 95% PCI = [0.41 – 0.50], $BF_{10} > 1000$) and BODS was related to perceived dissimilarity (mean posterior estimate = 0.09, 95% PCI = [0.03 – 0.16], $BF_{10} = 3.19$). The mediation analysis showed that dissimilarity partially mediates the relationship between BODS and xenophobia (see Fig. 3.).

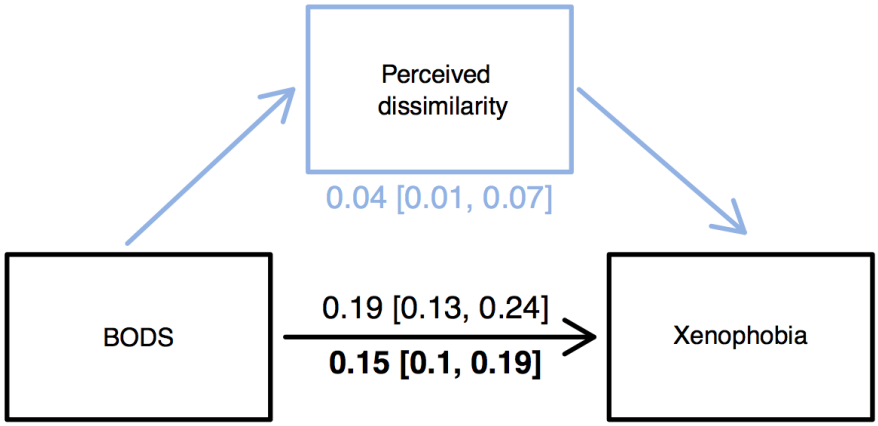

Fig. 3. Outgroup health and food practices dissimilarity (Perceived dissimilarity) partially mediates the relationship between body odor disgust sensitivity (BODS) and negative attitudes towards the fictive outgroup (Xenophobia). The mediation effects (indirect path) are depicted in a lighter color. Bold black text corresponds to the direct path effects (when accounting for Perceived dissimilarity), the total effect is marked in regular black text. Numbers in brackets correspond to 95% quasi Bayesian credibility intervals.

3.5 Negative attitudes towards an unfamiliar outgroup reflect general opposition to immigration

We found that negative attitudes towards the Dhrashneean's confidently predict general opposition towards immigration (mean posterior estimate = 0.87, 95% PCI = [0.82 – 0.93] and we found decisive evidence in support of Hypothesis 4 (BF_{10} > 1000). We found that although BODS predicted general attitudes towards immigration (mean posterior estimate = 0.08), the 95% PCI [0.01 – 0.15], the effect was close to zero, and the evidence is inconclusive in this regard (BF_{10} = 1.54), thus providing only anecdotal evidence in support

of Hypothesis 5. Fig. 4 summarizes the results from models 1-5 with regard to our preregistered pattern of relationships (Fig. 1).

