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RESEARCH

Greater Self-reported Health is Associated with Lower Disgust: Evidence for Individual Calibration of the Behavioral Immune System

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Abstract

A key theoretical component of the behavioral immune system is its functional flexibility, where an individual's reaction to pathogenic stimuli is designed to fluctuate based on individual costs and benefits. For example, those who perceive themselves to be more vulnerable to disease or are in poorer health should react more aversely to possible pathogenic agents because of the higher costs of infection. To test this hypothesis, we collected measures of current individual health (i.e., self-reported general health and self-perceived infectibility) and three domains of disgust in two studies: an in-person sample of United States university students and a global online sample of diverse ages. We also collected and assayed saliva samples for secretory immunoglobulin A (sIgA), provided by the university students. Results showed that lower sIgA and higher perceived infectibility independently predicted higher pathogen disgust. Poor self-reported general health was associated with higher pathogen disgust in the university sample, but not in the online sample. Finally, pathogen disgust mediated the effect of perceived infectibility on behavioral avoidance motivation. Overall, our findings support the functional flexibility of the behavioral immune system, such that those who are more vulnerable to disease are more likely to respond aversely to situations with high pathogen load; however, future research should consider other contextual factors which affect the strength of this relationship between individuals and populations.

Keywords Behavioral immune system · Perceived health · Cross-cultural research · Secretory immunoglobulin A

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Introduction

The "behavioral immune system" (BIS; Clark & Fessler, 2014; Fincher et al., 2008; Schaller & Park, 2011; but see Lieberman & Patrick, 2014), broadly conceived, operates by detecting cues of infectious agents in the immediate environment, making a probabilistic assessment of vulnerability to these cues (Tybur & Lieberman, 2016), triggering psychological responses, and prompting behavioral avoidance of infection risk. This system minimizes the energetic demands associated with mobilizing the physiological immune system, as well as the costs of morbidity and mortality, through early pathogen detection and probabilistic assessment of infection (Schaller & Park, 2011).

A central element of the BIS is the emotion of disgust (Clark & Fessler, 2014; Lieberman & Patrick, 2014; Neuberg et al., 2011; Rozin et al., 2000; Schaller & Park, 2011; Tybur & Lieberman, 2016). Tybur and colleagues (2009) proposed that disgust evolved to aid humans in three specific domains: (1) avoiding contact with infectious agents (i.e., pathogen disgust); (2) promoting successful mating strategies by avoiding partners who could decrease reproductive success (i.e., sexual disgust); and (3) avoiding individuals who violate social norms (i.e., moral disgust). While conceptually and statistically distinct, all three domains may influence pathogen avoidance (Al-Shawaf et al., 2015; Gruijters et al., 2016; Tybur et al., 2015; however, see Clark & Fessler, 2014, for an alternative view); however, we focus on pathogen disgust in the present research due to its clear links with infection risk.

Many studies have sought to explore the implications of individual differences in disgust (e.g., Aarøe et al., 2016; Al-Shawaf et al., 2015; Hlay et al., 2022; Navarrete & Fessler, 2006; O'Shea et al., 2019; Reid et al., 2012; Sevi et al., 2018; Tybur et al., 2011, 2015), but the question of why humans report different levels of disgust sensitivity has not been fully answered. In theory, some individual differences in disgust may be context-independent and others context-dependent. Twin studies suggest that about half of the variation in disgust can be attributed to environmental variation (Tybur et al., 2020a), and several studies have shown which environmental variables may influence disgust levels (Batres & Perrett, 2020; Hlay et al., 2021; Schaller & Murray, 2008; Skolnick & Dzokoto, 2013; but see Tybur et al., 2016). For instance, inter-population regional communicable disease mortality rates and COVID-19 infection rates predicted disgust across four countries, such that people in areas with a greater risk of mortality and infection tended to exhibit higher disgust (Hlay et al., 2021).

Even among those within the same population, disgust levels vary and may track individual differences in health and immune status. Several studies have shown that women in the luteal phase of their menstrual cycle and in the first trimester of pregnancy are more likely to have heightened disgust sensitivity, with researchers proposing that their disgust sensitivity increases to compensate for suppression of their adaptive immune system during these periods (Fessler, 2001, 2002; Fessler et al., 2005; Fleischman & Fessler, 2011; Milkowska et al., 2019; Miłkowska et al., 2021; but see Jones et al., 2018). A recent study among the Shuar of Ecuador showed that those with higher disgust sensitivity had lower levels of inflammation (Cepon-Robins et al., 2021). This body of research, along with the field of psychoneuroimmunology

more broadly (Clark & Fessler, 2014), suggests that the BIS and the physiological immune system are interdependent and have bidirectional influence (Ackerman et al., 2018; Miller & Maner, 2011; Oaten et al., 2009). Experimental studies have shown that disgust-inducing environments and stimuli can elicit physiological responses, such as salivary and blood inflammatory immune responses (Bradshaw et al., 2022; Stevenson et al., 2011, 2012; 2015), flares in herpes labialis (i.e., cold sores; Buske-Kirschbaum et al., 2001), and increases in tactile sensitivity (Hunt et al., 2017).

