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ORIGINAL PAPER

Disgust systematically tracks relative level of pathogen threat, not just presence or absence of pathogens

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Abstract

Disgust is a protective emotion that coordinates a suite of cognitive and behavioral changes to reduce people's likelihood of infection. Existing research demonstrates that people react with disgust to pathogenic stimuli compared to non-pathogenic stimuli, but there has been a paucity of research examining whether people are equipped with a more finely graded disgust response: do people discriminate between pathogen threats of different magnitudes and react with more disgust toward pathogen threats of a greater magnitude? We derived multiple novel predictions from the *Threat-Dependent Disgust hypothesis* and tested them across three experiments involving participants from the United States and India (total $n=1,333$). In Study 1 ($n=428$), we tested the prediction that people would be more disgusted by a pathogen threat touching their hand relative to their foot, given that touching a pathogen with the hand is more likely to result in the pathogen entering the body envelope (e.g., through the mouth). In Study 2 ($n=453$), we tested the prediction that people would be more disgusted by a pathogen threat touching *another* person's hand relative to another person's foot; people touch others more with their hands than with their feet, so a conspecific with a contaminated hand poses a greater disease threat than one with a pathogen on their foot. In Study 3 ($n=452$), we tested the prediction that people would be more disgusted by skin wounds caused by pathogenic infections than by surgical incisions; although both wounds pose the risk of exposure to another's bodily fluids, wounds caused by pathogenic infections pose a greater disease threat. Results across all three experiments suggest that disgust is sensitive to the magnitude of pathogen threat in a more finely tuned manner than previously demonstrated. Discussion focuses on interpretation of this gradient-like sensitivity of disgust, incorporating these findings into the broader disgust literature, and future directions.

Keywords Disgust · Emotion · Pathogen threat · Behavioral immune system · Disease avoidance · Evolved psychological mechanism

Disgust is hypothesized to be an evolved defense against the many pathogens living in the world alongside people and other animals (Curtis et al., 2004; Curtis, 2013; Curtis & Barra, 2018; Ryan et al., 2012; Tybur et al., 2013). On this view, disgust helps organisms avoid stimuli exhibiting cues to the presence of pathogens, thereby reducing the likelihood of infection (Al-Shawaf & Lewis, 2013; Al-Shawaf et al., 2015; 2016; 2018a; 2018b; Curtis & Biran, 2001; Curtis, 2013; Tybur et al., 2013). Research demonstrates that disgust is a species-typical emotion that coordinates a variety of communicative (e.g., changes in facial expressions), physiological (e.g., lower heart rate, higher skin conductivity; Stark et al., 2005), and psychological responses (e.g., appetite, attention, and more; Al-Shawaf et al., 2015; Curtis, 2013; Tybur et al., 2013, 2013; White et al., 2023). People experience disgust in response to a variety

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of different stimuli (e.g., feces, open wounds, rotten food, bodily fluids, poor hygiene) that harbor pathogens and pose an infection risk (Curtis, 2013; Curtis & Barra, 2018; Curtis & Biran, 2001; Tybur et al., 2013). Consistent with this pathogen avoidance theory of disgust, Curtis et al. (2004) tested people's disgust responses in 165 countries and found that people were more disgusted by images of infectious stimuli (e.g., an open wound) than by images of non-infectious stimuli (e.g., a healed wound).

The threat-dependent disgust hypothesis

Existing studies demonstrate that people respond with greater disgust to infectious stimuli than non-infectious stimuli (e.g., Curtis et al., 2004; van Leeuwen & Jaeger, 2022), but little research has tested whether, among potentially infectious stimuli, people's disgust responses systematically track the relative level of infection threat (cf. Stark et al., 2005). In existing models of disgust, (1) perceptual systems detect stimuli that cue the presence of pathogens, (2) computational processes integrate contextual cues to estimate the probabilistic costs and benefits of avoiding the stimulus, and (3) these computations produce an internal regulatory variable: the expected value of consumption or contact, and this drives avoidance or approach behavior (Lieberman et al., 2018; Tybur et al., 2013). These models are very informative and valuable, and they have led to numerous new discoveries about disgust (e.g., Al-Shawaf et al., 2018a; van Leeuwen & Jaeger, 2022; van Leeuwen et al., 2023; Tybur et al., 2016). However, these models do not suggest that the information-processing architecture includes an assessment of the level of pathogen threat; they only specify that the system is designed to assess the probabilistic presence of a pathogen threat. Assessing and responding to the relative level of threat, not merely presence or absence of threat, is likely to be key for adaptive decision making.

We should expect selection to have shaped the disgust system to operate in this more finely tuned manner. Experiencing disgust poses costs, such as when it motivates avoidance of nutritious food or of a person with whom we might otherwise have a valuable social relationship (see Al-Shawaf et al., 2016; Tybur et al., 2013). To avoid unnecessarily incurring these costs, selection should have shaped the disgust system to only activate when adaptive, and to an adaptive *degree*. In short, we expect the disgust system to respond differentially not only to threats vs. non-threats, but also to greater threats compared to lesser threats. We refer to this as the *Threat-Dependent Disgust (TDD) hypothesis.*

The current studies

Here, we derived different predictions from the TDD hypothesis and tested them across three studies investigating whether people react with more disgust toward greater pathogen threats and less disgust toward lower pathogen threats. Each of these studies included a sample from the United States and a sample from a non-W.E.I.R.D. (Henrich et al., 2010) population (India).