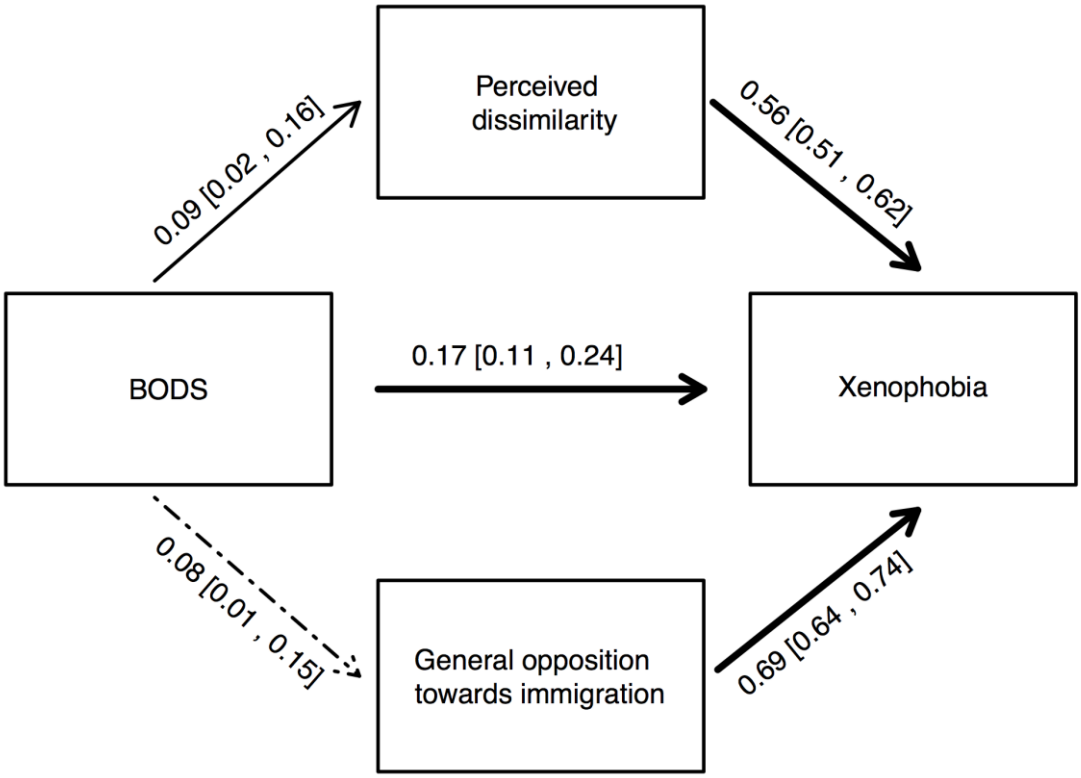

Fig. 4: Summary of the results from multiple regression models with regard to preregistered hypotheses. Evidence for the existence of relationship is marked by the thickness of the arrows with 3 steps: BF>1000 (thick solid arrow), BF > 3 (solid arrow), BF < 3 (two-dashed arrow). Coefficients and 95% PCIs are noted next to the corresponding arrows.

3.6 SEM results

Finally, our structural equation model reached a good fit (SRMR = .063, RMSEA = .081, TLI = .92, CFI = .93) and confirmed our predicted pattern of relationship (Fig. 5.). Analysis on the parameter estimates in Model A and the respective 95% bootstrapped confidence

intervals revealed that both of the indirect paths explained the relationship between the BODS and negative attitudes towards the Dhrashneean (BODS → General Opposition towards immigration → Xenophobia = 0.13, 95% CI [0.03, 0.13]; BODS → Perceived dissimilarity → Xenophobia = 0.08, 95% CI [0.02, 0.25]).

The bayesian SEM parameters from *blaavan* estimates were similar to those obtained from the non bayesian, ML-based SEM model from *laavan* reported above, and confirmed the same pattern (see Supplementary materials for details).