A theoretically important component of BIS theory is its "functional flexibility" (Murray & Schaller, 2016; Tybur & Lieberman, 2016); that is, the notion that it should integrate the costs and benefits of pathogen exposure and social avoidance to promote adaptive behavior (i.e., the "contact value index"; Tybur & Lieberman, 2016). For example, when individuals are more vulnerable to the costs of infection due to existing illness or immunosuppression, they should experience stronger aversive reactions to threats of contamination. Yet, to our knowledge, studies examining the effects of current or recent health status on disgust levels yield conflicting findings (De Barra et al., 2014; Gassen et al., 2019; Makhanova et al., 2022; Miller & Maner, 2011; Tybur et al., 2020b). Some studies indicate that recently ill individuals were more attentive towards and avoidant of disease cues (Miller & Maner, 2011); whereas, in other studies this was not replicated (Tybur et al., 2020b). Further, in some studies, those who perceived themselves as highly vulnerable to disease were more attuned to false pathogen cues – e.g., obesity (Lieberman et al., 2012) and foreigners (Faulkner et al., 2004; Moran et al., 2021; Reid et al., 2012) – and report cues to be more memorable and more indicative of pathogen risk (Miller & Maner, 2012). Notably, perceived control over one's environment may moderate the relationship one's health and pathogen avoidance motivation, as previous studies have found that those who view themselves as having less control over their environment report lower disgust (Batres & Perrett, 2020; Bradshaw et al., 2022). Thus, individuals may only raise their pathogen avoidance motivation in response to poor health when they have more control in their environmental context, such as resource acquisition.

Recent studies have accounted for variation in perceived vulnerability to disease with childhood illness history (De Barra et al., 2014; Makhanova et al., 2022), recent infection (De Barra et al., 2014; Gassen et al., 2019; Makhanova et al., 2022; Miller & Maner, 2011; Tybur et al., 2020b), current inflammation (Gassen et al., 2019), and chronic immunosuppression (Oaten et al., 2017). Several studies suggest that increased childhood illness (Makhanova et al., 2022) and recently having an infection (Gassen et al., 2019; Miller & Maner, 2011; Tybur et al., 2020b) are related to increased perceived vulnerability to disease and disease avoidance. In constrast, De Barra et al. (2014) found no association between early illness and disease vulnerability. Further, those that are immunosuppressed are more disease-avoidant than healthy individuals (Oaten et al., 2017). Only one study to our knowledge (Cepon-Robins et al., 2021) has directly tested associations between infection biomarkers and disgust sensitivity, with the finding that disgust sensitivity is negatively associated with infection. These results are in line with Gassen and colleagues (2019), which demonstrates that current inflammation is negatively associated with pathogen avoidance motivation. In sum, these results suggest that either those with lower disgust sensitivity are less protected against infection, as theory would predict (Clark & Fessler, 2014;

Schaller & Park, 2011), *or* that inflammation downregulates disgust (Cepon-Robins et al., 2021; Gassen et al., 2019). Moreover, each of these studies was conducted in a single population, limiting our ability to assess generalizability or the factors affecting inter-population variation.

Importantly, while recent studies have examined the relationship between disgust and inflammation, or the innate immune system, few studies have assessed the relationship between disgust and anti-bodies, or the adaptive immune system. The innate immune system provides a somewhat "fixed" first line of defense that reacts to most invader cells similarly; alternatively, the adaptive immune system provides a secondary, much more specialized and versatile attack on invader cells that make it past the innate immune system (Janeway et al., 2001). Previous research indicates that anti-body markers (as measured by salivary immunoglobulin A, or sIgA) and inflammation (as measured by tumor necrotizing factor alpha, or TNF-a) have significantly different relationships with disgust (Stevenson et al., 2011), such that sIgA is down-regulated, while TNF-a are up-regulated. The authors propose that differential responses to disgusting stimuli may have evolved in order to best conserve energy and proteins. While inflammatory markers have been studied previously (Bradshaw et al., 2022; Cepon-Robins et al., 2021; Gassen et al., 2019), anti-body markers remain understudied within the context of disgust. Further, while Stevenson and colleagues (2011, 2012) studied the effect of disgust-priming on sIgA levels and Stevenson and colleagues (2015) assessed disgust propensity as a moderating effect on the relationship between disgust stimuli and immune markers, no studies to our knowledge examine the direct relationship between trait disgust sensitivity and anti-body markers, as well as perceived health status.

