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What people believe about detecting infectious disease using the senses

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ABSTRACT

Do you believe you can tell if people are sick with infectious diseases by looking at, listening to, or smelling them? Research on pathogen detection and avoidance suggests that perceivers respond with caution both to true signs of infection and to cues only heuristically associated with infection threat. But what do perceivers actually believe about the effectiveness and use of specific sensory modalities for infection detection? In several studies, U.S. participants reported perceptions of effectiveness and likelihood of using each of the major senses to identify infection threat in two types of targets: people and food. Results revealed prioritization of sight and sound with person targets and prioritization of sight and smell with food targets. These patterns appear consistent with the use of “safe senses” (avoidance of cues involving high perceived transmission risk). Beliefs about sensory use also varied depending on the specific feature being examined, with different patterns of sensory beliefs associated with evaluation of pathogenic danger than with evaluation of desirability and fit with normative standards. We discuss these lay beliefs in the context of recent calls for descriptive research in psychology as well as their implications for current and future work on the behavioral immune system.

1. Introduction

Do you think you can tell if a person has a cold by looking at them? What about by listening to them or smelling them? If the stew you plan to eat for lunch has potentially spoiled, could you best determine this by tasting it, smelling it, or touching it? These kinds of questions highlight the role that sensory information plays in detection of infectious agents. They are also questions with objectively verifiable answers. We suggest that, accuracy aside, it is equally important to recognize the subjective appraisals people have about infection detection. The belief that tasting food is very effective for evaluating whether it has “gone bad” may be true, but it can also lead you to become sick. Similarly, believing that interpersonal indicators of infection are visually observable may often be appropriate, but when incorrect, this belief can lead individuals to put themselves or others in harm’s way. In times marked by widespread diseases such as SARS-CoV-2 (COVID-19), such beliefs appear especially critical to understand.

Psychological strategies for managing ecological pathogen threats are now broadly recognized, with research finding that both chronic and temporary concerns about disease produce disgust, avoidance, and heightened negative attitudes toward targets bearing features heuristically associated with infection, even when those features are objectively innocuous (Ackerman et al., 2018; Murray and Schaller, 2016). Because such biases reflect overgeneralized perceptions of threat, an understanding of the lay beliefs people hold about detecting pathogenic cues could help us predict when these biases (and their potential discriminatory consequences) are likely to emerge. The structure of these lay beliefs may even reveal theoretically useful insights into the threat detection processes involved in managing infectious disease. Here, we present five studies that help identify what sensory information people *believe* is effective and likely to be used in the context of pathogen threat.

2. Detecting infectious disease

For as long as we have been human, we have had an infectious disease problem. The pathogens and parasites that cause such diseases have been some of our biggest killers across history (Ackerman et al., 2018; Gangestad and Buss, 1993), and even today, people suffer high rates of illness (WHO, 2015), loss of functioning (Japsen, 2012), and death (Pirages, 2005; WHO, 2015) from these hazards. Consider the morbidity and mortality associated with the COVID-19 pandemic spreading across the globe while this article was written. Because of such issues, coupled with the fact that pathogens such as viruses and bacteria are often not directly detectable through normal sensory means (Lazcka et al., 2007; Murray and Schaller, 2016), identification of the reservoirs harboring disease-causing agents is a critical step toward effective defense. Aside from non-human animals, two primary reservoirs exist with which humans commonly interact—other humans and food. These do not always pose disease-relevant dangers, however, creating the need to discriminate between the presence and absence of threat.

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Work on pathogen avoidance psychology, otherwise known as the behavioral immune system, has highlighted cognitive and affective processes involved in the detection of interpersonal and food-borne pathogenic threats within one's local ecology. For instance, people exhibit disgust toward foods showing signs of spoilage, such as rotten meat (Curtis et al., 2004; Oaten et al., 2009), or possessing an aroma similar to other contaminated substances, as with durian fruit (Davidson, 2014). Similarly, aversion and stigmatization are associated with signs of interpersonal infection, such as lesions and open sores (Kurzban and Leary, 2001). Pathogen detection is imprecise, though, because infection can present in innumerable ways. As such, concerns about infectious disease predict negativity toward people bearing phenotypic abnormalities not necessarily indicative of infection, including disfigurement and obesity (Ackerman et al., 2009; Miller and Maner, 2012). Similarly, pathogen threat is associated with perceiving particular facial qualities (e.g., masculinity) to be more attractive (Watkins et al., 2012), though such qualities do not appear consistently linked with health or immunocompetence (Cai et al., 2019; Scott et al., 2013). Much of this research has focused on visible cues associated with threat (e.g., Michalak and Ackerman, 2020). But our eyes are not the only sensory mechanisms helpful in identifying pathogenic risk.

Research on sensory detection of disease spans a wide array of literatures, species, and empirical approaches. Many animals respond aversively to infected conspecifics, indicating they can detect this threat (e.g., Arakawa et al., 2011; Clayton, 1990; Hamilton and Zuk, 1982). Human studies have found that perceivers can use visual (Axelsson et al., 2018; Tskhay et al., 2016) and olfactory (Olsson et al., 2014) information to identify interpersonal infection at above chance levels. Interestingly, however, this may not be true when using auditory information (Michalak et al., 2020). Further, disease concerns can also trigger heightened tactile sensitivity (Hunt et al., 2017) and specificity (Oum et al., 2011). Though such findings are extremely intriguing, research on the psychology of human pathogen detection is quite novel, and a number of important questions remain, including the focus of the current research: How do people judge effectiveness, and prioritize the use, of sensory information when detecting infectious disease?

3. The importance of lay beliefs

To answer this, we measured lay beliefs about the use of sensory input in disease detection. Generally, lay beliefs give insight into how people form judgments and make decisions in a variety of different contexts. For example, believing that one's own health is unpredictable leads people to engage in more unhealthy behaviors (Riley et al., 2019), whereas believing that mental illness is biologically caused can reduce stigmatization of others suffering from mental disorders (though also increase the desire to maintain interpersonal distance; Kvaale et al., 2013). In moral decision-making, the belief that a person has control over their mental states predicts greater blame when that person acts badly (Cusimano and Goodwin, 2019), but when transgressions are made by one's ingroup, believing that those transgressions represent global, stable group traits decreases acknowledgment of ingroup wrongdoing (Bilali et al., 2019).