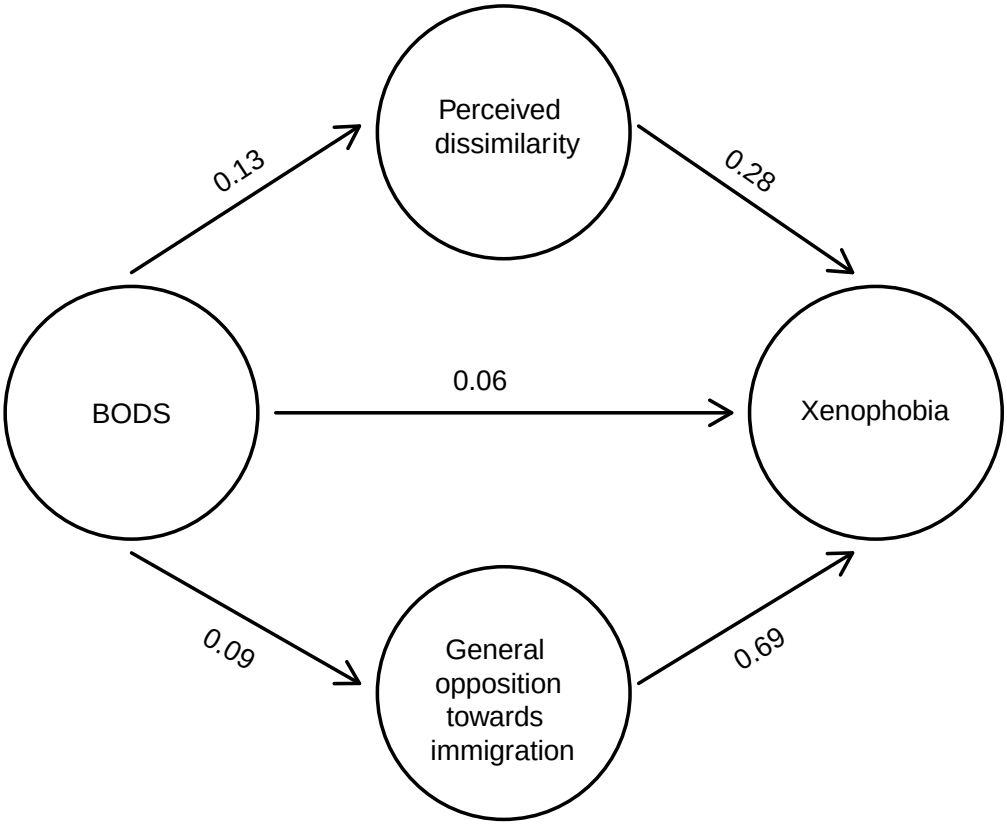

Fig. 5.: Results from the SEM analysis on the preregistered model of the relationship between body odor disgust sensitivity, xenophobia, perceived dissimilarity and attitudes towards immigrants using SEM. Latent variables are marked with circles and thick lines represent paths in which the bootstrapped CIs do not include 0.

3.7 Additional analyses

Although not planned, we compared our SEM model against the alternative model containing a complete mediation (SRMR = .067, RMSEA = .081, TLI = .92, CFI = .93). The model with the partial mediation, which includes the direct path from BODS to the negative attitudes towards the Dhrashneean, performed better (*delta $chi_{(1)}^2$ = 6.4, p = .012, *delta AIC = 4.4). The partial mediation model outperformed also other, alternative models (*delta chi^2 > 277 p < .001, *delta AIC > 271, see Supplementary materials for more details)

4. Discussion

May high levels of olfactory disgust sensitivity make some individuals prone to prejudice towards immigrants? We show that high disgust sensitivity to body odors is weakly, but confidently, related to higher levels of explicit xenophobia towards an unfamiliar African outgroup. This relationship is partially mediated by perceived dissimilarity of this outgroup. In other words, individuals who are more easily disgusted by body odors also tend to hold negative attitudes toward some immigrants, because they think of them as fundamentally different in terms of food, hygiene and sanitary customs. Our results strengthen the theoretical framework of the behavioral immune system which assumes that disease avoidance may underlie some forms of prejudice, suggesting also that reluctance to accept unfamiliar practices in basic aspects of life may at least partially explain this link.

Although body odors are universal elicitors of disgust (Curtis & Brian, 2001), research incorporating odor disgust to the BIS framework is yet scarce. As the sensitivity of BIS can be largely attributed to the fact that pathogens are invisible threats, hard to detect from visual cues (Tybur & Lieberman, 2016), we believe olfaction and olfactory disgust might be an important factor contributing to avoidant social behaviors. In support of this assumption,

pathological processes are reflected in odors such that the human nose is able to detect them (Olsson et al., 2014; Shirasu & Touhara, 2011). Moreover, perceived vulnerability to disease is more strongly linked to disgust sensitivity for odors, compared to other types of disgust (Liuzza et al., 2017a). Taken together, the olfactory system might be involved in shaping social attitudes and behaviors towards a rejection of the unfamiliar. Indeed, previous research from our group showed that BODS is related to authoritarianism, namely that individuals who are more sensitive towards body odor induced disgust have more authoritarian views (Liuzza et al., 2018). The current study went a step further and linked BODS to xenophobia and attitudes towards immigration, measured in an explicit way. Future research should focus on the association between body odor disgust sensitivity and implicit biases towards outgroups. Studying implicit attitudes is important because, in contrast to explicit bias (self-declared attitudes), it refers to the negative associations we have, but are either not aware of, or choose not to report.

