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Full-length Article

I see sick people: Beliefs about sensory detection of infectious disease are largely consistent across cultures

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ABSTRACT

Identifying cues to contagious disease is critical for effectively tracking and defending against interpersonal infection threats. People hold lay beliefs about the types of sensory information most relevant for identifying whether others are sick with transmissible illnesses. Are these beliefs universal, or do they vary along cultural and ecological dimensions? Participants in 58 countries (N = 19,217) judged how effective, and how likely they were to use, cues involving each of the five major sensory modalities in an imagined social interaction during a flu outbreak. Belief patterns were strongly consistent across countries (sight > audition > touch > smell > taste), suggesting a largely universal conceptualization of the role of sensory information for interpersonal respiratory disease detection. Results also support a safe senses hypothesis, with perceivers reporting that they would use senses that function at a distance—and thus reduce pathogen transmission risk—more than would be expected given participants' beliefs as to the efficacy of these senses for disease detection. Where societal variation did emerge, it was captured by a cohesive set of socio-ecological factors, including human development, latitude, pathogen prevalence, and population density. Together, these findings reveal a shared lens through which contagious respiratory disease is assessed, one that prioritizes minimizing risk to perceivers, and may offer leverage for designing interventions to improve public health.

1. Introduction

How do people know whether someone is suffering from a contagious illness? Identifying and defending against the threat of pathogens and parasites have been fundamental challenges throughout human evolution, as infections have likely killed more people than all wars, noninfectious diseases, and natural disasters combined (Inhorn & Brown, 1990). Efforts to understand the psychology of pathogen-threat management exploded following the COVID-19 pandemic. Here, we explore the initial stages of this management process in interpersonal contexts, asking how people judge the infectiousness of others.

Overt communication is important in efforts to avoid contagion, as people often simply say they are ill. However, such information is imperfect: sick people may not know whether their illness is transmissible (accurate diagnoses being historically recent, and, even today, medical care being limited for many), they may not believe they are sick, or they may be unwilling to disclose such information (e.g., Merrell et al., 2024). Importantly, overt communication is not the sole avenue for determining whether others might be ill, as sick individuals often evince a variety of cues detectable through sensory channels.

Research into the natural (i.e., unassisted by technology or training) use of sensory cues for contagious disease detection has generally followed two approaches. The first focuses on identification accuracy: perceivers attempt to determine targets' illness status from sets of sick (broadly defined) and non-sick stimuli (e.g., Arshamian et al., 2021; Axelsson et al., 2018; Hansson et al., 2023; Tognetti et al., 2023a). These stimuli commonly involve facial photographs or videos, making vision the sole sensory modality investigated. For example, participants judged photos of currently ill individuals to be sicker, more affectively unpleasant, and less attractive in an eye-tracking task (Leung et al., 2023). Research targeting other sensory modalities is less common and has shown inconsistent results. Perceivers were no better than chance at identifying contagious targets based on cough and sneeze sounds (Michalak et al., 2020), but the scent of sickness does appear detectable (Tognetti et al., 2023b) or at least more aversive (Moshkin et al., 2012; Sarolidou et al., 2020a).

A second approach, one we take here, examines lay beliefs about which sensory modalities afford disease detection. Notably, lay beliefs regarding how illnesses present can shape responses in contexts where disease transmission is possible. Beliefs likely influence the cues to which individuals attend, the ways they interact with others, and their subsequent behavior (Cameron & Moss-Morris, 2004). Such beliefs also have implications for those judged to be sick. Believing that others constitute disease threats may lead to avoidance, exhibition of intergroup prejudices, and support for restrictive policies as opposed to healthcare delivery (Choi et al., 2022; Ji et al., 2019; van Leeuwen and Petersen, 2018). Further, understanding lay beliefs about illness cues could inform public health knowledge gaps and misconceptions, and guide behavioral strategies for effective disease prevention.

1.1. Lay beliefs about infectious disease detection

A recent investigation of beliefs had U.S. participants judge the efficacy of information from the five major senses for identifying infection threats in others. Perceivers believed sight and audition to be the most

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effective modalities, followed by touch, smell, and taste, respectively (Ackerman et al., 2020). Critically, this sensory ordering was specific to interpersonal disease detection. Perceivers listed different sense orders for the effectiveness of pathogen identification in food (see also Ammann et al., 2019), and for the identification of non-transmittable personal characteristics (e.g., cleanliness, attractiveness). Thus, perceivers *believe* that cues processed through certain senses are better for accurately diagnosing disease hazards.

Evidence of adaptive design consistent with error management biases (Haselton & Nettle, 2006) was also present in the reported beliefs. When comparing perceived effectiveness with likelihood of use, perceivers reported being *more* likely to use sight and audition than they believed those cues to be effective, and they reported being *less* likely to use touch, smell, and taste than they believed those cues to be effective. A *safe senses hypothesis* was proposed to interpret this pattern. We clarify here two features of this hypothesis. First, sensory modalities vary in the spatial proximity required to obtain information, and proximity is a risk factor for pathogen transmission. As a result, in the context of potential interpersonal infection hazards, perceivers are biased to prefer senses that function at a presumably safe distance. Second, these beliefs are not substitutable. The bias toward more distal senses is specific to *use* of sensory modalities for detection. Even if a modality is believed to be effective for identifying sickness in others, the motivation to avoid close proximity will reduce intended use of that modality. As such, we should see downward pressure on use judgments relative to efficacy judgments for senses requiring close proximity.

Despite clear patterns in the Ackerman et al. studies, those data were collected only in the United States. This is a common limitation in the psychological literature (Henrich et al., 2010), as the vast majority of participant samples in published research are drawn from Western, Educated, Industrialized, Rich, Democratic (WEIRD) societies. This sampling bias also exists in related but separate literatures, including research on the behavioral immune system, which explores psychological mechanisms associated with detection and defense against infection threats (Ackerman et al., 2020; Gurven & Lieberman, 2020; van Leeuwen & Petersen, 2018; Schaller, 2011), and research on human sickness behavior, which investigates psychological, behavioral, and physiological changes during active infections (Dantzer & Kelley, 2007; Shattuck & Muehlenbein, 2015). Because previous work is limited to WEIRD samples, it is difficult to determine whether the documented lay beliefs are the product of panhuman, biologically evolved psychological mechanisms, parochial cultural/historical processes, or some combination. The cultural, educational, and ecological landscape of the U.S. may dictate people's understanding of infectious disease processes and the cues that best afford threat identification. For instance, it may be that models of contagious disease taught in the U.S., unlike some other countries, focus primarily on visual and auditory aspects of germ transmission (e.g., Centers for Disease Control and Prevention, 2023). Similarly, the unique physical and social ecologies (perhaps related to pathogen prevalence) of the U.S. could either evoke particular patterns of infection identification, or shape cultural beliefs about disease detection, that, respectively, are dissimilar to those in other parts of the world (e.g., Murray & Schaller, 2010; Oaten et al., 2011; Wormley & Cohen, 2022). For example, traditions linking fresh air to health, such as lüften in Germany and *havalandırma* in Türkiye (Hernández-Morales, 2021; Önder, 2007), may be associated with relatively greater emphasis on smell as an effective detection modality.