In the present study, we aim to expand our knowledge on the relationship between immunity, perceived health status, and disgust sensitivity. Specifically, we examine: (1) the relationship between objective health (as assessed through mucosal immunity) and pathogen disgust; (2) the relationship between perceived health, perceived infectability, and pathogen disgust sensitivity; and (3) the pathway by which health, pathogen disgust, and behavioral avoidance motivation may be related. We predict that lower perceived and objective health are associated with higher levels of pathogen disgust sensitivity; that is, if perceived infection vulnerability is high, health-protective psychology against infection should also be increased. Furthermore, we predict that pathogen disgust sensitivity is associated with behavioral avoidance motivation, such that pathogen disgust sensitivity mediates the relationship between health and behavioral avoidance motivation. This study focuses on the effect of health specifically on pathogen disgust sensitivity; we include sexual and moral disgust sensitivity in our model without hypotheses and results are included in the supplemental materials for interested researchers.

Study 1: US University

Methods

Participants

US University sample. One-hundred sixty-six students (28 women) were recruited at Boston University in 2017. The participants ranged in age from 18 to 40 years old (M_{age} = 21.20, SD=2.80), and self-identified as White (40.5%), Asian (19.0%), South Asian (14.9%), Latin American (10.7%), Black (7.4%), Arab West Asian (4.1%), South East Asian (1.7%). We recruited participants via advertisements placed in common areas throughout the campus and through online job adds for students. Participants were compensated 35.00 USD after completing the study. After accounting for missing data, the final sample was 144 (14 women).

Procedure

All procedures were approved by Boston University Institutional Review Board. After providing informed consent, all participants completed a questionnaire using Qualtrics as part of a larger study on health and mating. Participants were also instructed to provide three saliva samples, the first upon waking the morning following their first study appointment, the second sample that evening before going to sleep, and the third sample upon waking on the following day. Research assistants instructed participants not to eat, drink (except water), smoke, brush their teeth or use mouthwash, or engage in vigorous exercise for a minimum of one hour prior to providing samples. Participants were provided with a package containing three 2 mL polypropylene barcoded cryogenic vials (Globe Scientific) labeled with the day and time (AM or PM), instructions for providing saliva, and worksheets that the participants were to complete each time they provided a sample. Saliva was provided via passive drool.

To ensure that participants provided saliva at the designated times, participants recorded the date they provided each sample, the time they began providing the sample, and the time they finished providing the sample on their worksheet. The worksheets also asked participants to report whether they had consumed alcohol, nicotine, and/or medication in the previous 12 h, whether they had engaged in vigorous exercise, and whether they had any symptoms of illness. These answers were screened as potential confounds for analyses presented in Hodges-Simeon et al. (2020; see supplement for more detail). Nicotine use was significantly associated with sIgA for the first sample; however, this association disappeared when all three saliva samples were averaged.

Participants were also instructed to take a time-stamped photograph of themselves, using their cellphone, each time they began to provide a sample. The research assistant instructed participants to refrigerate each sample immediately after collection. Presser et al. (2014) showed that sIgA was stable at room temperature for 15 days; therefore, it is unlikely that any sample degredation occured in the 24 h in the refrigerator. Nevertheless, sIgA averages from the present research should not be

compared with studies where samples were frozen immediately. The mean sample provision start times were: 8:42 AM (SD = 1 h 46 min), 11:23 PM (SD = 1 h 30 min), 8:42 AM (SD = 1 h 53 min) for the day 1 morning sample, day 1 evening sample, and day 2 morning sample, respectively. At the follow-up appointment the research assistant checked the participants' worksheets and photographs, as well as inspected each sample for noticeable impurities using the Blood Contamination in Saliva Scale (Kivlighan et al., 2004). Participants were also asked if they had incurred an oral injury recently. In total, only four samples were collected following an oral injury. Among these, just one sample from one participant exhibited a noticeable change in saliva color (BCSS = 2; sample showed a "hint of color"). Further analyses indicated that sIgA and BCSS score were not correlated. Therefore, all samples were included in the following analyses.

Enzyme Linked Immunosorbent Assays (ELISA)

Saliva samples were stored at -80 °C until assayed using commercially available enzyme immunoassay kits (DRG International, NJ, USA). Samples were centrifuged for 15 min at 3000 rpm. Samples were diluted in a two-step procedure for the assaying of sIgA, to a final dilution of 1:1000 using the provided assay buffer solution. sIgA samples were assayed in duplicate where the average of the duplicates (log-transformed) was used for all statistical analyses. Average intra- and inter-assay coefficients of variation were 4.85% and 20.67% for sIgA. We then averaged the three sIgA measures to produce one sIgA value for each person.

Measures

Perceived General Health Status

Following Mossey and Shapiro (1982), general health status was assessed using the single self-report item, "In general, for your age, would you say your health is excellent/very good/good/fair/poor?" Mossey and Shapiro's (1982) self-rated general health measure is correlated with morbidity and mortality, over and above other prominent risk indices such as socioeconomic status and gender (Mossey & Shapiro, 1982). In a review of 27 international studies examining global self-rated health, this measure was an independent predictor of mortality in nearly all reports, controlling for numerous other health status indicators and relevant covariates (Idler & Benyamini, 1997).