Our results resonate with a sentimentalist, or intuitionist, view (Haidt, 2001) of moral judgment, which contends that affect may play a causal role in moral judgment. In fact, core - pathogen - disgust and moral disgust seem to be closely intertwined (Chapman et al., 2009; Vicario et al., 2018) and may share a common neurocognitive system (Vicario, Rafal, Martino, & Avenanti, 2017). Our participants had to express moral-related judgments (e.g., "The Dhrashneean refugees are, given that they are allowed to immigrate to United States of America, likely to bring criminal problems to the area.") on a fictive group that they did not know. Since we observed harder judgment by participants who scored higher on disgust sensitivity, we may assume that they relied more on gut-feelings, in accordance with a neo sentimentalist view of moral judgment.

One strength of our study is that we used BODS, which is a well-validated scale (Liuzza et al., 2018; 2017a, 2017b), and strictly related to olfactory-elicited disgust which is

highly relevant for BIS and disease avoidance (Stevenson, 2010). Furthermore, BODS, as a scale, is arguably free from social and moral domain overlap. For these reasons, BODS is a promising tool for measuring disgust within the BIS framework. Another strength is that, by using Structural Equation Models, we investigated the relationship across latent variables taking into account the measurement error that varies across indicators. We used an unusually thorough approach to data analysis, including quality checks on the measurements we used to ascertain the validity and reliability of scales and refined them in order to get a more valid and reliable measure. Although these checks should be mandatory for all studies involving psychometric measures, their details are rarely provided in prior BIS research.

Last but not least, we used a preregistered, Bayesian approach to data analysis and hypothesis testing. Preregistration allowed to reduce the researchers' degrees of freedom (Simmons, Nelson and Simonsohn, 2011), making our conclusions more solid, which is an important goal considering the psychology credibility crisis that stemmed from the observation of the low replicability rate in the field (Open Science Collaboration, 2015). Furthermore, the use of Bayesian approach to hypothesis testing allowed us to evaluate the probability of our hypotheses being true in the light of obtained data, which is in vast contrast to the well-known limitations of p-values (Dienes, 2008).

Despite the abovementioned merits of our study, it is not free from limitations. First of all, the sample used in the study is draw from the population of Amazon Mechanical Turk (MTurk) workers, not randomly drawn from the entire population. Although samples recruited through MTurk workers surely differ from the general population (Paolacci, Chandler, Ipeirotis, 2010), MTurk samples have been shown to be more diverse and representative than common convenience samples (e.g. college students) typically used in psychological research (Buhrmester, Kwang, Gosling, 2011; Berinsky, Huber and Lenz, 2012), and data from Mechanical Turk studies have been shown to be psychometrically valid

(Shapiro, Chandler and Mueller, 2013). Furthermore, the relationship between disgust sensitivity and opposition to immigration appears to be of the same magnitude among MTurkers and US nationally representative samples (Aarøe et al., 2017). An important limitation is that our sample was restricted to the USA. Our results need to be replicated for groups living in other areas of the world. Although most research on xenophobia focuses on developed, western societies, the phenomenon is not unique to these societies (Rannou, 2017). Cultural contexts can affect moral judgment (Ho, 2010), which is related to the domain of ideology and prejudice (Graham, Haidt and Nosek, 2009). It is therefore of paramount importance to extend our results to other cultural contexts. Another limitation lies in the fact that we did not include a measure of income in our study. Lower income, as a measure of lower socioeconomic status, has often been associated with opposing immigration (Espenshade & Hempstead, 1996) and would therefore be adequate to use in our analysis. Nevertheless, we adjusted our models for education, which can be treated as a proxy for socioeconomic status, as well as other lifestyle factors.