Consistent with the potential for cross-cultural differences in lay beliefs, aspects of folk biology and psychology vary across cultures (Boyer & Petersen, 2018; Gelman & Legare, 2011; Medin & Atran, 2004). For example, depending on the culture, people may rely primarily on morphological, ecological, biological, and/or relational similarities to represent categories of living kinds (Atran, 1998; Busch et al., 2018). Of particular relevance, cognitive models of contamination show cultural distinctions, as in the belief that a given object is more material or spiritual in its contaminating properties (Hejmadi et al., 2004). Social norms may influence sensory beliefs even when those norms are only indirectly connected to disease, as in preferences for interpersonal distance (Sorokowska et al., 2017). Finally, linguistic indicators of sensory concepts vary between language families: though vision terminology overshadows use of verbs connoting other senses, no universal ordering of sense modalities exists (San Roque et al., 2015). Cultures thus differentially emphasize sense concepts, and hence sensory beliefs regarding infection detection may vary, aligning with culturally- or ecologically-specific features of each society.

An alternate, universalist account predicts a more consistent pattern of lay beliefs across societies. This could arise for multiple reasons, including the manner in which evolution has prioritized various senses. For example, across primates, more of the brain is devoted to visual processing than processing of other sensory information (Van Essen et al., 1990), and, in humans, vision typically dominates other senses experientially (Stokes & Biggs, 2014). However, a fixed sensory processing hierarchy is unlikely to account for a universal pattern of infection-detection lay beliefs. For one thing, the affordances for detection vary across categories of threats, and perceivers appear sensitive to these affordances, prioritizing different senses when identifying interpersonal versus food-based pathogen dangers versus non-pathogenic characteristics (Ackerman et al., 2020). Therefore, if a relatively universal pattern of lay beliefs regarding interpersonal disease detection exists, this may reflect either a shared mental model of infectious disease symptomology (perhaps informed by sensory affordances), an evolved cognitive bias (Haselton et al., 2015) consistent with the safe senses hypothesis, or both. Consistent with a universalist account, evidence suggests that specific physical cues motivate interpersonal avoidance and may be associated with identification of acute inflammatory activity across many cultures (Arshamian et al., 2021; Oaten et al., 2011).

1.2. Current research

Which account better characterizes beliefs about sensory detection of interpersonal infection threats, a relativist or universalist perspective? Recognizing the dearth of cross-cultural research on cognitive models of disease and its avoidance (Oaten et al., 2011), we examined this and related questions among participants from approximately 30 % of the world's countries, spanning all major world regions. Although we employed convenience samples—and acknowledge they are not representative—we nevertheless sought to avoid biasing our samples toward highly Western-oriented participants by employing the most prevalent local language (for countries where English is not widely used) and using recruitment methods preferred by local collaborators. We replicated methods from Ackerman and colleagues (2020) to examine two types of lay beliefs about the five major senses in the context of disease detection, namely (1) effectiveness and (2) likelihood of use. A relativist account would predict substantive variation in these beliefs, whereas a universalist account would predict relatively little variation. Lastly, we sought to explore potential correlates of (possible) cross-cultural variation, including factors such as societal-level pathogen prevalence, population density, human development, and latitude (all of which could affect both disease risk and knowledge thereof; Van de Vliert & Van Lange, 2019), as well as possible differences in sample characteristics across study sites.

2. Method

This study is one of five distinct, preregistered components of an omnibus survey. Each component featured unique measures, hypotheses, and exclusion criteria.

Project collaborators were invited on a convenience basis and through snowball recruitment. At each collaborating site, investigators were asked to ensure adherence to institution-specific regulatory guidelines for human research (e.g., informed consent), presuming those existed. Collaborators at all sites reported either obtaining site-specific approval, or that this process was not applicable at their institution. In two countries, multiple sites were sampled by multiple teams.

We report all data exclusions and measures relevant to the current study. Survey materials in English, translations, datasets, analysis code, original preregistration, and a preregistration amendment are at: https://osf.io/9vj6t/?view_only=e67cc933a20841ec86dec87e44c988cc. (See Supplement Table S1 for the amendment's updates to the original preregistration.)

2.1. Participants

Adults (18 and over) in 62 countries participated between September 3, 2021 and March 21, 2022. Collaborators were asked to recruit at least 300 participants at their site, though this number was reached (following preregistered exclusions) at only 44 sites, with 10 other sites exceeding 150 participants, and 8 sites recruiting less than 150 participants. For the current project component, a power analysis for a sensory modality by rating type interaction (based on effect sizes from Ackerman et al., 2020) indicated that samples of less than 80 would be inadequately powered (80 %, $\alpha = 0.05$), hence data from 4 countries were excluded (Argentina, Ethiopia, India, Russia).

Participation occurred either online or at local study locations per collaborator preference. Participants included unpaid volunteers, credited students, and paid workers, with compensation depending on the study site. See Table S2 for a list of study sites, recruitment procedures, and participant demographics. Overall, 31,644 participants started the survey.

2.2. Measures and procedure

Participants were recruited for a study titled "Reactions to Sight, Sounds, and Events" which included all project components. They accessed the study through a web page presenting basic information, followed by the Qualtrics-hosted survey, both of which employed the site-specific language. Participants completed the survey in a single session.

Where deemed appropriate by collaborators, survey materials were translated from English and back-translated to English by separate, fluent bilingual speakers. Back-translations were checked by the principal investigator team. Table S3 lists departures from the original due to the absence of corresponding terms in the target language.

The measures reported here appeared at the beginning of the survey, before other facets of the project (results of which will be reported elsewhere). Participants read the following vignette text.

> *Imagine that over the last couple of weeks, a very bad flu outbreak has occurred (not COVID-19). People infected with this illness have gotten extremely sick, and vaccinations have been useless against this particular disease. Public health officials have urged people to be cautious about their behavior and take appropriate steps to prevent infection.*
> *Now imagine you will be speaking with another person. You will be in a closed room (or other close interaction) with this person for at least an hour. However, you are unsure if this person has the flu or not. They may not even know themselves.*

Participants then addressed each of the five major senses (sight, audition, smell, taste, touch) on measures assessing beliefs about senses in the vignette situation. First, they rated how "effective or useful" each sense would be in determining whether the person is sick, using a scale from 1 (not useful at all) to 7 (extremely useful). Second, they rated how "likely you are to use" each sense in determining whether the person is sick, using a scale from 1 (not at all likely to use) to 7 (extremely likely to use).

Participants then responded to demographic items, reported any technical problems, provided feedback, were debriefed, and, if applicable, compensated.

Socio-ecological variables were later coded for each country (see Supplementary Methods for source details).

2.3. Data approach

Following preregistered criteria, data were screened for minimum timing, completeness, and correct answers to attention checks. Participants were excluded if they did not answer all lay belief items (accounting for most of the exclusions). Excluding countries with fewer than 80 participants per the preregistration amendment, 58 countries remained (see Fig. 1), with a final total sample of 19,217 participants (65 % women, 31 % men, 4 % other; $M_{age} = 27.59$, $SD_{age} = 11.20$). The Supplementary Materials includes details on exclusion criteria and per-country information on the 12,427 exclusions (Table S2). For all major analyses, comparable results were found when including all participants (i.e., no exclusions; see Supplementary Methods, p. 16).