Perceived Vulnerability to Disease (PVD)

The Perceived Vulnerability to Disease questionnaire (Duncan et al., 2009) contains 15-items which measure perceived susceptibility to infectious diseases (perceived infectibility) and emotional discomfort and behavioral avoidance towards potential pathogenic contexts (germ aversion). The perceived infectibility subscale contains 7 items; example items include: "In general, I am very susceptible to colds, flu and other infectious diseases". The germ aversion subscale includes 8 items; example

items include: "I prefer to wash my hands pretty soon after shaking someone's hand". The measure has shown good internal consistency ($\alpha_{\text{Perceived Infectibility}} = 0.87$; $\alpha_{\text{Germ Aversion}} = 0.74$). Participants responded to each item using a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). Studies using this measure have found that those who report higher perceived infectibility also report higher incidence of illness in the previous year, as well as higher perceived danger from disease relevant animals (Makhanova et al., 2022; Prokop et al., 2010); further, higher childhood illness prevalence has also been linked to higher adult perceived infectibility scores (Makhanova et al., 2022). This scale has also been reported as valid and reliable (Díaz et al., 2016).

Mucosal Immunity (sIgA)

For a measure of mucosal immunity, we use salivary immunoglobulin A (sIgA), the most common antibody in the mucosa (Jemmott & McClelland, 1989; Macpherson, McCoy, Johansen, & Brandtzaeg, 2008; Tomasi, 1970; Van Damme et al., 1992; Williams & Gibbons, 1972). Salivary IgA is secreted into the saliva after being produced in local plasma B cells, where it provides a first line of defense against pathogens and foreign bodies (Macpherson et al., 2008; Brandtzaeg, 2009). It does this, in part, through immune exclusion—blocking access to epithelial receptors, binding pathogens in mucus, and aiding their removal by the body. Because low levels of sIgA have been associated with increased risk of respiratory illness (Nieman et al., 2006), studies have used sIgA as a proxy for overall or respiratory health (Drummond & Hewson-Bower, 1997; Evans et al., 1995; Nakamura et al., 2006; Norhagen et al., 1989; Reid et al., 2001). Further, several studies have identified sIgA is a key antibody in oral health, aiding in the prevention of dental caries and oral diseases (Golpasand Hagh et al., 2013; Gornowicz et al., 2014; Koss et al., 2016; Rashkova & Toncheva, 2010; Thaweboon et al., 2008).

Three Domains of Disgust Scale

Tybur and colleagues (2009) developed the Three Domains of Disgust Scale (TDDS), a measure that contains 21 items which participants are asked to rate on a scale of not at all disgusting (0) to extremely disgusting (6). The scale has been administered to several diverse populations (Tybur et al., 2016), and has been demonstrated to have good internal consistency ($\alpha = 0.83 - 0.89$) and a coherent factor structure (Tybur et al., 2009). Example items for each domain are as follows "stepping on dog poop", (pathogen disgust), "watching a pornographic video" (sexual disgust), and "stealing from a neighbor" (moral disgust). Pathogen disgust is the primary focus of the current research; however, results for sexual and moral disgust are included in the supplement.

Data analysis Strategy

We used SPSS 24 to examine bivariate correlations and mean differences. We used t-tests to compare males and females in terms of self-reported perceived infectibility, general health, and disgust scores; all scores were calculated by averaging the items

from the respective subscales. To test our theoretical models, we specified and tested structural equation models (SEMs) using the MPlus 8.10 software package (Muthén, & Muthén, 1998–2017) and the Robust Weighted Least Squares (WLSMV) estimator because our model contained categorical variables (Muthén et al., 1997). In all analyses, we conducted significance testing at $\alpha = 0.05$.

Hypothesized Model

We specified and tested our hypothesized SEM using general health, perceived infectibility, and sIgA (along with sex and age), as explanatory variables predicting pathogen disgust. The disgust and perceived infectibility items were specified as reflective indicators of their latent factors, whereas the sIgA indicators were averaged to construct a composite score. We controlled for sex and age because previous research has identified differences in disgust levels between sexes (Al-Shawaf et al., 2015; Al-Shawaf et al., 2018; Hlay et al., 2021; Tybur et al., 2009).

Model fit. We used a variety of indices to obtain a robust assessment of model fit. We considered the substantive meaningfulness of the model and regarded Tucker-Lewis (TLI) indices greater or equal to 0.95 (Byrne, 2001; Hu & Bentler, 1999), along with root mean square error of approximation values of less than or equal to 0.05 (RMSEA; Browne & Cudeck, 1993) as evidence of acceptable fit to the data. We also considered significant χ^2 likelihood ratio statistics as evidence that the hypothesis of exact fit should be rejected (Bollen, 1989).