Given the relevance of lay beliefs for influencing cognitions and behavior, an understanding of the particular beliefs people hold about disease detection is important for several reasons. First, lay beliefs provide insight into the mental framework people use to conceptualize infectious disease, helping us evaluate the adequacy and completeness of existing theoretical models. Consider an example from the psychology of the supernatural. One theoretical perspective proposes that the idea of an afterlife emerges exclusively as a function of cultural learning. If this model is correct, we should expect that older children hold this belief more strongly than younger children, as older children have had a longer period of cultural exposure, but this is precisely the opposite of what has been found (Bering, 2006; for other examples of this approach, see Fletcher and Haig, 1989; Pocheptsova and Novemsky, 2010; Rozin et al., 1986). Second, beliefs can influence behavior, focusing attention on certain types of sensory information and pulling attention away from other types (Driver, 2001; Hagger and Orbell, 2003; Johnston and Dark, 1986). Such biases could lead to dysfunctional outcomes when beliefs are erroneous. For instance, people may believe they can detect interpersonal infection through sound (to preview our findings, this is indeed the case). Because existing evidence for detection does not support this ability—perceivers using auditory cues were no better than chance when attempting to identify whether coughs and sneezes were infectious in origin (Michalak et al., 2020)—this belief could lead people to engage in social interactions that increase their risk of infection or to needlessly avoid others who pose no disease threat. Research on these beliefs therefore provides an essential complement to work investigating the accuracy of detection capabilities. Third, a better understanding of perceiver beliefs may help researchers generate new predictions and suggest sensory modalities in need of further empirical investigation, especially given the dominance of vision-based work in this literature (see Section 9 for examples). In fact, given the associations identified between pathogenic cues (even incorrect ones) and expressions of interpersonal prejudice and discrimination (e.g., Faulkner, Schaller et al., 2004; Huang et al., 2011; Park et al., 2007), data on the sensory beliefs people hold may be useful for targeting effective leverage points for social interventions. Last, ongoing questions about best practices in empirical research have highlighted the value of descriptive work for improving our basic understanding of psychological phenomena and measurements, potentially helping to address problems with generalizability and reproducibility (e.g., Yarkoni, 2020). Insight into the lay beliefs people hold provides this type of descriptive contribution.

4. Current research

Here, we investigated lay beliefs about the perceived effectiveness and likelihood of use for the five major senses when identifying dangers associated with the pathogenic reservoirs of people (Study 1) and food (Study 2). In Study 3, we examined whether patterns of sensory beliefs were specific to the target of evaluation (e.g., people, food), or if perceivers express different patterns of belief depending on the type of evaluation being made (e.g., pathogenic danger, fit with normative standards, desirability), even when the target is the same.

We also considered two possible reasons why patterns of beliefs might emerge, one focused on the perceived risks associated with sensory use and one focused on perceived base rates of sensory cues. First, perceivers may prioritize the use of sensory modalities that are viewed as requiring less close proximity between individuals and therefore less risk of germ transmission (e.g., sound requires less proximity than taste). We refer to this prioritization as use of "safe senses." Second, perceivers may prioritize the use of sensory cues thought to be relatively more available in detection environments (e.g., we may believe that sounds like coughs and sneezes are more common than particular odors when attempting to identify whether another person is ill). We refer to this availability as perceived base rates.

Across studies, we addressed issues relating to statistical power by collecting large participant samples, frequently using within-participant designs, and using items to assess understanding of procedural instructions and appropriate cultural knowledge (as recommended with online data collection; TurkPrime, 2018). As discussed later, this approach led to many significant effects being well beyond standard thresholds ($p < .001$), and so we focus largely on effect size comparisons. All power analysis details are provided in the Supplementary Material.

The Supplementary Material section also contains additional information about methods, materials, and exclusion criteria for each study (including the pilot and Study S1) as well as many further analyses, tables, and data not discussed in the paper.

5. Pilot study

An initial pilot study was conducted in which participants imagined wanting to identify whether a social interaction partner was sick with an infectious disease or not. Three hundred participants drawn from Amazon's Mechanical Turk (MTurk) ranked the five senses on perceived effectiveness and likelihood of use when evaluating whether another person was infected. They then reported their likely emotional reactions and avoidance intentions when experiencing individual sensory cues in the same context.

For rankings of both effectiveness and likelihood, the modal order was: (1) sight, (2) sound, (3) touch, (4) smell, (5) taste. Reported emotions following sensory cues were much more negative than positive, but taste produced especially strong negative reactions and avoidance intentions compared to the other senses. Exemplifying this, one participant commented, "I hope I never have to lick someone to find out if they are sick!" It seems from the pilot study that, in interpersonal situations of infection detection, people prioritize sensory information involving less close proximity and contact. We built from these findings to construct Studies 1 and 2, which assess a wider variety of responses in two separate contexts of infection detection.

6. Studies 1 (target people) and 2 (target food)

6.1. Method

Studies 1 and 2 differed only in the type of pathogen source (people or food, respectively) that participants considered. Because of the similarity in approach across studies and that they were launched on the same day (participants were limited to only one study), we report methods and results for both studies together. Aspects of the data collection, including sample sizes, exclusion criteria, key hypotheses, and primary analyses were preregistered at https://aspredicted.org/ag8zq.pdf. All data and analysis syntax across studies can be found at https://osf.io/7zspe/?view_only=0b030d43177d469ea35d3957ff608bb7.

6.1.1. Participants and design

For both studies, participants were recruited from MTurk in exchange for \$0.75. Following our exclusion criteria, final sample sizes of 718 for Study 1 (mean age = 37.69; 56.8% female, 39.1% male, 4.0% unknown) and 725 for Study 2 (mean age = 39.94; 58.2% female, 38.1% male, 3.7% unknown) were obtained. Modal education level for both studies was college degree or equivalent (Study 1 = 45.0%; Study 2 = 47.6%), with ≤ 10% reporting formal education of high school or less. Each study used a fully within-participants design, though we also tested for the influence of relevant individual differences in exploratory analyses. Sample sizes were chosen to achieve adequate power to detect small effects and to ensure a range of participant backgrounds (e.g., across studies, approximately 25% of the participants were non-White, 50% self-identified as politically moderate-to-conservative, and 33% did not have a college degree). These samples provided 95% power to detect an effect size of at least $r = .051$ with $\alpha = .05$, a quite small effect by traditional standards.

6.1.2. Procedure

After providing informed consent, participants in Study 1 read a vignette where they imagined themselves during a bad flu outbreak having to meet with a coworker who may or may not be sick. Participants in Study 2 read a similar vignette where they imagined themselves during a bad foodborne sickness outbreak having to attend a lunch meeting with food that may or may not be contaminated by germs. The lunch meeting in the latter study involved one other person, thereby mimicking the vignette in Study 1, allowing for cross-study comparisons.

Participants then evaluated each of the major five senses (sight, sound, smell, taste, touch) on several measures assessing beliefs about sensory processing in the situation outlined in the vignette. First, they rated how effective or useful each sense would be in determining whether the person [food] is sick [contaminated by germs] on a scale ranging from 1 (not useful at all) to 7 (extremely useful). Second, they rated how likely they would be to use each sense in determining whether the person [food] is sick [contaminated by germs] on a scale from 1 (not at all likely to use) to 7 (extremely likely to use). For exploratory purposes, they then repeated this likelihood rating but evaluated the likelihood that *other* people would use each sense.