Analyses were conducted in R, version 4.4.0. For the primary tests of sensory ratings (Results 3.1 & 3.4), ratings were regressed on the interaction between sense type and rating type using restricted maximum likelihood linear mixed regression, with random effects set for participants nested within study sites to account for the non-independence of ratings both within individuals and within countries. Consistency across countries (Results 3.2 & 3.5) was assessed through descriptive comparison of sense rankings and means, and also quantified by calculating Kendall's coefficient of concordance (Field, 2005) and the adjusted intraclass correlation coefficient. Finally, as an exploratory analysis of variation across countries (Results 3.3), we calculated site-specific mean sense ratings for each unique combination of sensory modality and rating type and conducted Bayesian linear regressions using the *brms* package in R (Bürkner, 2017), which allows for control of cultural and geographic proximity (potential sources of non-independence). Table 1 presents the full set of model variables.

3. Results

3.1. Question 1: What are people's lay beliefs about sensory efficacy and likelihood of use for detecting disease?

Using a pooled sample across all study sites, we examined beliefs about the effectiveness of, and likelihood of using, each of the five senses in detecting disease. Based on estimated means from the restricted maximum likelihood linear mixed regression model, sight was rated the most efficacious sense, followed by audition, touch, smell, and taste. Estimated means significantly differed across all five senses ($Bs = 0.46$–3.58, $ps < 0.0001$); the estimated mean for sight efficacy (5.90) was 3.58 units higher than that for taste efficacy (2.32). The same ordering of senses obtained for likelihood ratings, with all pairwise differences being statistically significant ($Bs = 0.64$–4.52, $ps < 0.0001$). These results replicate the pattern previously found in the U.S. (Ackerman et al., 2020). See Fig. 2 and Table 2 for a plot and list of estimated means, respectively.

Demographic variables did not meaningfully moderate or impact the effects of sense type and rating type on sense ratings (see Supplementary Results 1).

3.2. Question 2: Are sensory patterns consistent across study sites?

Though predicted global means of the sense ratings are readily visualized, cross-cultural differences in the patterning of sense ratings are not as easily summarized. Therefore, we present several visualizations of these ratings across study sites to explore possible cross-cultural variation. See Supplementary Table S4 for site-specific estimates.

We examined the relative importance of the five senses by plotting the rank order of efficacy and likelihood of use ratings at each study site individually (i.e., ordering the senses based on mean ratings within each site). The sense with the highest efficacy or likelihood of use rating was

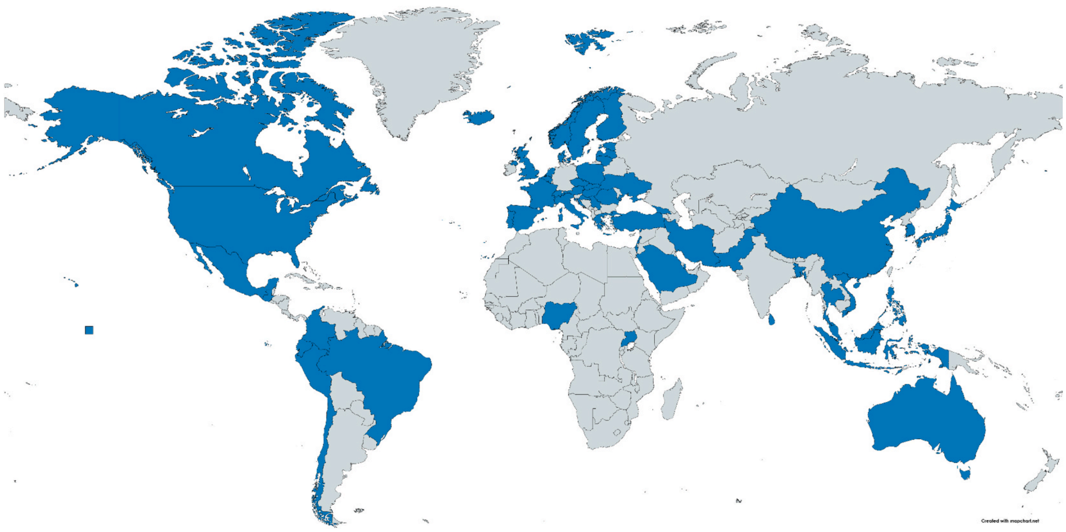

Fig. 1. Map of countries with sampled study sites (blue).

Table 1
Analytic model details.

Results section	Model description	Independent variables	Dependent variable	Random effects
3.1 & 3.4	Individual-level effects of rating type and sense type on sense ratings	Rating TypeSense TypeRating * Sense Interaction	Individual-level sense ratings (1–7 scale)	ParticipantCountry
3.3	Effects of geospatial flourishing index on sense ratings	Rating TypeSense TypeGSIRating * Sense * GSI Interaction (and all two-way interactions) Geographic Subregion	Country-level sense averages (1–7 scale)	Linguistic ProximityGeographic Proximity

ranked 1, and the sense with the lowest rating was ranked 5. We then plotted these rankings for efficacy and likelihood ratings separately (see Fig. 3).

To quantify variation in sense rankings, we used two approaches. First, Kendall's coefficient of concordance (*W*), where 0 represents no agreement across sites and 1 represents total agreement, was 0.95 for the efficacy rankings and 0.97 for the likelihood of use rankings, indicating near-perfect agreement (Field, 2005). Converting these values to Spearman correlation coefficients for ease of interpretation gives identical values ($r_s = 0.95, 0.97$). Second, the adjusted intraclass correlation at the country grouping level was very low (0.014), indicating that the ratings of individuals across all senses within countries were essentially no more similar than the ratings of individuals across countries. As visualized in Fig. 3, sight was ranked most effective in 54 out of 58 study sites, and most likely to be used in 57. Audition was rated as second most efficacious in 44 sites, and as second most likely to be used in 53. Touch was rated as third most efficacious in 46 sites, and as third most likely to be used in 53. Smell was ranked second to last for efficacy at all sites, and second to last for likelihood of use ratings at all but one site. Across all sites, taste was rated as least efficacious and least likely to be used. The overall ranking consistency is particularly strong when considering the number of possible rank orders that exist (120 per country). Where variation occurred, it was predominately between touch and audition rankings. Across senses, variation also was more likely in efficacy ratings (14 sites) than in likelihood of use ratings (6 sites). Of the six sites that had non-typical likelihood of use rankings, five also had non-typical efficacy rankings.

3.3. Question 3: What predicts variation in sensory patterns across study sites?

We next examined whether country-level factors accounted for deviations in sense rankings (see Fig. 3). We stress that these analyses were exploratory, and the high degree of consistency across sites suggests that results should be interpreted with caution. Socio-ecological factors, including pathogen prevalence, population density, human development index (HDI), and latitude, could plausibly associate with variation in responses to disease (e.g., Thornhill & Fincher, 2014; Tybur et al., 2016; but see Bromham et al., 2018; Currie & Mace, 2012). These factors shape environmental affordances involving disease exposure and transmission (e.g., Wong & Li, 2020), affordances involving sense use (e.g., high population density may force relatively greater use of close proximity modalities), many cultural outcomes in general (Wormley et al., 2023), and they may also play a role in education about contagion processes. Additionally, variation in rankings is likely to cluster as a function of cultural and geographic proximity between countries (Bromham & Yaxley, 2023; Claessens et al., 2023).