Lastly, we would like to comment on the reduction of the BODS scale for the analyses performed in this study. Although it would be premature to shorten the BODS scale basing on this one study, attention should be paid to see if the same pattern will be repeated in the future, to decide on the best version of the scale.

5. Conclusions

Consistently with the theoretical framework provided by the BIS, we found that body odor disgust sensitivity is related to prejudice and attitudes towards immigrants. Higher levels of BODS are associated with higher levels of prejudice and this association is mediated by perceived dissimilarity in hygiene and food preparation practices. BODS is a promising,

well validated instrument that can be used to further our understanding of the relationship between prejudice against outgroups and evolutionary disease avoidance mechanisms. Olfactory assessments may be well suited to assess potential sensory roots of outgroup prejudice.

Author Contributions

M.T. Liuzza, T. Lindholm and J. Olofsson developed the study concept and design. A. Blomkvist prepared study materials and collected data. M. Zakrzewska and M.T. Liuzza performed the data analysis and drafted the manuscript, all authors provided critical revisions and approved of the final version of the manuscript for submission.

Open Practices Statement

Data analysis plan including hypotheses and tools to test them were preregistered at OSF. The data, analyses scripts, as well as all materials used in the study are available online at https://osf.io/fsbna/.

Founding

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Conflict of interest

The authors declare no conflicts of interest.

SUPPLEMENTARY MATERIALS

1. Methods

1.1 Hypothesis 2

In our preregistration we hypothesized (Hypothesis 2) that the similarity ratings should have differed confidently from the midpoint (5.5 in a 1-10 scale). Although we later realized that this formulation was not appropriate for the unipolar scale used in the study (1 = *not similar at all*, 10 = *highly similar*, then reverse-coded), we still tested whether the intercept differed from the midpoint when controlling for the demographic variables.

2. Results

2.1 Unidimensionality and internal consistency of the scales used in the study

All the following check were done using the *lavaan* R package (Rosseel, 2012).

2.1.1 Xenophobia scale

A first inspection of the unidimensionality of the xenophobic attitudes towards the Drashneeans scale, revealed a poor fit for the unidimensional model (SRMR = 0.073, RMSEA = 0.363, TLI = 0.587, CFI = 0.86). A further inspection of the modification indexes suggested to model the covariance within the straight and the reverse keyed items, which led to an optimally fitting model (SRMR = 0.005, RMSEA = 0.000, TLI = 1, CFI = 0.999). Although the model appears to be underidentified here, it is identified when included in the full SEM model. Thus, we left the scale as a unidimensional measure, which appears to have a good internal consistency (Cronbach's α = 0.85).

2.1.2 BODS

The unidimensional model for the BODS did not reach acceptable fit values (SRMR = 0.091, RMSEA = 0.191, TLI = 0.722, CFI = 0.773). Modeling it as a bi-factorial construct substantially improved the fit, although the fit indexes were still sub-optimal (SRMR = 0.042, RMSEA = 0.121, TLI = 0.888, CFI = 0.91). After a further inspection of the modification indexes, we decided to remove the six items that showed an excessive covariance across residuals. This led to an acceptable fit among the remaining six items. (SRMR = 0.024, RMSEA = 0.095, TLI = 0.957, CFI = 0.977). The items removed pertained to body odors of sweat, feces and urine, from both external and internal sources. Thus, items related to breath, feet and gas were kept for the analysis.

Despite the reduction of items, the scale displayed a good internal consistency as a whole and in internal and external sub-scales (Cronbach's α 's > 0.84). However, we observed a high correlation between the two subscales (Pearson's r = 0.62), and we aimed to avoid multicollinearity issues. We thus decided to run our analyses on the BODS as a unique scale, similar to prior work (Liuzza et al., 2018). The scale had a good internal consistency (Cronbach's α = 0.88).