Participants next indicated perceptions of sensory base rates by judging how frequently they typically experience cues to each sense when detecting sickness in people using sliders that ranged from 0% of situations – 100% of situations. Base rates here refer to participant beliefs about the prior probability that cues to a given sense (e.g., hearing someone cough, seeing someone's runny nose) would be available for use when attempting to identify illness in others. Participants then provided up to three free-response examples of cues they would pay attention to for each sense when attempting to identify disease (for exploratory purposes).

Following this, participants completed a set of individual difference measures comprised of the Perceived Vulnerability to Disease scale (PVD; Duncan et al., 2009), which includes two subscales, germ aversion and perceived infectability, measuring the extent to which individuals perceive themselves to be averse to and vulnerable to infectious disease, respectively. Additionally, the pathogen subscale of the Three-Domain Disgust Scale (Tybur et al., 2009), which measures sensitivity to pathogen disgust, and the Ten-Item Personality Inventory (TIPI; Gosling et al., 2003), a brief measure of the Big-Five personality domains, were included. They then completed manipulation checks, demographic items, and were debriefed. On average, the studies took 11–12 min (Study 1: $M = 664.7$s, $SD = 323.0$s; Study 2: $M = 687.6$s, $SD = 327.4$s).

6.2. Results

6.2.1. Data analytic plan

We examined two key questions as shown in the section headers below: (1) what are people's lay beliefs about infection detection, and (2) what explanations might account for these beliefs. To address these questions, we provide descriptive data about lay beliefs and use repeated measures analyses to evaluate differences across the senses. Pairwise comparisons are evaluated with Bonferroni corrections. Differences in degrees of freedom are due to missing data. Because the large sample sizes rendered most comparisons significant at $p < .001$, we group reporting of pairwise p-values rather than reporting each individually. Instead, to better interpret these response patterns, we report effect sizes using Hedge's g_{av}, which uses a correction for correlated groups and can be interpreted similarly to Cohen's d (Lakens, 2013). We also focus on relative differences in effect sizes, as these are more informative than absolute sizes for making inferences between the senses. Tests for the two dependent measures, perceived effectiveness and likelihood of use, are presented separately. Finally, to help streamline reporting of the major analyses, we present comparisons of effect sizes for each sense, and discuss results of analyses for evaluations of others' behavior, free-response examples of sensory cues, and all individual difference measures only in the Supplementary Material.

6.2.2. Question 1: what are people's lay beliefs about sensory detection of infectious disease?

Participants reported their beliefs about the (1) effectiveness of, and their (2) likelihood of using each sense when identifying whether another person was infected or not (see Table S2 in the Supplementary Material).

6.2.2.1. Study 1 (target people). Testing differences across the senses, a repeated measures ANOVA revealed variation in beliefs about perceived effectiveness (see Fig. 1, panel A), $F(4,2796) = 1107.89$, $p < .001$,

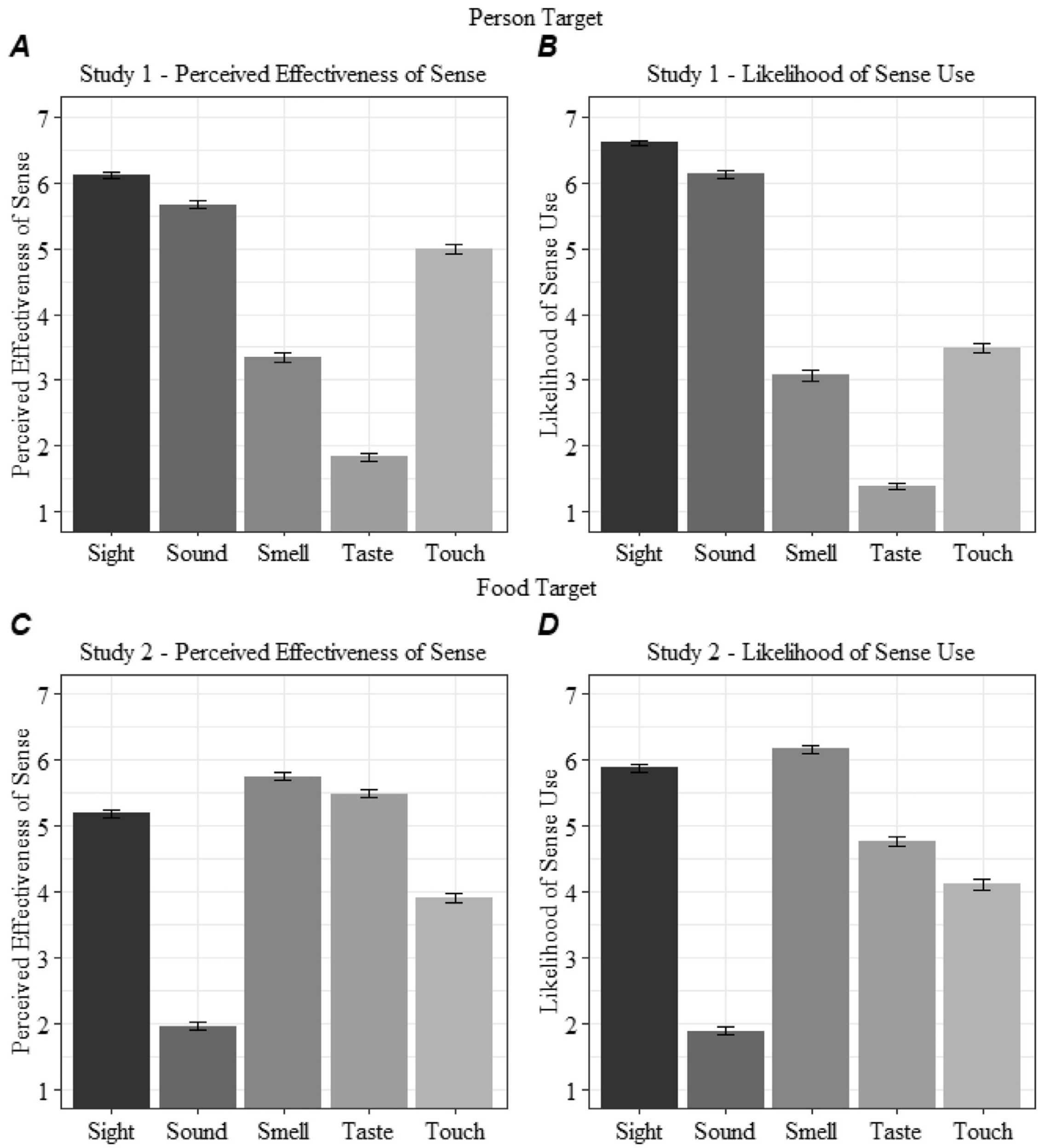

Fig. 1. Perceived effectiveness and likelihood of using senses in Study 1 (panels A and B: target person) and Study 2 (panels C and D: target food).