Results

There were no significant sex differences in perceived infectibility; however, women were higher on all domains of disgust (Table S1); however, these results should be interpreted with caution as the sample includes a low number of women compared to men.[1] General health and perceived infectibility correlated with each other ($N = 166$, $r = -.27$, $p < .001$, VIF = 1.00), but neither measure correlated with sIgA. All samples of sIgA correlated with each other significantly (Table 1).

Table 1 Correlations between all variables in Study 1 ($N = 144$)

	1.	2.	3.	4.	5.	6.	7.
1. Perceived Infectibility		−0.27**	0.16*	−0.07	−0.11	−0.01	−0.04
2. General Health	−0.27**		−0.15*	−0.02	−0.02	−0.12	0.08
3. Pathogen disgust sensitivity	0.16*	−0.15*		−0.15	−0.18*	−0.07	−0.09
4. Average sIgA	−0.07	−0.02	−0.15		0.80**	0.74**	0.81**
5. Day 1 morning sIgA	−0.11	−0.02	−0.18*	0.80**		0.36**	0.43**
6. Day 1 night sIgA	−0.01	−0.12	−0.07	0.74**	0.36**		0.47**
7. Day 2 morning sIgA	−0.04	0.08	−0.09	0.81**	0.43**	0.47**	

Note *$p < .05$; **$p < .01$; **$p < .001$

[1] Because of the lower number of women, we also tested our SEM while excluding women and found no substantively important differences in parameter estimates.

Model fit of the SEM appeared marginally sufficient ($\chi^2[439]=604.34$, $p<.001$; TLI = 0.94; CFI = 0.95; RMSEA = 0.05; SRMR = 0.10). General health was a significant inverse predictor of pathogen disgust ($b=-0.15$, $SE=0.06$, $p=.010$, $\beta=-0.24$); that is, those with lower self-perceived health reported higher pathogen disgust levels. Perceived infectibility positively predicted pathogen disgust ($b=0.10$, $SE=0.04$, $p=.016$, $\beta=0.17$). sIgA was inversely related to pathogen disgust ($b=-0.27$, $SE=0.13$, $p=.047$, $\beta=-0.20$). See Table 2 for the statistical model and Table S2 for all results including other domains of disgust.

Study 2: Global Online

Methods

Participants

The first online sample was collected in 2018. We recruited 306 online participants (259 women) from Amazon's Mechanical Turk (MTurk). The participants ranged in age from 18 to 63 years old (M_{age} = 26.12. $SD=5.50$). Participants were from 23 countries[1]; the two largest groups were from India (142; 43 women) and the US (217; 154 women). Participants were compensated 1.50 USD after completing the study.[2]

In April 2020, we recruited a second sample of 1495 online participants using MTurk as part of a separate study on interpopulation variation in disgust and COVID-19 risk. After accounting for failed attention checks, repeat IP addresses, and missing data, we were left with 821 participants (257 women). The participants ranged in age from 18 to 72 years old (M_{age} = 31.55, $SD=9.91$); 210 (67 women) were from Brazil, 205 (44 women) were from India, 178 (57 women) were from Italy, and 228 (90 women) were from the US. These countries were chosen to be diverse in culture, economic development, and infection prevalence.

The samples had similar demographic make-ups and received the same surveys. Although one sample was collected after the outbreak of the SARS-CoV-2 pandemic, we found no significant differences between samples in any of the variables using t-tests (pathogen disgust $p=.193$; perceived infectibility $p=.06$; germ aversion

Table 2 Health measures predicting pathogen disgust in Study 1

Sample	b	β	SE	*p*	*r*
US University					
Perceived Infectibility	0.10	0.17	0.04	0.016	0.16*
General Health	**−0.15**	**−0.24**	**0.06**	**0.010**	**−0.15***
Average sIgA	**−0.27**	**−0.20**	**0.13**	**0.047**	**−0.15**
Sex	−0.15	−0.12	0.13	0.265	−0.04
Age	<0.01	0.02	0.01	0.844	−0.04

Note Sex coded as 0 = female, 1 = male * $p<.05$; ** $p<.01$

[2] The remaining respondents were from: Albania, Algeria, Argentina, Australia, Bangladesh, Brazil, Canada, Ecuador, Germany, Grenada, Hong Kong, India, Indonesia, Ireland, Italy, Jamaica, Mexico, Morocco, Romania, Turkey, United Kingdom, United States, Venezuela.

$p = .146$; general health $p = .146$); thus, we combined the two samples to yield more power. After accounting for failed attention checks, repeat IP addresses, and missing listwise data, we were left with 1195 participants in total.

Procedure

Survey procedures, measures, and data analyses were the same as described in Study 2. Additionally, we used the Germ Aversion subscale of the PVD to measure variation in behavioral avoidance motivation. Although the Germ Aversion subscale can sometimes be viewed as psychological motivation rather than behavioral towards pathogen avoidance, the majority of items (75%) ask about behavioral tendencies (e.g., "I prefer to wash my hands soon after shaking someone's hand" and I am comfortable sharing a water bottle with a friend"). Therefore, we use Germ Aversion as a self-reported behavioral measure of pathogen avoidance in the present study.