For each study site, we calculated mean sense ratings for each unique combination of sense and rating type. Like the individual-level data, we then lengthened this country-level data such that there was a single sense rating variable with ten observations per study site, and indicator variables corresponding to each unique combination of sense and rating type. We regressed the sample-mean ratings on the interaction between rating type and sense type. Models were fit using Bayesian linear regressions, because the *brms* package in R (Bürkner, 2017) has features that can be used to control for cultural and geographic proximity, two primary sources of potential non-independence across countries (Claessens et al., 2023). For cultural proximity, we specified a covariance matrix for study site-level intercepts based on linguistic phylogenetic proximity. For geographic proximity, we modeled a Gaussian Process over study site latitudes and longitudes. A series of models tested: (1) the effects of four socio-ecological variables (pathogen prevalence, population density, HDI, latitude), and (2) the effects of various sample demographics, including mean sample age, mean sample socioeconomic status, and use of student versus non-student samples (dichotomous).

We aggregated the four socio-ecological variables based on the

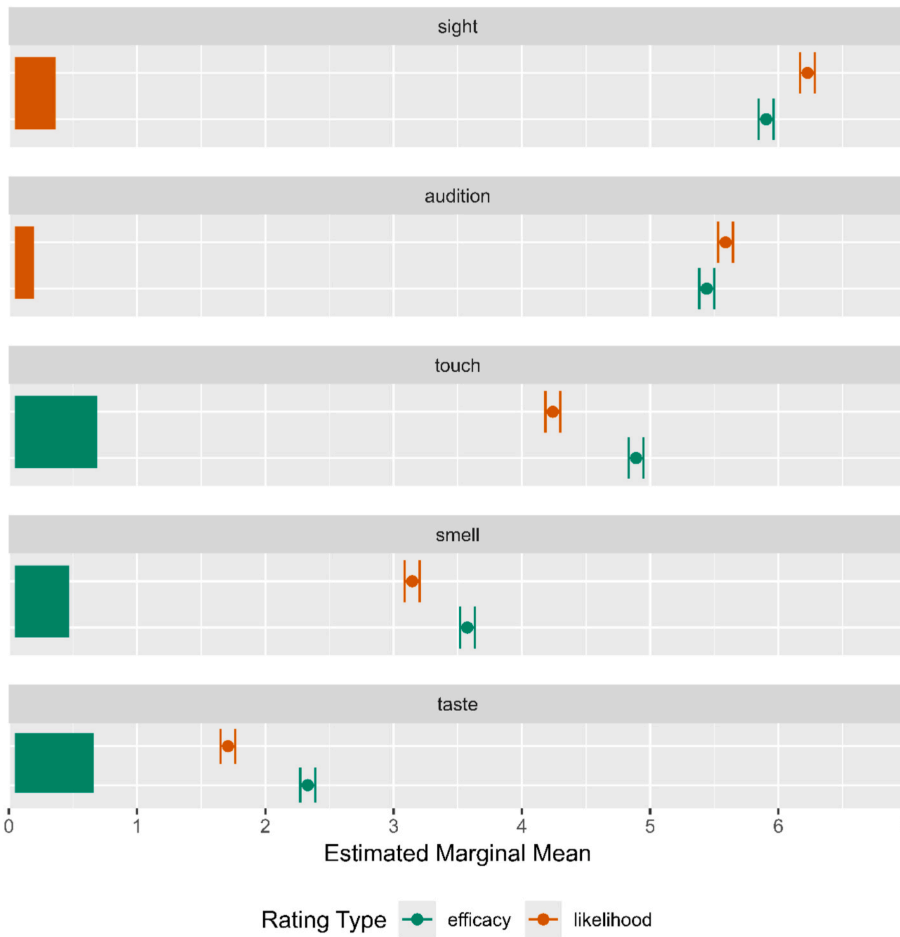

Fig. 2. Estimated efficacy and likelihood ratings for the five senses. Plot showing the predicted values, 95% CIs, and simple effects from a moderated mixed regression in which ratings were regressed on the interaction between sense type and rating type in a pooled sample across all 58 countries. Bars indicate the raw difference (starting linearly at zero) between the estimated efficacy and likelihood ratings for each sense, with colors corresponding to whether efficacy or likelihood ratings were higher. See Table 2 for estimated means and Table 3 for simple effects.

Table 2
Estimated means for efficacy and likelihood of use sense ratings.

Sense	Efficacy				Likelihood			
	Estimated Mean	SE	Lower 95 % CI	Upper 95 % CI	Estimated Mean	SE	Lower 95 % CI	Upper 95 % CI
Sight	5.90	0.01	5.87	5.92	6.22	0.01	6.20	6.24
Audition	5.43	0.01	5.41	5.46	5.58	0.01	5.56	6.60
Touch	4.88	0.01	4.86	4.91	4.23	0.01	4.21	4.26
Smell	3.57	0.01	3.54	3.59	3.14	0.01	3.11	3.16
Taste	2.32	0.01	2.30	2.35	1.70	0.01	1.68	1.73

Note. Estimates are unstandardized and are along a 1–7 scale. SE = standard error, CI = confidence interval.

results of a principal component analysis (see Supplementary Results 3), resulting in a composite we label the Geospatial Flourishing Index (GFI). Higher scores on the GFI represent greater HDI and latitude, and lesser pathogen prevalence and population density. Including this as a moderator of the rating type X sense type interaction, there was an effect on sense ratings, controlling for geographic and linguistic proximity (see Fig. 4). As GFI increased, participants rated sight and audition more positively and other senses more negatively. The simple slopes for GFI were modest (Bs = −0.37 − 0.29); except for sight and smell efficacy ratings and smell likelihood ratings, the 95 % credible intervals were non-overlapping with zero (see Supplementary Results 4 for simple slope coefficients and their posterior distributions). This pattern was invariant across efficacy and likelihood ratings ($B = 0.00$, 95 % credible interval [−0.06, 0.06]), although the magnitude of the slopes for some senses varied across efficacy and likelihood ratings (see Supplementary Results 4). Overall, based on information criteria and an examination of the contrasts between the simple slopes, model results indicate that GFI meaningfully moderated the effects of sense and rating type on sense ratings (see Supplementary Results 4).

As reversals between audition and touch ratings were the most common source of cross-cultural variation, we probed whether GFI explained those reversals by comparing simple slopes and contrasts from the prior moderation model. When GFI was −2 SD from the mean, there was no difference between audition and touch ratings for both efficacy ($B = -0.08$, 95 % CI[−0.36, 0.20]) and likelihood ($B = 0.00$, 95 % CI [−0.28, 0.28]) ratings. However, as GFI increased, the difference between audition and touch ratings also progressively increased such that, when GFI was + 2 SD above the mean, there were relatively large