$n_p^2 = .61$, with all pairwise comparisons significant (*ps* < .001). Sight, sound, and to a lesser degree, touch, were rated as most effective. A similar pattern was found for beliefs about likelihood of using each sense (see Fig. 1, panel B), $F(4,2816) = 1513.94$, $p < .001$, $n_p^2 = .68$, again with all pairwise comparisons significant (*ps* < .001). Here, people reported being most likely to use sight and sound, with touch rated relatively less strongly. Overall, people appeared to prioritize sight and sound for detecting interpersonal infection hazards.

6.2.2.2. Study 2 (target food). A repeated measures ANOVA revealed variation in beliefs about perceived effectiveness (see Fig. 1, panel C), $F(4,2836) = 1029.75$, $p < .001$, $n_p^2 = .59$, with all pairwise comparisons significant (*ps* < .001). The pattern of means across senses differed from the prior study, however. Sight, smell, and taste were rated as most effective. A similar pattern emerged for beliefs about likelihood of using each sense (see Fig. 1, panel D), $F(4,2808) = 852.01$, $p < .001$, $n_p^2 = .55$, again with all pairwise comparisons significant (*ps* < .001). Here, sight and smell remained highly rated, though the rating for taste was somewhat lower. Overall, people prioritized sight and smell, and to a degree taste, for detecting food-borne pathogen hazards.

6.2.2.3. Cross-study comparisons (people vs. food). We predicted that prioritization of certain senses would depend on the target of perception, with sight and sound rated more highly when the target was a person, and smell and taste rated more highly when the target was food. These predictions are supported by the preceding, within-study results, though sight was also rated highly with food. We next tested effects between the studies.

A mixed ANOVA comparing the target of Study 1 to that of Study 2 on perceived effectiveness found that the main effect of the sense factor, $F(4,5632) = 474.96$, $p < .001$, $n_p^2 = .25$, was qualified by an interaction with target type, $F(4,5632) = 1672.29$, $p < .001$, $n_p^2 = .54$, with all pairwise comparisons significant between the targets (*ps* < .001). To explain this interaction, we examined effect size differences between studies. Consistent with predictions, for perceived effectiveness, the largest differences showed that participants believed sound to be more effective when identifying sickness in people ($g_{av} = 2.63$), whereas smell

($g_{av} = 1.39$) and taste ($g_{av} = 2.25$) were more effective when identifying contaminated food.

A test of likelihood of use revealed a comparable pattern, with the main effects of the sense factor, $F(4,5624) = 864.13$, $p < .001$, $n_p^2 = .38$, and of target type, $F(1,1406) = 66.56$, $p < .001$, $n_p^2 = .05$, qualified by a significant interaction, $F(4,5624) = 1479.27$, $p < .001$, $n_p^2 = .51$, with all pairwise comparisons significant between the targets (*ps* < .001). Again, the largest differences involved participants reporting they would more likely use sound with people ($g_{av} = 2.90$), but smell ($g_{av} = 1.75$) and taste ($g_{av} = 1.93$) with food.

In total, people prioritized sight and sound for detecting interpersonal infection, but sight, smell, and taste for food contamination. These patterns support our cross-study predictions about sense prioritization in all cases except for sight. It appears that perceivers believe sight to be useful when detecting pathogens in *both* people and food (though sight was viewed as more effective with people than with food). Although not specified in our preregistration, this is sensible from the viewpoint that cues of age and spoilage (e.g., mold) are often visible in foods.

6.2.3. Question 2: what might account for these particular patterns of belief?

Our focus was primarily on identifying the lay beliefs people hold about sensory input in disease-relevant situations. However, we were able to use participant responses to address, in preliminary fashion, two possible reasons why people hold these patterns of belief: (1) that people prioritize senses perceived as "safer"—those involving lower pathogen transmission risk (e.g., less close proximity and contact with possible pathogen sources), and (2) that perceived base rates for specific sensory cues predict use of those senses. To preview the results, we find that perceivers report using base rate information and "safe" senses more than "less safe" senses when targets are potentially infected people. The same also appears true when targets are potentially contaminated foods, though the patterns are less easily interpretable.

6.2.3.1. Safe senses. Sensory information involving sight and sound can be encoded at greater physical distances, and thus their use presents less risk of pathogen transmission relative to taste, touch, and smell (senses effective at greater distances also allow earlier identification, and perhaps avoidance, of infected targets). Therefore, people may be more willing to use "safe senses," even if these are believed to be comparably less effective. In our preregistration, we predicted that sight and sound would be especially relevant to detection with interpersonal targets, whereas smell and taste would be more relevant for food targets (the latter set because of how food is consumed). To provide an initial test of this idea, for both Studies 1 and 2, we compared effectiveness judgments to likelihood judgments within each sense to determine if perceivers preferred to avoid use of some senses despite perceiving them as high in effectiveness (and vice versa). [In the Supplementary Material, we also report factor analyses examining judgment similarity in light of the "safe senses" concept, finding that sight and sound are indeed evaluated differently than other senses when evaluating people, though the patterns when evaluating food are less clear.]

In Study 1, a repeated measures ANOVA found a significant senses by rating type (effectiveness, likelihood of use) interaction, $F(4,2752) = 240.84$, $p < .001$, $n_p^2 = .26$. Comparisons within each sense revealed that, when evaluating other people as potential pathogen sources, perceivers believed their likelihood of using sight and sound was greater than the effectiveness of these senses (*ps* < .001), whereas their likelihood of using smell, taste, and touch was lower than the effectiveness of these senses (*ps* < .001). The biggest difference emerged for touch ($g_{av} = .81$), indicating that, although participants viewed touch as relatively effective ($M = 4.99$, $SD = 1.67$), they were relatively averse to using it ($M = 3.50$, $SD = 2.03$) to detect possible sickness in another person.

In Study 2, a repeated measures ANOVA again found a significant senses by rating type interaction, $F(4,2756) = 91.29$, $p < .001$, $n_p^2 = .12$. Comparisons within each sense revealed that, when evaluating food as a potential pathogen source, perceivers believed their likelihood of using sight, smell, and touch was greater than the effectiveness of these senses (*ps* ≤ .004), whereas their likelihood of using taste was lower than its effectiveness ($p < .001$). No differences were present for sound, $p = .40$. The biggest difference involved sight ($g_{av} = .42$), with taste a close second ($g_{av} = .37$).