Additional Data Analysis

We planned to use the same software package, modeling approach, and estimator as in Study 1. Extending upon Study 1, we included germ aversion within the SEM as an outcome variable. Sex and age were again included as covariates and fixed effects were estimated for country of origin.

Results

There were no significant sex differences in perceived infectibility; however, women were higher on all domains of disgust and lower in perceived general health (Table S1). Perceived infectibility and general health did significantly correlate ($N = 1195$; $r = -.09$, $p = .02$, VIF = 1.00; Table 3).

For the SEM analysis, initial model fit appeared poor ($\chi^2[336] = 3911.64$, $p < .001$; TLI = 0.82; CFI = 0.85; RMSEA = 0.09; SRMR = 0.07) and modification indices suggested this was due to the presence of cross-loadings among the disgust sensitivity subscales. Therefore, we used exploratory structural modeling (ESEM; Marsh et al., 2014) to allow cross-loadings in the measurement portion of the model. Using ESEM, we tested our full SEM once again, and found that fit appeared sufficient ($\chi^2[300] = 1{,}657.13$, $p < .001$; TLI = 0.92; CFI = 0.94; RMSEA = 0.06; SRMR = 0.03). Perceived infectibility positively predicted pathogen disgust ($b = 0.17$, $SE = 0.03$, $p < .001$, $\beta = 0.16$; Table 4). Perceived general health did not predict pathogen disgust ($p = .430$). See all results in Table S2.

Table 3 Correlations between all variables in Study 2 ($N = 1195$)

	1.	2.	3.	4.
1. Perceived Infectibility		−0.92*	0.18**	0.36**
2. General Health	−0.09*		−0.04	0.03
3. Pathogen disgust sensitivity	0.18**	−0.04		0.38**
4. Germ Aversion	0.36**	0.03	0.38**	

Note *$p < .05$; **$p < .01$; **$p < .001$

Table 4 Health measures predicting pathogen disgust in study 2

Sample	b	β	SE	*p*	*r*
Global online					
Perceived Infectibility	0.17	0.16	0.03	<0.001	0.18**
General Health	0.03	0.02	0.04	0.430	−0.04
Sex	**−0.52**	**−0.30**	**0.04**	**<0.001**	**−0.18****
Age	<0.01	0.06	<0.01	0.065	0.03

Note Sex coded as 0 = female, 1 = male * $p < .05$; ** $p < .01$

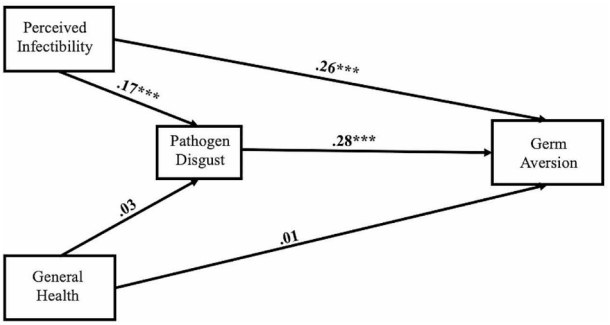

Fig. 1 Mediational analysis of perceived health variables, pathogen disgust, and germ aversion. *Note*. ***$p < .001$

Table 5 Mediation analysis pathogen disgust as mediator between perceived infectibility and general health and germ aversion in the global online sample ($N = 1195$)

	b	β	SE	*p*
PERCEIVED INFECTIBILITY				
Direct Effect	**.32**	**.35**	**.02**	**<.001**
Indirect Effect				
Pathogen Disgust	**.05**	**.05**	**.01**	**<.001**
GENERAL HEALTH				
Direct Effect	.02	.02	.01	.156
Indirect Effect				
Pathogen Disgust	.01	.01	.01	.434

We then tested if disgust might mediate the relationships between germ aversion and perceived general health and perceived infectibility. Germ aversion was directly predicted by pathogen disgust ($b = 0.28$, $SE = 0.03$, $p < .001$), and perceived infectibility ($b = 0.26$, $SE = 0.02$, $p < .001$). The estimated indirect effect of perceived infectibility on germ aversion, via pathogen disgust, was statistically significant ($b = 0.05$, $SE = 0.01$, $p < .001$); no variable appeared to mediate the relationship between general health and germ aversion (see Fig. 1 and Table 5; for all domains of disgust, refer to Table S3 and S4).

Discussion

The current investigation provides novel insight into the relationship between individual health and disgust sensitivity. Theory suggests that the behavioral immune system is functionally flexible; that is, pathogen aversion should be calibrated to individual costs, such as immunosuppression, and benefits, such as food acquisition or disease avoidance. For the present research, we hypothesized that people who are more vulnerable to illness should generally show greater levels of pathogen disgust sensitivity and behavioral avoidance motivation due to the relatively higher costs incurred from infection from those with weaker immunity (Ackerman et al., 2018). Our results provide some support for this hypothesis.