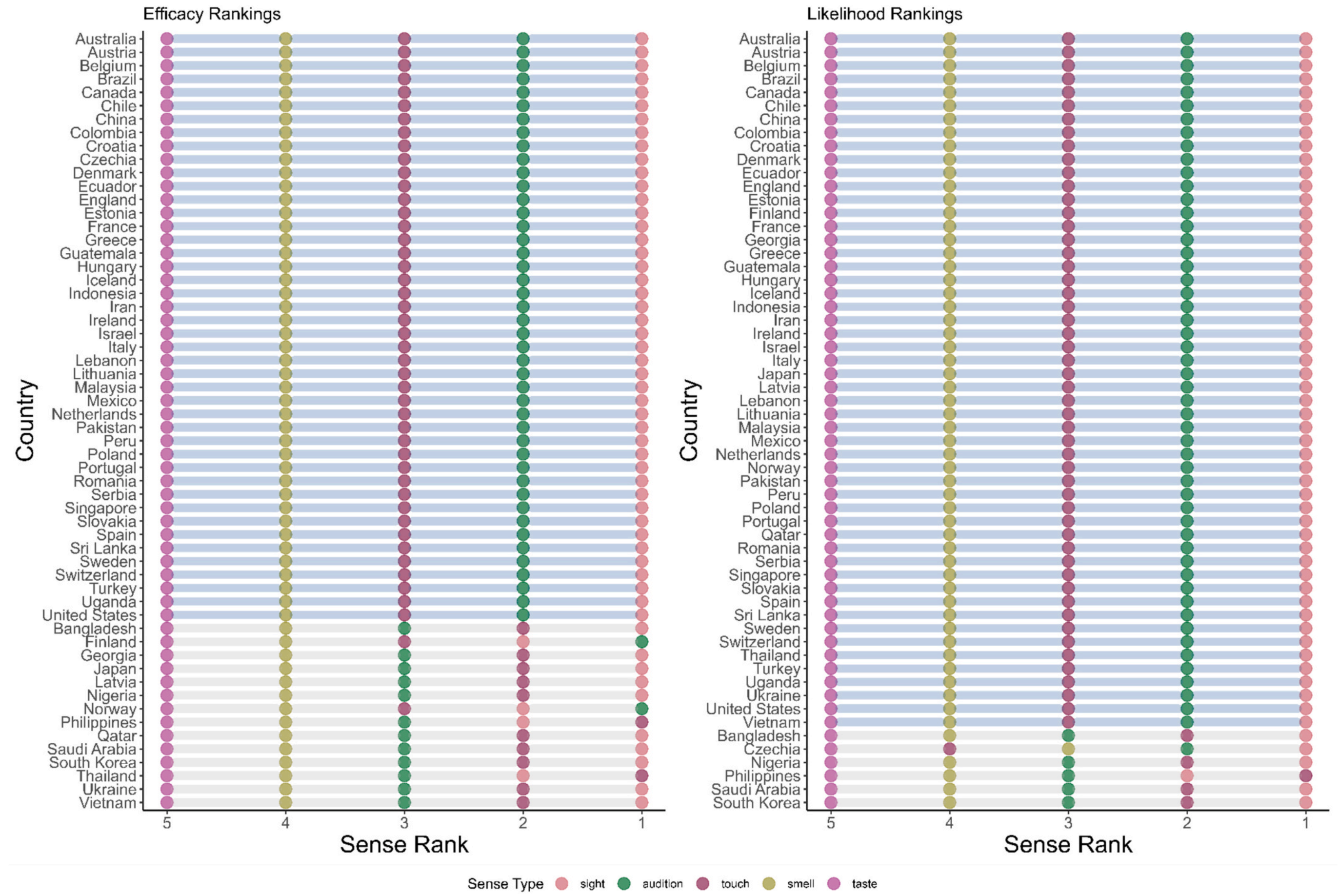

Fig. 3. Sense rankings across study sites. Chart visualizing the relative efficacy and likelihood of use rankings of the five senses across study sites. A ranking of 1 indicates that that sense had the highest mean response at a given study site, while a ranking of 5 indicates the lowest mean. The left panel shows rankings for the efficacy ratings, while the right panel shows rankings for the likelihood of use ratings. Gray lines indicate that the rank order for that country deviated from the modal pattern for at least 1 sense.

differences for both efficacy ($B = 1.15$, 95 % CI[.88, 1.43]) and likelihood of use ($B = 2.67$, 95 % CI[2.39, 2.96]) ratings. (See Supplementary Results 5 for estimates of pairwise differences between audition and touch ratings across the range of GFI.) In sum, low GFI scores were associated with more similarity between audition and touch ratings, indicating that reversals were more likely to happen when HDI/latitude were relatively low and pathogen prevalence/population density were relatively high.

Unlike GFI, sample-level demographic variables did not explain meaningful variation in sense ratings across sites (see Supplementary Results 6).

3.4. *Question 4: Do people prioritize safe senses?*

Senses that can be used to detect disease at a sufficient distance (i.e., sight, audition) entail less risk of contagion compared to senses requiring greater proximity. Do perceivers prioritize "safer" senses at rates higher than their expected disease-detection efficacy would imply, and deprioritize "less safe" senses relative to their expected efficacy? We tested this in our global sample using the mixed effects model described earlier.

Examining the pairwise comparisons from the interaction model reported in section 3.1, efficacy and likelihood of use ratings significantly differed across all five senses ($Bs = -0.32 - 0.65$, $ps < 0.0001$, see Table 3, panel B). Supporting the safe senses hypothesis, and consistent with prior U.S. research (Ackerman et al., 2020), participants reported being more likely to use sight and audition in detecting disease relative to the perceived efficacy of these senses. In contrast, participants rated touch, smell, and taste as more efficacious than would be expected given the reported likelihood of using said senses.

Finally, we tested whether an interaction between rating type and sense type emerged, such that the magnitude of the difference between likelihood and efficacy ratings significantly differed across all five senses. A likelihood ratio test was conducted comparing the model with the interaction term between sense type and rating type to a reduced model without the interaction. The test ($\chi^2(4) = 3333.80, p < 2.2\text{e}{-16}$) indicated that there was a significant interaction between sense type and rating type. Note that models were refit using maximum likelihood in order to conduct the likelihood ratio test. See Fig. 2 and Table 3 for a plot and list of simple effects, respectively. Results were not affected when adjusting for demographic covariates (see Supplementary Results 1).

3.5. *Question 5: Are differences between efficacy and likelihood of use ratings consistent across study sites?*

To test the safe senses hypothesis by country, we assessed differences between efficacy and likelihood of use ratings for each sense across sites. Fig. 5 shows average efficacy and likelihood ratings for all five senses by site, as well as the raw mean difference between efficacy and likelihood ratings. Predicted values in the pooled sample suggested that efficacy ratings tended to be higher than likelihood ratings for smell, taste, and touch, whereas likelihood ratings were relatively higher for audition and sight. The descriptive data plotted in Fig. 5 suggests this pattern is generally consistent across sites.