2.1.3 Perceived dissimilarity of the Dhrashneean refugees

The three items used to measure perceived similarity with the Dhrashneean refugees showed an excellent fit with a unidimensional model (SRMR = 0, RMSEA = 0, TLI = 1, CFI = 1), although the small number of indicators warrants some caveat on the interpretability of the fit indexes. The scale also had an excellent internal consistency (Cronbach's α = 0.93).

2.1.4 General attitudes towards immigration

The items on the general attitudes towards immigration showed an acceptable fit with a unidimensional model (SRMR = 0.028, RMSEA = 0.104, TLI = 0.961, CFI = 0.977). An inspection of the modification indices showed that there was no room for an improvement of the fit. The scale had a good internal consistency (Cronbach's α = 0.89).

2.2 Demographic characteristics of the sample size

In our sample, 444 participants identified as female, 358 as male and 3 as other. Table S1 shows the declared level of highest education accomplished by participants.

Education level	
No schooling completed	-
8th grade education or less	-
Some high school	1.1 %
High school diploma or equivalent	11.2 %
Some college without degree	20.5 %
Associate degree	10.7 %
Bachelor's degree	39.1 %
Master's degree	14.4 %
Professional degree	1.1 %
Doctorate degree	1.9 %

Table S1. Information about participants education. Numbers represent percentage of participants who chose a given level as the highest completed level of education.

2.3 The effects of gender, age and education on all hypotheses

Although the effects of gender, age and education were not of primary interest from the point of view of tested theoretical framework, they may have an effect on prejudice and were therefore included in all regression models. Here, we provide information about their effects. In general, gender had marginal effects (95% PCI including 0, mean posterior estimates <