This is the first study to test the relationships among individual differences in health, disgust, and pathogen aversion using both self-perceived health and a biomarker of anti-bodies. Specifically, among the US university student population we sampled, those with lower levels of sIgA antibodies in their saliva (indicating higher vulnerability to respiratory illness) had higher pathogen disgust sensitivity. This is in line with previous findings that inducing disgust experimentally can also down-regulate sIgA, while upregulating inflammatory markers (Stevenson et al., 2011, 2012, 2015). Reduced levels of sIgA have been linked to compromised immunity and an increased susceptibility to infections (Fahlman & Engels, 2005; Gleeson, 1999, 2002; Gleeson et al., 2011; Neville et al., 2008). Similar associations between diminished sIgA concentrations and elevated risks of upper respiratory tract infections or symptoms related to colds/flu have been observed in studies involving both children and adults (Fahlman & Engels, 2005; Gettler et al., 2014; Gleeson, 1999, 2002; Gleeson et al., 2011; Neville et al., 2008). Furthermore, a longitudinal study spanning 19 years revealed a notably higher mortality rate, especially from cancer and respiratory diseases, among individuals with low sIgA (Phillips et al., 2015). There is also a growing body of evidence suggesting that sIgA levels may play a crucial role in the severity of SARS-CoV-2 (i.e., COVID-19) infection, vaccine effectiveness, and prolonged viral shedding (Chao et al., 2020; Naito et al., 2020; Wang et al., 2020). In summary, those with low concentrations of sIgA are more vulnerable to illness; upregulating pathogen disgust sensitivity when more vulnerable may be an adaptive response to avoid the costs of exposure to infectious agents.

In our US university sample, our models showed that those with lower self-perceived infectibility had lower pathogen disgust sensitivity. Further, this was independent from the effects of sIgA; that is, both perceived infectibility and sIgA antibodies explained unique variance in pathogen disgust sensitivity. We then replicated the relationship between perceived infectibility and disgust using a large, global sample of diverse ages, showing that those who are more likely to become infected if exposed to pathogens exhibit stronger motivation to avoid exposure to those pathogens. One previous study showed that individuals who have recently been unwell exhibit heightened attention to and avoidance of disease-related cues (Miller & Maner, 2011; though, see Tybur et al., 2020b who did not replicate this finding). Moreover, those who perceive themselves as highly susceptible to disease tend to be more sensitive to false pathogen cues (i.e., obesity, Lieberman et al., 2012; interactions with foreigners, Faulkner et al., 2004; Moran et al., 2021; Reid et al., 2012). Our findings add

to this literature, suggesting associations between individual variation in health and pathogen disgust sensitivity.

In addition to sIgA and perceived infectibility, we examined a third potential measure of immune vulnerability – self-perceived general health. General health status was assessed using the single self-report item, "In general, for your age, would you say your health is excellent/very good/good/fair/poor?" (Mossey & Shapiro, 1982). Global self-rated health is a consistent predictor of mortality internationally, controlling for numerous other health status indicators and relevant covariates (Idler & Benyamini, 1997). In our US university population, general health was also an independent predictor of pathogen disgust sensitivity. In line with our predictions, those that saw themselves as having poorer health were more likely to report higher pathogen disgust sensitivity. We attempted to replicate this finding in our large, online sample; however, we did not find that general health predicted pathogen disgust sensitivity in this sample. Since general health is linked to general mortality and not specifically infectious mortality, it is possible that the connection to disgust is less robust. Especially in a global setting, where there is much wider variation in healthcare access and environmental pathogen load, individual's disgust sensitivity may be more reactive to explicit infection risks and vulnerability. In this case, we would predict pathogen disgust sensitivity to be more reactive to one's own perceived vulnerability to disease, which our results support, or fluctuations in infection risk in one's environment, which previous studies have supported (Hlay et al., 2021; Skolnick & Dzokoto, 2013).

Mediation analyses also suggest that pathogen disgust sensitivity mediates the relationship between perceived infectibility and germ aversion, but not general health and germ aversion. These results expand on our knowledge of the pathway from psychological detection of pathogen cues to behavioral avoidance motivation. In line with our other results, behavioral avoidance of pathogens may be more reactive to one's perceived vulnerability to infection, compared to general health. This suggests that an individual may change their disease avoidance strategies only when their health is impacted by infection, compared to a general decline in health. Overall, the mediation results imply that the BIS is reactive specifically to pathogen threats and one's vulnerability; thus, we may not see similar shifts in behavior to avoid non-pathogenic health threats. Future work should investigate these differences in behavioral motivation towards infectious versus non-infectious threats.