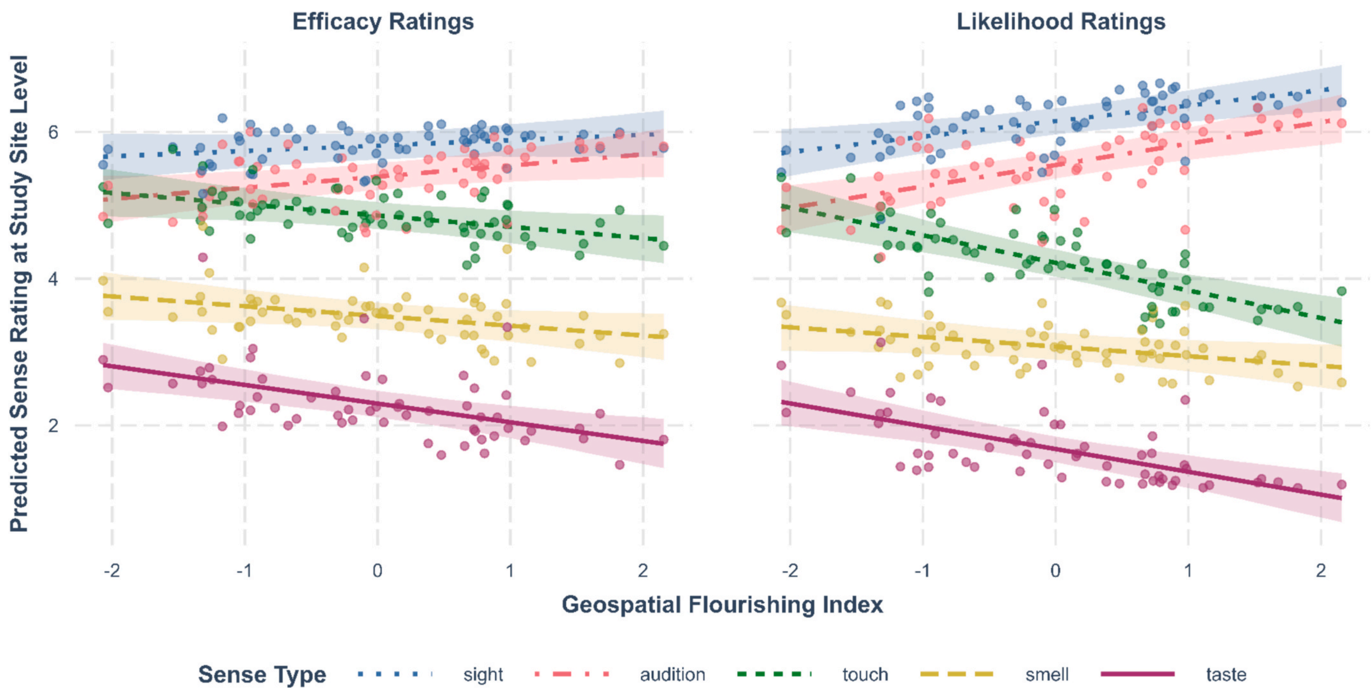

Fig. 4. Predicted sense ratings as a function of socio-ecological differences. Simple slopes taken from a Bayesian linear regression in which sample-mean sense ratings were regressed on the three-way interaction between sense type, rating type, and our Geospatial Flourishing Index (human development index, pathogen prevalence, latitude, and population density; positive GFI values indicate that human development index and latitude are high, and population density and pathogen prevalence are low). Model included covariance controls for geographic and cultural proximity. X-axis represents standard deviations of GFI, and y-axis represents the original 1–7 scale participants used to rate senses. Lines represent estimates of the relationship between GFI and sense ratings for each combination of sense type and rating type; shaded areas represent their 95% credible intervals. Dots are partial residuals: each dot corresponds to the country-level predicted values for sense rating and GFI for each unique combination of sense type and rating type, accounting for geographic and cultural proximity. Additionally, to address geocultural confounds with the socio-ecological variables, a fixed effect control for global region (Global South or Global North) was added. Results are not conceptually affected by modeling the socio-ecological variables individually (see Fig. S3).

For sight ratings, mean likelihood responses were higher than mean efficacy responses in 55 out of 58 sites, although the magnitude of the difference varied from 0 to 0.89 across sites. For audition ratings, more cross-cultural variation was present, with likelihood means higher than efficacy means at 43 sites; the mean difference ranged between 0 and 0.74. For touch ratings, efficacy was higher than likelihood at 57 of the 58 sites; the mean difference ranged from 0.12 to 1.73. For smell ratings, efficacy was higher than likelihood at all study sites; the mean difference ranged from 0.05 to 1.02. For taste ratings, efficacy was higher than likelihood at all sites; the mean difference ranged from 0.07 to 1.33. Thus, the safe senses hypothesis was supported across countries, with variation (in a minority of sites) occurring primarily with regard to audition.

Table 3
Simple effects for sense rating comparisons.

Sense comparisons	Efficacy ratings		Likelihood ratings	
	Simple Effect	SE	Simple Effect	SE
A				
sight − audition	0.46	0.02	0.64	0.02
sight − touch	1.02	0.02	1.99	0.02
sight − smell	2.33	0.02	3.08	0.02
sight − taste	3.58	0.02	4.52	0.02
audition − touch	0.55	0.02	1.35	0.02
audition − smell	1.87	0.02	2.44	0.02
audition − taste	3.11	0.02	3.88	0.02
touch − smell	1.32	0.02	1.10	0.02
touch − taste	2.56	0.02	2.53	0.02
smell − taste	1.24	0.02	1.44	0.02

	Efficacy-likelihood comparisons	
	Simple Effect	SE
B		
Sight	−0.32	0.02
Audition	−0.15	0.02
Touch	0.65	0.02
Smell	0.43	0.02
Taste	0.62	0.02

Note. Estimates are unstandardized, along a 1–7 scale. All effects are significant at $p < 0.0001$. Panel A represents individual sensory modality comparisons; Panel B represents rating type comparisons within each sensory modality (negative values indicate relatively stronger likelihood ratings). SE = standard error.

4. General discussion

Many infectious diseases spread interpersonally, making attunement to interpersonal infection threats vital. What do people believe about the use of sensory information in detecting these threats, and are these beliefs shared globally? Across 58 nations, we found support for a generally universal pattern of lay beliefs regarding both the effectiveness and likelihood of using specific senses to identify infection in others. This cross-national consistency emerged in mean ratings, rankings of the five major senses (sight > audition > touch > smell > taste), and comparisons between judgments of efficacy and reports of likelihood of use. Consistency in sense rankings across countries ranged from 0.95 to 0.97, indicating almost perfect agreement. Common demographic variables did not meaningfully moderate this consistency.

When response variation in sense rankings did emerge, it occurred primarily with regard to audition and, to a lesser extent, touch. Relative to the modal ranking of modalities, audition was devalued in 12 societies on perceived effectiveness, and in 5 societies on likelihood of use. Further, efficacy-likelihood comparisons for audition showed reversals (though not necessarily significant ones) in 17 societies.