Together, these patterns provide some initial support for the concept of "safe senses" when evaluating people and food, though this interpretation is clearer with target people. Compared to sight and sound, smell, taste, and touch involve closer proximity to targets and thus perceivers may infer a greater possibility of pathogen transmission, especially in interpersonal contexts where infection can occur because of others' actions. With food, proximity may be interpreted as generally less risky because actual consumption is necessary for pathogen transmission, thereby increasing the relative use of smell and touch (the very low perceived effectiveness of sound likely makes use of this sense futile). Finally, looking between studies, the largest drop in likelihood of use relative to perceived effectiveness occurred for touch with person targets and for taste with food targets, each a primary means of pathogen transmission (and thus risk) for that specific type of target.

6.2.3.2. Base rates. Another explanation for the origin of beliefs about sensory effectiveness and likelihood of use is that these beliefs track expectations of whether specific sensory cues are common (i.e., perceptions of sensory base rates in relevant environments). Though we could not assess causality in the present studies, we examined associations between sensory ratings and base rates in two ways: (1) by testing frequency estimates of sensory cues, and (2) by computing correlations between frequency estimates and effectiveness/likelihood of use ratings.

In Study 1, a repeated measures ANOVA on frequency estimates revealed significant variation (Fig. S1 in the Supplementary Material), $F(4,2732) = 1540.20$, $p < .001$, $n_p^2 = .69$, with the frequency pattern largely corresponding to that for likelihood of use (i.e., all comparisons between means in the same directions, *ps* < .001). Second, the average correlation between sense-specific frequencies and likelihood of use ($r_{avg} = .62$) was higher than the correlation between frequency estimates and effectiveness ratings ($r_{avg} = .47$). Thus, participants reported being more likely to use a certain sense to the extent they believed the base rate for that sense was higher. Base rates were less associated with the perceived effectiveness of a given sense.

In Study 2, the frequency estimates also showed evidence of variation (see Fig. S1), $F(4,2812) = 1240.06$, $p < .001$, $n_p^2 = .64$. Unlike in Study 1, the frequency pattern largely corresponded to that for effectiveness (i.e., all comparisons between means in the same directions, *ps* < .001, though sight and taste were not different). However, similar to Study 1, the average correlation between sense-specific frequencies and likelihood of use ($r_{avg} = .54$) was higher than the correlation between frequency estimates and effectiveness ratings ($r_{avg} = .46$). This mixed pattern of findings suggests that base rates are relevant for beliefs about food-related sensory cues, but their connection to likelihood judgments is less consistent than when targets are people.

6.3. Discussion

Findings from both Studies 1 and 2 demonstrate that people hold specific patterns of belief around the relevance of sensory modalities for identifying pathogenic dangers. Sight and sound were considered both effective and likely to be used when attempting interpersonal identification. When identifying food contamination, perceivers prioritized sight, smell, and taste.

We considered two possible reasons that certain patterns of belief might exist. First, do perceivers prioritize "safe senses" involving less proximity and contact? This does appear to be the case when detecting interpersonal pathogen threat as well as food-borne pathogen threat (e.g., with food, despite the high effectiveness associated with taste, perceivers deemphasized actually using this risky sense). Second, do people default to the sensory modalities for which cues are commonly available in detection contexts? Again, it appears so. Perceptions of base rate frequencies matched the likelihood of using those senses for interpersonal identification and were more strongly correlated with those likelihood of use beliefs than with effectiveness beliefs for both person and food targets.

Thus far, the results of two studies indicate that people hold sensory beliefs that conform to the particular affordances of targets. Perceivers appear to prioritize sensory information in ways that, to an extent, trade off the effectiveness of that information for personal safety. However, this interpretation relies largely on the intuition that sensory modalities usable at greater distances involve less risk than those modalities that require closer proximity. Is this actually how perceivers understand the use of these senses? We conducted an exploratory study to directly assess beliefs about what using these senses entails.

In Study S1 (Supplementary Material), we measured perceptions of risk and degree of proximity required for the senses when attempting to detect pathogenic danger. For both person and food targets, sight and sound were rated the least risky and usable at greater distances. Taste was rated the most risky sense and the one necessitating the closest proximity (along with touch). Generally, these findings support our "safe senses" interpretation of the data from Studies 1 and 2 showing that sight is prioritized and taste/touch are deprioritized in the context of pathogen threat. However, other findings potentially conflict with this interpretation. For instance, all senses (except smell) were judged usable at greater distances when detecting disease in people as opposed to food, yet all senses (except sight) were also judged more risky when used with people than with food. Distance also was inversely correlated with perceived risk only in several instances (e.g., sight and taste with person targets). It may be that "necessary distance" is not a feature specific to risk or is only one component of risk perception. Still, senses rated as riskier were typically less likely to be used than senses rated as less risky according to the findings of Studies 1 and 2, suggesting perceiver sensitivity to sense-specific danger in pathogen detection.

7. Study 3

Across studies, patterns of sensory beliefs involving pathogen hazards appear tailored to the specific affordances of targets. Some evidence suggests these patterns may stem from both the perceived risk of using specific senses and the availability of sensory cues in this dangerous context, and perhaps more so for person targets than food targets. However, an alternate possibility remains. Perceivers may believe that a given target requires a specific pattern of sensory modality use, regardless of what is being evaluated in that target. For instance, we might prioritize sight and sound when attempting to evaluate *any* feature of another person, whether that is their infection status, their personality, even their job. If so, this would indicate that sensory beliefs are target-specific rather than evaluation-specific. Study 3 was designed to examine this possibility. Do patterns of sensory beliefs differ depending on the context of evaluation and not only on the type of target? To test this, we again focused on two types of targets—people and food. We compared beliefs about the use of sensory modalities in three contexts: (1) assessing pathogenic danger through infection (people) and germ contamination (food), (2) assessing normative standards through hygiene (people) and quality (food), and (3) assessing desirability through romantic attractiveness (people) and liking (food). Beliefs in context 1 represent a replication of earlier studies. Beliefs in contexts 2 and 3 represent new evaluation types that are relevant to the specific target but do not explicitly involve pathogen detection. Further, context B (normative standards) represents a distinct "threat" evaluation, whereas context C (desirability) represents a positive, "opportunity" evaluation.

7.1. Method

Aspects of the data collection, including sample sizes, exclusion criteria, key hypotheses, and primary analyses were preregistered at https://aspredicted.org/7472p.pdf. All data and analysis syntax can be found at https://osf.io/7zspe/?view_only=0b030d43177d469ea35d3957ff608bb7.