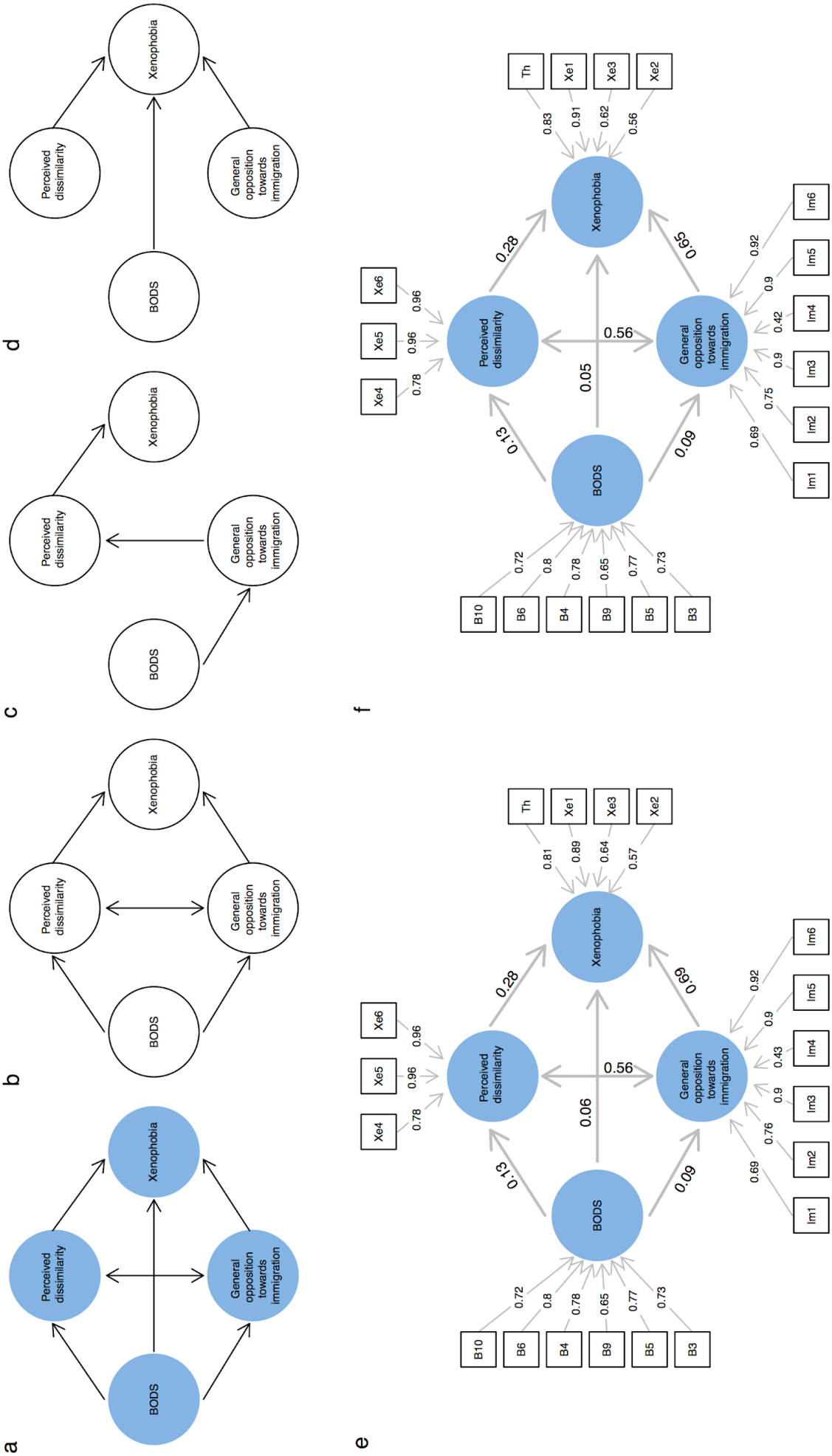
0.06). There might be a marginal effect of gender on xenophobia (Hypothesis 1), with females scoring lower than other genders. Education had small effects on all tested hypotheses, some of these effects being of similar magnitude to the effect of BODS and some being rather marginal (see Table S2. for details). Higher levels of education were related to less negative attitudes towards Drashneeans and the immigration in general, as well as perceiving the outgroup as less different. Age had an effect on perceived dissimilarity of the Drashneeans, as well as xenophobia in the direct path of the mediation, with the ratings on both scales increasing with age.

Hypothesis	Mean posterior estimate (95% PCI)		
	Gender	**Age**	**Education**
Hypothesis 1	**0.07 [0.01 0.12]**	0.06 [0 0.11]	**-0.08 [-0.14 -0.03]**
Hypothesis 2	0.01 [-0.14 0.15]	**0.27 [0.12 0.41]**	**-0.17 [-0.32 -0.02]**
Hypothesis 3A	0.04 [0 0.09]	-0.01 [-0.06 0.04]	**-0.07 [-0.11 -0.02]**
Hypothesis 3B	0.01 [-0.05 0.08]	**0.13 [0.07 0.2]**	**-0.07 [-0.14 -0.01]**
Hypothesis 4	0.01 [-0.04 0.05]	0.02 [-0.02 0.07]	**-0.07 [-0.11 -0.02]**
Hypothesis 5	0.05 [-0.02 0.12]	0.07 [0 0.14]	**-0.15 [-0.21 -0.08]**

Table S2. **Effects of gender, age and education on all tested hypotheses.** The values in bold highlight effects for which 0 lies outside the 95% PCIs.

2.4 SEM analysis

The following analyses were done using the *lavaan* R package (Rosseel, 2012) and then repeated using a Bayesian SEM in *blavaan* package (Merkle & Rosseel, 2016). We used the same priors as for the regression analyses (normal distribution with a mean = 0 and SD = 0.25). The models we tested and compared are depicted in Figure S1 (a-d).