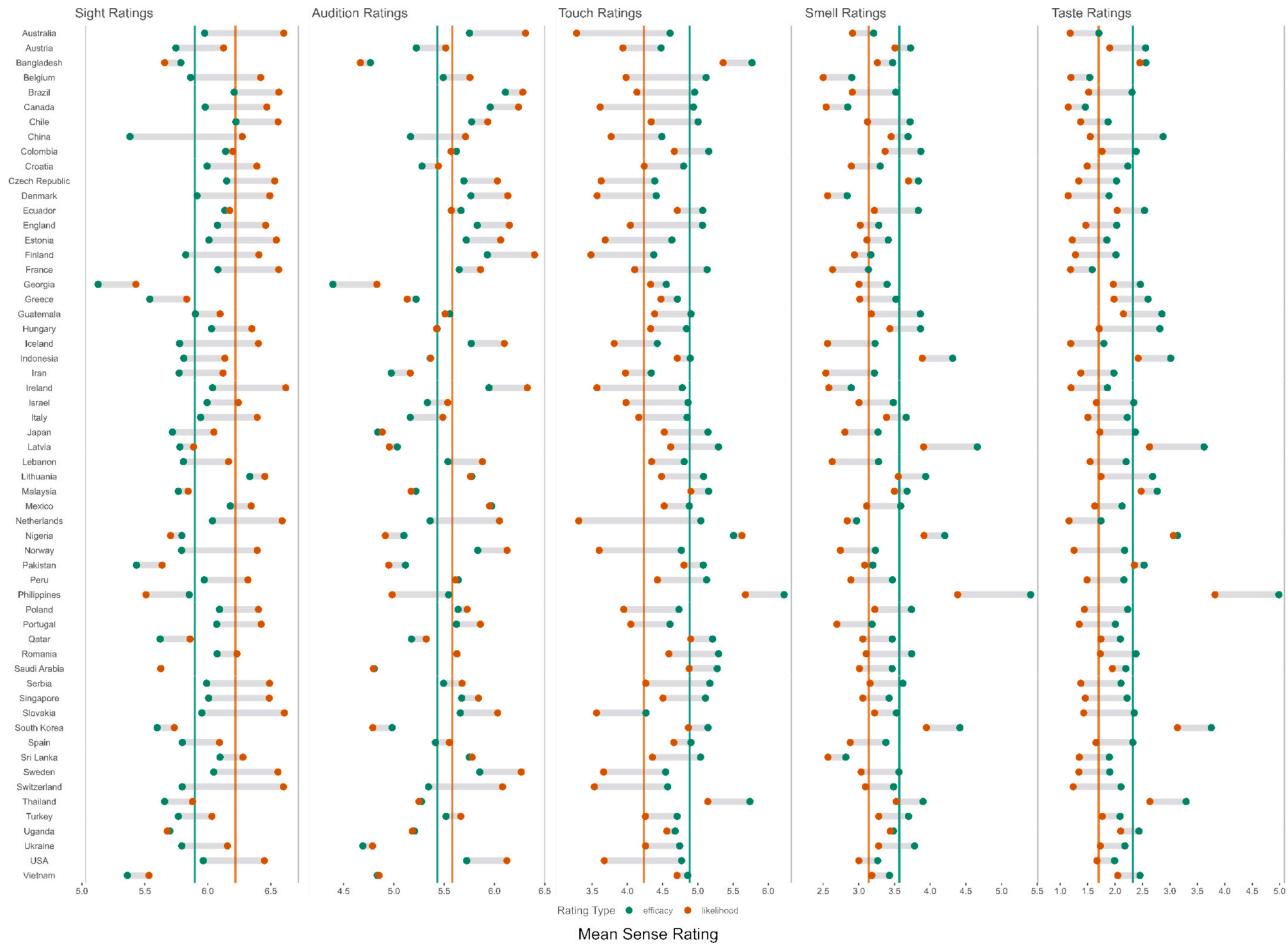

Fig. 5. Mean difference between efficacy and likelihood ratings for all five senses. Green and orange dots correspond to mean efficacy and likelihood of use ratings, respectively, at each study site. Green and orange vertical lines correspond with the global mean across all study sites combined. Efficacy and likelihood of use were both rated on 1–7 scales.

We identified one source of relevant variation—socio-ecological differences across sites. Countries higher in latitude and the human development index but lower in pathogen prevalence and population density showed greater valuation of sight and audition and lower valuation of the other senses as cues to interpersonal infection. Conversely, countries characterized by the opposite pattern on this Geospatial Flourishing Index drew fewer distinctions between audition and touch in particular, making ranking reversals for those modalities more likely. Speculatively, these characteristics may reflect patterns of education about infectious disease (though quantity of formal education was not a meaningful predictor) or cultural traditions about disease and/or context-specific sensory prioritization. Intriguingly, these patterns are the inverse of what would be predicted by accounts explaining cross-cultural differences as outputs of biologically evolved mechanisms that adjust prophylaxis in light of pathogen prevalence (e.g., Thornhill & Fincher, 2014), suggesting other factors are at play. One possibility is that extensive disease avoidance (plausibly manifested as greater disgust sensitivity) is a luxury most readily afforded—and least subject to erosion by habituation—among people in prosperous societies with low disease burdens (cf. Cepon-Robins, 2024); as a result, the senses entailing the lowest risk of pathogen transmission may be more preferred in such countries. While a definitive explanation for this socio-ecological variation remains to be determined, it nonetheless pales in comparison with the extensive cross-cultural uniformity in lay beliefs we observed.

4.1. Theoretical implications

To the extent that lay beliefs influence behavior, and given the impact of disease transmission on both individual and collective welfare, it is plausible that these beliefs are associated with socially and biologically functional outcomes. It is unlikely that a majority of societies simply happened upon a virtually identical ordering of sensory modalities, especially given that sensory beliefs change depending on the inferential characteristic in question (Ackerman et al., 2020). Cultural transmission of disease-relevant information through exposure to common sources of medical knowledge (the internet; formal schooling; etc.) may account for some of the overlap. Alternatively, an evolutionary ecological perspective suggests that specific problems may afford specific solutions (Schaller, 2020).

For multiple reasons, when a hazard manifests similarly across human groups, we can expect that the senses used to identify that hazard will be similar. First, beliefs regarding the disease-detection utility of a given sense could reflect evoked culture (Tooby & Cosmides, 1992)—similarities in ideation and behavior that reflect the outputs of panhuman psychological mechanisms responding to similar inputs (e.g., disgust reactions to signs of illness, etc.). Second, the responses of such mechanisms could constitute cultural attractors in cultural evolutionary processes (Sperber, 1996), making some ideas more intuitively appealing than others, and thus leading to the success of particular beliefs in cultural marketplaces of ideas. Lastly, because disease detection and avoidance can impact group welfare, cultural evolution may result in convergence of efficacious beliefs and biases across cultures, as societies with effective beliefs will grow faster and persist longer (via both reproduction and recruitment) than societies without such beliefs (Fessler et al., 2014; Henrich & Henrich, 2010). As one result, if influenza infection often causes visually detectable physical changes, then, across many societies, people may hold beliefs prioritizing the use of vision.

Save for the cultural group selection account, the previous possibilities do not imply that beliefs necessarily reflect *accurate* identification of hazards. Our participants believed audition to be effective, but independent evidence suggests that (U.S.) perceivers do not accurately discriminate between infectious and noninfectious coughs and sneezes, instead being biased to presume that all disgust-eliciting sounds signal danger (Michalak et al., 2020). Such signal-detection biases have utility and are likely adaptive, as the costs of missing an infection threat are typically higher than the costs of false alarms (Haselton & Nettle, 2006). Here, the prioritization of audition may reflect a bias toward use of "safe senses" which function at greater interpersonal distance than other senses, decreasing infection risk. Consistent with this interpretation, participants reported using distal senses more than would be expected if their use was based solely on perceptions of those senses' efficacy, whereas the opposite was true for more proximal senses. Thus, people may share a type of disease detection bias, suggesting shared inaccuracies in how we connect sensory information to infection manifestation.