7.1.1. Participants and design

Participants were recruited from MTurk in exchange for \$0.90. Using our exclusion criteria, we obtained a final sample size of 462 (mean age = 37.69; 43.1% female, 56.5% male, .2% unknown or preferred not to answer). Modal education level was college degree or equivalent (45.9%), with ≤ 10% reporting formal education of high school or less, and approximately 24% of the participants were non-White, similar to earlier studies. The study used a 2 (Target Type: people, food; between-participants) X 3 (Evaluation Type: pathogen threat, normative standards, desirability; between-participants) X 5 (Senses; within-participants) design, although we focused on tests within each level of target in our preregistration. Power analysis using effect sizes from our earlier studies indicated that a very low number of participants (12) was necessary to appropriately test effects at $\alpha = .05$. Because we did not want to sacrifice generalizability by using such a small number, we recruited at least 100 participants per between-participant condition prior to exclusions. Following exclusions, our sample provided 95% power to detect an effect size of at least $r = .081$ with $\alpha = .05$ in the largest examined interaction.

7.1.2. Procedure

After providing informed consent, participants read a vignette similar to those used earlier in which they imagined themselves in a two-person focus group meeting. The meeting would purportedly continue for hours and lunch would be included. This was followed by more specific instructions relevant to each condition. As in earlier studies, participants in the pathogen threat conditions rated the senses on their effectiveness and likelihood of use for determining whether another person or a food was an infection risk. For participants in the other conditions, because the characteristics used to evaluate normative standards and desirability are not the same for people and food, slightly different instructions were used. For normative standards, participants rated the senses for determining whether another person engaged in bad hygiene practices (specified as cleanliness but explicitly not associated with disease) or whether a food possessed low-quality, generic ingredients. For desirability, participants rated the senses for determining whether another person was attractive as a romantic partner or whether a food would be liked by that participant.

Sensory ratings used the same measures from Studies 1 and 2. Effectiveness was rated on a scale ranging from 1 (not useful at all) to 7 (extremely useful). Likelihood of use was rated on a scale from 1 (not at all likely to use) to 7 (extremely likely to use). Participants next indicated perceptions of sensory base rates by judging how frequently they experience cues to each sense in the relevant condition context using sliders that ranged from 0% of situations – 100% of situations. As in Study S1, they then rated each sense on necessary distance from the target necessary to use each sense, risk associated with using each sense with the target, and the pathogen subscale of the Three-Domain Disgust Scale (see Supplementary Material for analyses of these measures). They then completed quality checks, demographic items, and were debriefed. On average, the study took just under 9 minutes ($M = 526.1$s, $SD = 290.4$s).

7.2. Results

7.2.1. Data analytic plan

We preregistered two primary types of analyses: (1) testing whether the interaction of sensory ratings and target type replicates the prior study findings for disease-relevant evaluations, and (2) testing the interaction of sensory ratings and evaluation type within each level of target type. Tests for the two dependent measures, perceived effectiveness and likelihood of use, are presented separately. Pairwise comparisons are evaluated with Bonferroni corrections. Additionally, we provide descriptive data for people's lay beliefs (see Table S8). Differences in degrees of freedom are due to missing data. We focus on relative differences in effect sizes, as these are more informative than absolute effect sizes for making inferences between the senses. We present findings grouped by the two primary questions of interest.

7.2.2. Question 1: what are people's lay beliefs about sensory detection of infectious disease?

To replicate the analyses from Studies 1 and 2, we conducted mixed measures ANOVAs on effectiveness and likelihood of use beliefs. For perceived effectiveness, variation in beliefs was present (see Fig. 2, panels A and B, "germs" column), $F(4,612) = 116.40$, $p < .001$, $n_p^2 = .43$, with significant pairwise comparisons found between targets for sound, smell, and taste ($ps < .001$), but not for sight and touch ($ps > .08$).

For likelihood of use, a comparable interaction pattern was found (see Fig. 2, panels C and D, "germs" column), $F(4,620) = 116.90$, $p < .001$, $n_p^2 = .43$, with significant pairwise comparisons found between targets for sound, smell, and taste ($ps < .001$), but not for sight and touch ($ps > .06$).

In earlier studies, we compared perceived effectiveness to likelihood judgments to evaluate a "safe senses" explanation. To replicate this analysis, we ran a mixed ANOVA which revealed a significant, though not especially strong, target type X senses X rating type interaction, $F(4,612) = 5.94$, $p < .001$, $n_p^2 = .04$. When evaluating other people as a potential pathogen source, comparisons within each sense indicated that the biggest difference in rating type emerged for touch ($g_{av} = .46$). As in Study 1, although participants viewed touch as relatively effective ($M = 4.17$, $SD = 1.94$), they were relatively averse to using it ($M = 3.25$, $SD = 2.08$). When evaluating food as a potential pathogen source, comparisons indicated the biggest difference in rating type emerged for sight ($g_{av} = .20$). Similar to Study 2, participants were more interested in using sight ($M = 5.69$, $SD = 1.60$) than in believing it was effective ($M = 5.36$, $SD = 1.76$). Unlike Study 2, however, no difference emerged for taste, $p > .30$.

7.2.3. Question 2: do sensory beliefs vary depending on the type of evaluation?

To answer this question, we analyzed beliefs about effectiveness and likelihood of use for each evaluation type, separately by target people and food (see Table S8 for means and results of all comparisons between evaluation types).

7.2.3.1. Target people. A senses X evaluation type interaction emerged on effectiveness beliefs (see Fig. 2, panel A), $F(8,908) = 35.10$, $p < .001$, $n_p^2 = .24$. Participants believed that sight and sound were most effective at detecting interpersonal infection (sight vs. sound, $p = 1.0$), smell was most effective at detecting interpersonal hygiene with sight a close second (smell > sight, $p = .009$), and sight was most effective at detecting interpersonal attractiveness. We next compared differences between evaluation types within each sense. In summary, participants emphasized sound and touch for disease judgments, smell for hygiene judgments, and sight and touch for attractiveness judgments. The perceived effectiveness of taste did not differ between evaluation types.

A senses X evaluation type interaction also emerged on likelihood of use beliefs (see Fig. 2, panel C), $F(8,900) = 26.45$, $p < .001$, $n_p^2 = .19$. The descriptive patterns of prioritization and significance tests within types of evaluation all matched those just reported for sensory effectiveness, except smell and sight were equivalent when evaluating hygiene ($p = .26$). We next compared differences between evaluation types within each sense. Mimicking the findings for effectiveness, participants emphasized sound and touch disease for judgments, smell for hygiene judgments, and sight and touch for attractiveness judgments. Again, the perceived effectiveness of taste did not differ between evaluation types.

Together, these findings for target people indicate that the context of evaluation matters for the beliefs professed about sensory prioritization. This suggests that the patterns found for interpersonal infection in earlier studies are not simply a function of the specific target.