Note: B - BODS scale items, X - Attitudes towards the Dreashnee refugees questionnaire items, Th - the feeling thermometer, Im - items from the general attitudes towards immigration questionnaire

Fig. S1. SEM analyses: (a - d) models used for model comparison and estimates for the winning model using (e) ML based SEM and (f) bayesian SEM. Depiction of the (a) partial mediation model and alternative models used in the SEM analyses: (b) complete mediation model, (c) chain model and (d) an additive regression model with three independent predictors. Preregistered model is represented using filled circles.

2.4.1 Maximum Likelihood (ML) - based SEM

Our preregistered structural equation model (the partial mediation model, Model A) reached a good fit (SRMR = .063, RMSEA = .081, TLI = .92, CFI = .93) and confirmed our predicted pattern of relationship (see Figure S1e. for details). It performed better than the complete mediation model (model B). Both the chain model (model C) and the model with three independent predictors (model D) performed worse (Table S3, Table S4).

	ML based SEM								Bayesian SEM		
	chi 2	**DF**	**SRMR**	**RMSEA**	**TLI**	**CFI**	**AIC**	**BIC**	**BIC**	**WAIC**	**LOOIC**
model A (partial mediation)	866	144	0.063	0.081	0.92	0.932	41170	41383	41407	41121	41121
model B (complete mediation)	872	145	0.067	0.081	0.92	0.932	41174	41383	41405	41124	41124
model D (additive model)	1143	147	0.165	0.094	0.891	0.907	41442	41641	41662	41391	41392
model C (chain model)	1312	146	0.118	0.102	0.872	0.891	41613	41817	41846	41566	41567

Table S3. Model fit details including: standardized root mean square residual (**SRMS**) , root mean square error of approximation (**RMSEA**), Tucker Lewis index (**TLI**), Akaike information criterion (**AIC**), Bayesian information criterion (**BIC**), widely applicable information criterion (**WAIC**) and leave-one-out information criterion (**LOOIC**).

	ML based SEM			Bayesian SEM				
	$chi_{(1)}^2$	***p value***	*delta AIC	*delta **LOO**	*delta **LOO SE**	*delta **WAIC**	*delta **WAIC SE**	**BF**
model A vs B	6.4	0.012	4.4	-1.9	2.1	2.0	2.1	0.6
model A vs C	446.7	< 0.0001	422.7	222.0	20.3	222.0	20.3	209.8
modelA vs D	277.7	< 0.0001	271.7	134.8	15.7	134.8	15.7	131.2

Table S4. Model comparison details including: chi^2 difference (*delta chi^2), the *p value* for the comparison, leave-one-out difference (*delta **LOO**), standard error of the leave-one-out difference (*delta **LOO SE**), WAIC difference (*delta **WAIC**), the standard error of the WAIC (*delta **WAIC SE**) difference and the BF for the comparison. Positive chi^2, *delta **LOO** and *delta **WAIC** values speak in favor of the base model (model A) as compared to the other models. Smiliary, small *p values* as well as greater BFs correspond to a better performance of the base model (model A).

2.4.2 Bayesian SEM

The preregistered structural equation model (the partial mediation model, Model A) outperformed the chain model (Model C) and the model with three independent predictors (Model D), while performing similarly to the complete mediation model (Model B) thus partially repeating the model hierarchy obtained from the non-bayesian SEM (Table S3, Table S4). The model confirmed the patterns of relationship and the magnitudes of the coefficients from the ML-based SEM analysis (see Figure S2f. for details)

Analysis on the parameter estimates in Model A and the respective 95% highest posterior density interval (HPDI)[2] confirmed again that both indirect paths explain the relationship between the BODS and negative attitudes towards the Dhrashneean (BODS → General Opposition towards immigration → Xenophobia = 0.11, 95% HPDI [0.02, 0.21]; BODS → Perceived dissimilarity → Xenophobia = 0.07, 95% HPDI [0.03, 0.12]).

[2] Similarly to the posterior credibility interval (PCI), the highest posterior density interval (HPDI) represents a range of probable values for the parameter estimates.

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