These patterns of sensory beliefs may help explain certain stigmas. Stigmas against disfigurement and disability, among others, are tied to pathogen avoidance by motivating interpersonal aversion, thereby decreasing proximity and close contact (Cottrell & Neuberg, 2005; Kurzban & Leary, 2001; Oaten et al., 2011). Lay beliefs about disease detection may feed into psychological mechanisms that calculate and track such responses: stigmas associated with pathogen threat would be more likely to develop toward individuals exhibiting features that approximate true infection cues, are relatively easy to detect, and can be assessed without close contact. Moreover, such stigmas should exhibit biases toward false positive identification errors (Kurzban & Leary, 2001). Correspondingly, the average magnitude of false positive errors in intentional disease detection may be greater for sight and audition compared to smell, touch, and taste.

Given that scientifically derived medical diagnoses are an evolutionarily recent innovation, for most of our species' existence, sensory cues have been the default forms of evidence used to determine whether others pose a risk of disease transmission. Many models of illness (including cultural traditions and practices) have leveraged sensory beliefs, as in the notion of noxious air characterizing miasma theory (Karamanou et al., 2012). Today, medical diagnoses provide more accurate conceptual information, information that is often independent of sensory cues. Presumably, people who have access to conceptual information—through, for example, formal education, or even via others' self-disclosure of their illness status—should prioritize such information over that derived from sensory cues. However, this prioritization requires a superordinate belief, namely that said conceptual information is valid. Therefore, we might expect that people's privileging of conceptual information over sensory cues is greater in societies marked by high trust in others and in social institutions. Importantly, there is considerable variation both between and within countries in the extent and direction of such trust (Ferrin & Gillespie, 2010). Public health authorities' recommendations concerning effective prophylactic behaviors are often disregarded by groups that distrust scientists and/or authorities in general. Tragically, even during the recent devastating pandemic, compliance with such directives was not always high (Ackerman et al., 2023; Haston et al., 2020; Lieberoth et al., 2021), and was actively opposed by some (Choi et al., 2023; Schmelz & Bowles, 2022). Importantly, the impact of trust (or the lack thereof) may be heightened when sensory cues believed by laypeople to be associated with infection are absent or unexpected (e.g., with some strains of COVID-19), as this likely reduces attunement to, and motivation to avoid, pathogen threats (Ackerman et al., 2021).

4.2. Limitations and future directions

Though the present study featured a relatively large number of countries, variations in recruitment and setting (e.g., community members versus students; online versus classrooms) were present across study sites due to the convenience sampling approach used at most locations. Similarly, as noted, our sampling tactics greatly constrained the representativeness of the samples, limiting how broadly the findings should be interpreted. Despite this, the near-universal pattern of results (even when controlling for many demographic features) suggests that our key findings are robust.

An additional limitation concerns the scope of the disease context examined here. This context was described in a vignette, limiting the ecological validity of the stimulus. Further, participants considered a severe flu outbreak, with this likely bringing to mind specific characteristics and symptoms. Lay beliefs about detection of non-respiratory afflictions should reflect prioritization of different sensory modalities depending on whether relevant symptoms are gastrointestinal, neurological, psychiatric, or dermatological in nature (e.g., Kupfer & Fessler, 2018). This may include use of multisensory cues (e.g., Regenbogen et al., 2017; Sarolidou et al., 2020a), a possibility not examined here. Future research could examine detection beliefs in real social interactions, thereby simultaneously presenting cues associated with multiple sensory modalities and eliminating the need to imagine reactions. This approach could also help bridge research within the generally disconnected behavioral immune system and sickness behavior literatures.

We also note that the timing of the study—conducted 18–24 months following the onset of the COVID-19 pandemic—could raise questions regarding the pandemic's influence on lay beliefs. However, two points somewhat mitigate this concern. First, participants were told to disregard COVID-19 when considering the study vignette. Second, the global belief patterns replicate those found with U.S. samples prior to the emergence of COVID-19 (Ackerman et al., 2020). Nevertheless, experiences during the pandemic likely play an important role in other aspects of disease detection, such as trust in others to reveal current illnesses. Finally, the title of the study referenced sight and sound, but not other senses. However, the title was only presented to participants at the time of recruitment and was followed by extensive information before participants responded to the key measures, thus the title wording was unlikely to meaningfully influence responses.

Our findings raise questions about how lay beliefs concerning the use of sensory input might guide disease detection. As mentioned earlier, recent research finds that perceivers can correctly detect sickness above chance levels using certain senses (vision, olfaction), but finds no evidence of accuracy for others (audition). A complete mapping of detection beliefs to detection accuracy would illuminate how lay beliefs about disease predict action, and would identify leverage points for interventions to mitigate disease spread. Relatedly, methodological differences in prior studies highlight the need to better define the concept of detection accuracy. Recent sickness-detection research has perceivers judge sick versus non-sick targets, with the "sick" designation often involving controlled immune stimulation rather than actual infection (e.g., Arshamian et al., 2021; Axelsson et al., 2018; Hansson et al., 2023). Studies examining naturally ill targets have similarly focused on sick versus non-sick comparisons (Leung et al., 2023). Though useful, these approaches suffer limitations. Findings based on endotoxin-triggered immune responses may not fully replicate those based on natural illness (Sarolidou et al., 2020b). Further, sick/non-sick discrimination does not answer the question of infection detection. As discussed earlier, perceivers showed no ability to distinguish contagious versus non-contagious sneezes and coughs (Michalak et al., 2020), and infection detection accuracy may be low for other sensory modalities as well.

Instead, both prior accuracy findings and our results involving lay beliefs about sensory cues may reflect error management biases (where the costs of false alarms are relatively low).

A second promising direction concerns the perceiver-target relationship. The degree to which perceivers value relationships with specific others can modulate willingness to engage in close contact, even when that contact affords potential pathogen transmission (Curtis et al., 2004; Poirotte & Charpentier, 2020; Tybur et al., 2020; but see Bressan, 2021). Although interpersonal closeness should not influence judgments of how effective senses are for disease detection, closeness may affect likelihood of sense use. If so, the safe senses hypothesis supported here may not apply when considering family members, intimate partners, or close friends. For these individuals, care-based motives may be prioritized (Kessler, 2020; Park & Akello, 2017; Pick et al., 2022; Sng et al., 2024), leading to increased willingness to use sensory cues that involve close proximity. Generally high levels of trust with these partners could also facilitate use of conceptual knowledge, including self-disclosed health information. Likewise, familiarity in close relationships could heighten sensitivity to subtle sensory cues, leading to overestimation of disease presence.

Finally, a fruitful avenue for future research would be to examine lay beliefs held by the targets of disease detection—the sick individuals themselves. Because people tend to react negatively toward, and avoid, those exhibiting signs of sickness, many individuals suffering infectious illnesses conceal their condition in order to continue pursuit of social goals (Merrell et al., 2024). If sick people believe that others rely on specific sensory information to detect sickness, they may strategically prioritize masking certain symptoms, e.g., by applying makeup or suppressing coughs (e.g., Ackerman et al, 2018; Tan et al., 2023). Future research could explore how individuals' beliefs about sensory detection influence their methods of concealing illness.

4.3. Conclusion

The psychology of pathogen threat management has received substantial attention in recent years. To fully illuminate how people manage these threats, we must first understand how such threats are detected. The present study demonstrates that folk beliefs about the use of sensory information to detect flu-like pathogen hazards display strong cross-cultural consistency, setting the stage for future conceptual and translational research, and entailing broad public health implications.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bbi.2025.04.020.

Data availability

Data, code, and materials are provided in a repository through a link in the manuscript

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