7.2.3.2. Target food. A senses X evaluation type interaction emerged on effectiveness beliefs (see Fig. 2, panel B), $F(8,904) = 3.56$, $p < .001$, $n_p^2 = .03$. Despite this weak interaction, patterns of beliefs across the senses were identical within evaluation types. Taste was considered the most effective sense, or equally effective to sight and smell, for each evaluation type. Differences between evaluation types within each sense also appeared only sporadically. No differences were found for sight or smell. However, participants emphasized touch for disease judgments, taste for quality judgments, and sound, taste, and touch for liking judgments.

A weak senses X evaluation type interaction also emerged on likelihood of use beliefs (see Fig. 2, panel D), $F(8,912) = 3.78$, $p < .001$, $n_p^2 = .03$. As with effectiveness, patterns of beliefs across the senses were virtually identical within evaluation types. Taste again was prioritized, except in the context of contamination. Differences between evaluation types within each sense also appeared only sporadically. No significant differences were found for sight, smell, or touch. However, participants emphasized sound and taste for liking judgments and taste for quality judgments.

These findings for target food reveal variation across contexts of evaluation, although this variation is substantially less than with target people. As above, this suggests that the patterns found for germ contamination in earlier studies are not simply a function of the specific target.

7.2.4. Exploratory analyses

The Supplementary Material section features analyses of perceived risk, proximity, and base rate measures. Evaluations in the context of pathogenic threat generally mirrored those from Study S1, with participants reporting less likelihood of using senses perceived as more risky, and perceiving closer distances as necessary for the sensory processing of food compared to people. We highlight one additional finding here: Perceived base rates of sensory cues varied across evaluation contexts. For example, with target people, sound cues were believed to be common when judging potential infection, scent cues were believed common when judging hygiene, and only sight cues were judged especially common when judging attractiveness. This variation suggests that base rate availability may not be a causal predictor of sensory effectiveness and use beliefs. Evaluation goals cannot alter the objectively available sensory information in situations without precipitating additional action. Instead, variation in perceived base rates may be best explained by as a consequence of perceivers focusing on (different) aspects of the situation that align with their goals. If so, both sensory beliefs and perceived base rates may be outcomes of the particular evaluation context rather than causally linked.

7.3. Discussion

Findings from our prior studies indicated that perceivers hold sensory beliefs about pathogen detection that differ for person and food targets. The current study reveals that these beliefs are not only target-specific, they also depend on the particular feature under evaluation. When evaluating pathogenic danger, patterns of belief largely matched those found in Studies 1 and 2. However, those patterns diverged when evaluating a different potential threat (fit with normative standards) and a positive property of targets (desirability). This rules out the possibility that the sensory beliefs uncovered in earlier studies were simply "default" ways in which people perceive a given stimulus.

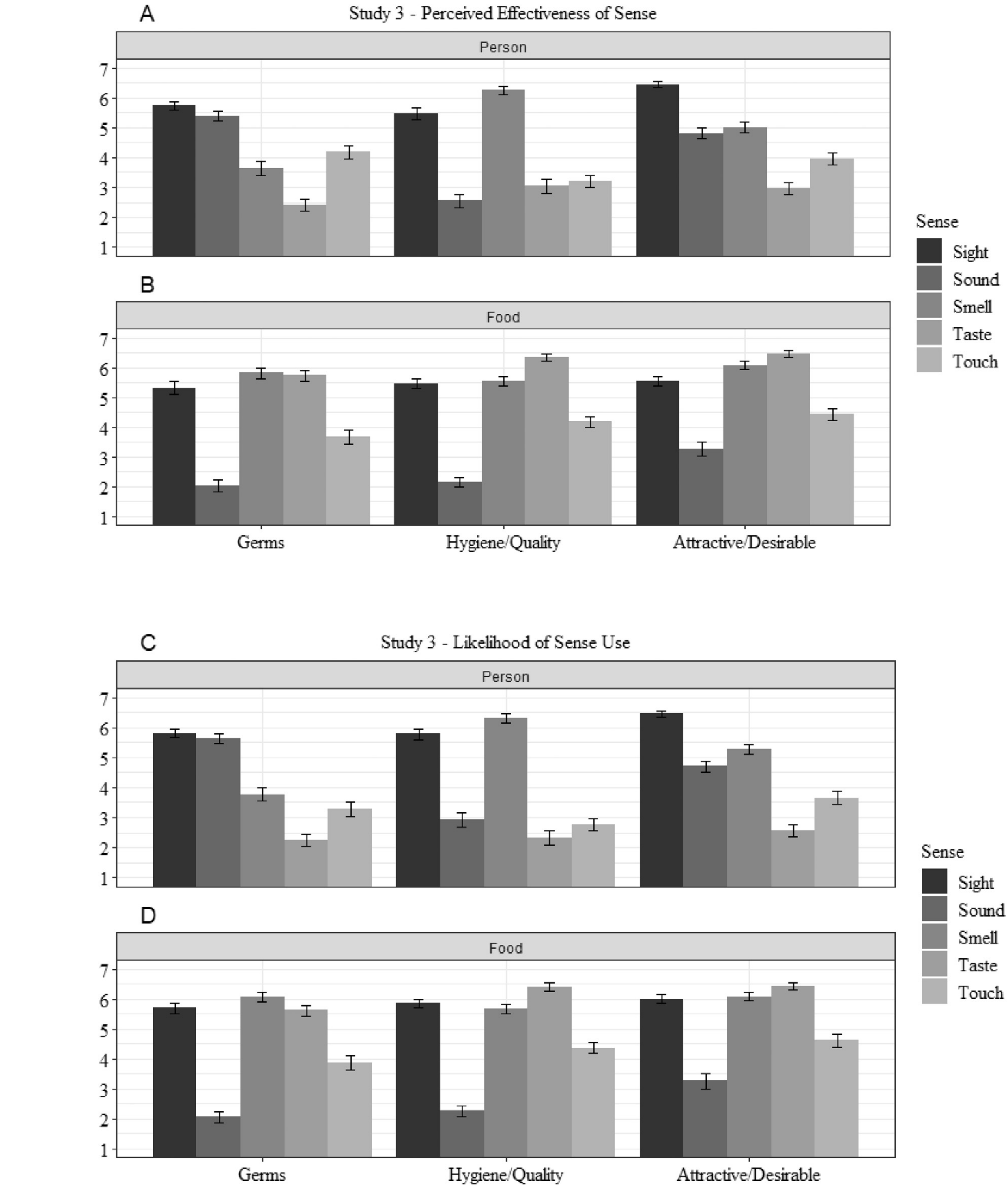

Fig. 2. Perceived effectiveness (top rows) and likelihood of using senses (bottom rows) for person (panels A, C) and food targets (panels B, D) in Study 3.