While we included all domains of disgust to account for shared variance in our statistical model, pathogen disgust sensitivity provides the most consistent connection to individual health. This aligns with previous work on the BIS, as well as common sense notions of the utility of pathogen disgust sensitivity, which is the domain of disgust on the TDDS that most transparently mitigates pathogen risk (e.g., the inclination to sit next to someone who has red sores on their arm; Tybur et al., 2009). sIgA only significantly predicted pathogen, but not sexual or moral disgust sensitivity. This finding suggests that pathogen disgust sensitivity may therefore be unique among the three domains in its association with mucosal immunity – although more research is needed to replicate this finding.

While perceived general health and perceived infectibility are significantly correlated, neither variable significantly correlates with sIgA, in line with previous

research (Cai et al., 2019). Future research should further assess the relationship between immunity, perceived infectibility, and pathogen avoidance motivation, as much of the current literature focuses on inflammation in relation to pathogen avoidance psychology (Bradshaw et al., 2022; Cepon-Robins et al., 2021; Gassen et al., 2019). It is also possible that disgust sensitivity is more reactive to perception (Galperin et al., 2013; Kecinski et al., 2016), as is inflammation (Bradshaw et al., 2022). Throughout our evolutionary history, it would have been more advantageous to overreact than underreact to pathogen threat. Error management theory proposes that overestimation can occur in many domains of cognition (e.g., men's overestimation of women's sexual interest and women's underestimation of men's interest; Haselton & Buss, 2000). In the case of dangerous pathogenic stimuli, individuals may perceive stimuli as more perilous.

Limitations and Future Directions

There are several limitations of the present research that suggest avenues for future research. First, sIgA is not a comprehensive measure of immune system vulnerability. Previous researchers have suggested that sIgA should be conceptualized as a measure of mucosal immunocompetence (Stone et al., 1987) or oral health (Golpasand Hagh et al., 2013; Gornowicz et al., 2014; Koss et al., 2016; Rashkova & Toncheva, 2010; Thaweboon et al., 2008), rather than general health or overall immunocompetence. Therefore, other measures of anti-bodies and immunity should be studied in conjunction with self-reported or perceived health in the future. In future investigations, researchers should examine the influence of health on disgust using multiple disparate measures of immunity, such as inflammatory markers (Cepon-Robins et al., 2021; Gassen et al., 2018; Gassen & Hill, 2019), C-reactive protein (Blackwell et al., 2010; McDade et al., 2005), and immunoglobulin E (Blackwell et al., 2010), to create a more inclusive profile of an individual's current immune state. Additionally, future research should examine reverse causality by testing if priming disgust decreases sIgA (Stevenson et al., 2011).

In addition, future studies should consider controlling for additional variables beyond sex and age. For example, it is possible that socioeconomic status is a confound; that is, people with high social and/or economic status may perceive themselves as healthier or actually be healthier—possibly through greater access to healthcare and higher quality resources (Sapolsky, 2004). Previous research suggests that disgust may sometimes be a signal of status, with higher status people displaying higher disgust; that is, wealthier people can afford to be choosier (Bradshaw et al., 2022; Cepon-Robins et al., 2021; Conway et al., 1999; Knutson, 1996; Rottman et al., 2018; Steckler & Tracy, 2014). Finally, replicating our Study 1 findings with larger samples will be key given the sample size was smaller. Moreover, while a while 14 was not a count low enough to preclude us from including sex as a covariate in Study 1, and precision appeared sufficient (i.e., sex had significant effects), the number of women limits generalizability and future research should attempt to replicate our findings using more balanced samples.

Conclusion

In line with our predictions, mucosal immunity, measured by sIgA, negatively predicted pathogen disgust sensitivity, and perceived infectibility consistently predicted pathogen disgust sensitivity. Specifically, as perceived infectibility increases, pathogen disgust sensitivity increases. These findings contribute to the growing literature exploring how and why individuals vary in disgust sensitivity. While environment and cultural context can influence disgust sensitivity (e.g., Batres & Perrett, 2020; Hlay et al., 2021; Prokop et al., 2011; Reid et al., 2012; Skolnick & Dzokoto, 2013; Tybur et al., 2016), our results highlight that individual variation in health is also a significant predictor, such that disgust sensitivity is influenced by one's perceived heath and mucosal immunity. Future work can build on these results by using additional measures of health (e.g., objective health biomarkers, including disparate and complimentary indicators of immune function) to explore individual variation in disgust sensitivities, as well as predict resulting pathogen avoidant behaviors and assess their success in the reduction of infection exposure.

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Author Contributions JKH conceptualized the study, collected data for Sample 2, ran statistics, and wrote and edited the manuscript. GA collected data for Sample 1, ran statistics, and edited the manuscript. CB aided in data collection and edited the manuscript. GR ran statistics, provided funding, and edited the manuscript. NL ran laboratory saliva analyses. ADB edited the manuscript. CRH-S aided in conceptualizing the study, provided funding, and edited the manuscript.

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Data Availability Data from this study is not yet publicly available.

Declarations

Ethical Approval Ethical approval for this study was provided by the Boston University Institutional Review Board (IRB #5216X).

Conflict of Interest The authors declared that they have no conflict of interest.

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