8. General discussion

People most commonly became aware of infection-relevant threats through their senses. Does this sensory significance translate into beliefs about the value of sensory cues for detecting pathogenic dangers? When the possibly infected target was another person, participants believed that sight and sound were more effective, and especially more likely to be used, than other senses. In contrast, participants evaluating potential food contamination believed that sight, smell, and taste were more effective than the other senses. They also preferred to use sight and smell, but less so taste. These patterns are consistent with a “safe senses” interpretation in which individuals prioritize sensory information involving relatively lower perceived risk of germ transmission.

Looking between different target types, participants believed sound was relatively more important for detection with people, whereas smell and taste were more important with food, consistent with predictions. Sight was believed important for detection in both people and food.

These patterns indicate that lay beliefs reflect a degree of specialization toward the threat-related affordances of targets. That is, perceivers interpret the value of sensory information in line with the modes of sensation they believe are effective for evaluating pathogenic danger but also are relatively less risky.

The last study expanded on this idea by demonstrating that it is not merely the targets themselves that help shape patterns of sensory beliefs, but the features being evaluated in those targets. The particular patterns of belief found in Studies 1 and 2 were replicated when assessing pathogenic danger, but not when assessing desirability or fit with normative standards. Thus, perceivers do not merely associate targets with a fixed set of sensory cues; instead, perceiver goals shape the sensory modalities that are seen as effective and likely to be used for evaluating those targets.

As an alternate approach to the “safe senses” view on explaining such patterns, we measured base rates of the perceived availability of sensory cues in detection contexts. These yielded a complex picture. In Studies 1 and 2, we found that these base rates matched reported patterns for likelihood of use of sensory information. This suggested that participants may have been employing a pragmatic use-what-is-available approach in the context of possible pathogenic danger. However, in Study 3, we found that base rates were perceived to vary depending on what was being evaluated in targets. Logically, the true availability of sensory information does not differ as a function of one’s evaluation goals (though it could across targets or situations). This latter finding instead suggests that perceivers may be attending to sensory information they believe relevant to the feature they are evaluating rather than basing their use of sensory information on what is actually available. If so, base rates cannot provide an adequate causal explanation for the patterns of sensory lay beliefs.

In total, these findings represent an important complement to existing work on the psychological and behavioral responses perceivers exhibit in contexts of pathogen threat (e.g., Ackerman et al., 2018; Murray and Schaller, 2016; Neuberg et al., 2011; Tybur et al., 2016). Such research has found that people often respond with aversion and avoidance to targets that are normatively deviant but not truly hazardous. These overgeneralizations of threat rest on associations between certain features and germ danger. Similarly, patterns of lay beliefs about pathogen detection may inform our understanding of how the mind structures information about this type of threat and may also predict biased responses toward non-threatening targets.

9. Limitations and future directions

We note one key limitation (common in much of the psychology literature) that will require future research to support wide generalizations about human psychology—the present data were collected from relatively well educated U.S. participants obtained online. Variation in cultural, educational, and ecological factors may influence patterns of lay beliefs, the cues to which perceivers attend, and the manner in which they respond to specific pathogen threat targets, much as such factors shape broader conceptualizations of folk biology and psychology (e.g., Jones and Rua, 2006; Keil et al., 1999; Lupton, 2012; Sng et al., 2018; Robins, 2015; Vapnarsky et al., 2001). Linguistic indicators of certain sensory concepts do vary across cultures (San Roque et al., 2015), but as far as we are aware, no research has yet examined how these types of variation affect beliefs about the use of sensory information in disease detection, making this a fruitful avenue for future work. This said, we believe the current data to be valuable for the broader literature—most of the existing research on pathogen avoidance and the behavioral immune system is grounded in studies of Western (WEIRD) samples. Therefore, establishing an initial picture of the beliefs of these samples, as was done here, helps to inform current knowledge.

These data on lay beliefs set the stage for at least two additional interesting research questions. Foremost, how accurate are these beliefs? As discussed earlier, recent findings have shown that certain sensory cues are effective in truly identifying pathogenic infection. Others are less useful. On their face, it appears that patterns of belief about the effectiveness of sensory modalities only sometimes parallel evidence for accurate identification (e.g., sight is both believed useful and is actually useful, whereas sound is believed useful but may not be; Axelsson et al., 2018; Michalak et al., 2020). Little evidence exists to date about whether perceivers can effectively use touch and taste (or other, “less traditional” sensory modalities) to detect true pathogen threat. As a whole, it is important to know whether perceived effectiveness corresponds with actual effectiveness. A great deal of psychological evidence shows that beliefs may be biased or altogether incorrect (e.g., Alba and Hutchinson, 2000; Kruger and Dunning, 1999; Wells et al., 2006), and that the processing of sensory content may occur outside of conscious awareness (e.g., Dijkerman and de Haan, 2007; Tamietto and De Gelder, 2010), perhaps leading to weak associations between explicit beliefs about sensation and judgment accuracy. A comprehensive approach to matching lay beliefs with accuracy requires more extensive investigation of identification performance, however.

Finally, an interesting direction would be to explore a signaling framework considering the perspective not only of perceivers, but also people who are targets of disease detection. In contexts where disease detection has important implications for interaction, targets are motivated to send signals that promote their own goals (e.g., healthiness when establishing coalitional or mating relationships, sickness when seeking care), while perceivers attempt to judge the veracity of these signals (e.g., Steinkopf, 2017). From the target’s perspective, believing that perceivers will prioritize certain sensory information in these contexts may lead targets to conceal or enhance relevant features, from wearing perfume and makeup to stifling coughs and sneezes (see Ackerman et al., 2018; Weiss, 2008), that increase signal strength but decrease honesty. Such steps are analogous to those often taken to hide aspects of one’s stigmatized identity (e.g., Miller and Major, 2000; Pachankis, 2007; Smart and Wegner, 1999). It may be that that if particular identities are strongly associated with specific sensory modalities (e.g., groups stereotyped as loud or pungent), people holding those identities may experience increased anxiety and thus exhibit counter-stereotypic sensory cues as a means of obviating actual discrimination in situations that evoke potential pathogen threat.

10. Conclusion

People possess particular patterns of belief about the role of sensation in infectious disease detection. These appear to stem from an understanding about the availability of sensory cues as well as sensitivity to the possible risks that processing sensory information entails. By documenting such beliefs, we may help inform questions about how people understand their own pathogen threat psychology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Open practices

Materials and data are available at https://osf.io/7zspe/?view_only=0b030d43177d469ea35d3957ff608bb7

Preregistration is available at https://aspredicted.org/ag8zq.pdf (Study 1 and 2) and https://aspredicted.org/7472p.pdf (Study 3)

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