Study 1: My hand vs. my foot vs. the leg of a chair

The face houses multiple entry points for pathogens and parasites to enter the body, such as the nose and mouth (Rozin et al., 2008; Tybur et al., 2013). This makes the face a particularly vulnerable location in need of extra protection. The Threat-Dependent Disgust hypothesis suggests that people should therefore experience a stronger disgust response to infection risks with greater chances of coming into contact with the face (and therefore greater likelihood of entering the body) compared to those with a lower likelihood of coming into contact with the face. For example, because there is greater distance from the feet to the face than from the hands to the face, and people more commonly touch their face with their hands than with their feet, a harmful microorganism on a person's hand is more likely to come into contact with that person's face than the exact same microorganism on that person's foot. This suggests that the exact same pathogenic stimulus poses a greater infection risk for a person when it is located on that person's hand compared to their foot. The TDD hypothesis therefore generates the prediction that people will respond with disgust when *either* their hand or foot come into contact with a pathogen, but will respond with *greater* disgust to their hand coming into contact with a pathogen than to their foot coming into contact with that same pathogen. Study 1 tested this prediction in samples from the United States and India.

Study 1 method

Participants

We sought to attain a sample large enough to detect a small-to-medium effect using a mixed-model ANOVA. An a priori power analysis showed that 204 participants were needed to detect an estimated effect (*F*) size between small and medium. Four hundred twenty-eight participants: 210 (112 women, 98 men) Amazon Mechanical Turk workers (M_{age} = 39.26, SD = 12.04) living in the United States of America and

218 (76 women, 142 men) Amazon Mechanical Turk workers (M_{age} = 33.82, $SD = 7.20$) living in India participated in Study 1. All participants were fluent in English and compensated for their participation. The study was approved by the Institutional Review Board at the University of Colorado, Colorado Springs and all participants provided informed consent prior to their participation.

Materials and procedure

Participants signed up to participate through MTurk, where they completed a Qualtrics survey about "Emotional Responses to Different Items." After providing informed consent, participants viewed images of potential pathogen vectors (i.e., vomit, feces, an oozing wound, a cockroach, and rotten food). Each image was accompanied by instructions asking participants to imagine the depicted substance in one of three conditions: the substance touched their hand (high infection threat), the substance touched their foot (intermediate infection threat), or the substance touched the leg of a nearby chair (low infection threat). Each image was presented to each participant in all three conditions, resulting in 15 trials total. The trials were presented in random order, with randomization occurring anew for each participant; some participants were presented with a trial from the low infection threat first, others were presented with a trial from the intermediate infection threat first, and still others were presented with a trial from the high infection threat first. For each trial, participants rated how disgusting (1 = *not at all disgusting*; 7 = *extremely disgusting*) it would be for the substance to touch the indicated object (i.e., their hand, their foot, or the leg of a nearby chair). After completing the 15 trials, participants answered demographic questions and were debriefed.

Study 1 results

The TDD hypothesis leads to the key predictions that participants will report greater disgust in response to (1) high pathogen threats relative to intermediate threats and (2) intermediate threats relative to low threats. To test these predictions, we conducted a 2 (culture) × 3 (infection risk) mixed-model ANOVA with disgust ratings entered as the dependent variable. There was a significant main effect of infection threat on magnitude of disgust, $F(1.34$[1], $569) = 128.66$, $p < .001$, $\eta_p^2 = 0.23$. This overall main effect was underpinned by precisely the pairwise effects predicted by the TDD hypothesis: post hoc comparisons indicated that participants rated the high threat condition ($M = 5.82$, $SD = 0.95$) as significantly more disgusting ($p < .001$) than the intermediate threat condition ($M = 5.71$, $SD = 0.99$), which they rated as significantly more disgusting ($p < .001$) than the low threat condition ($M = 5.23$, $SD = 1.20$).

Although the TDD hypothesis does not generate a priori predictions about any effects of culture (and these effects therefore have no bearing on the hypothesis), we nonetheless report the relevant effects below as part of the complete reporting of the mixed-model ANOVA. The main effect for culture was not significant, $F(1, 426) = 0.65$, $p = .437$, $\eta_p^2 = 0.00$. There was a significant interaction between culture and infection threat levels, $F(1.34^{\dagger}, 569) = 16.01$, $p < .001$, $\eta_p^2 = 0.04$): Participants from the United States reported significantly higher disgust ratings than participants from India in the high infection condition ($p = .019$), but not in the low ($p = .111$) or intermediate ($p = .055$) infection threat conditions (Fig. 1).

Study 2: Another person's hand vs. their foot vs. the leg of their chair

In Study 2, we further tested the prediction that people will exhibit stronger disgust responses to greater infection risks compared to lower infection risks by examining disgust responses to a potential infection threat on *someone else.* People more commonly touch objects—*and other people*—with their hands than with their feet. This means that pathogens on a person's hand are more likely to be transmitted to other people than the same pathogens on a person's foot. In other words, the same pathogenic stimulus poses a greater infection risk when it is on another person's hand compared to when it is on another person's feet. The Threat-Dependent Disgust hypothesis therefore generates the prediction that people will exhibit disgust in response to pathogens on another person's hand and on another person's foot, but that people will exhibit *greater* disgust in response to pathogens on another person's hand than the same pathogens on that person's foot. Study 2 tested this prediction in samples from the United States and India.

Study 2 method

Participants

An a priori power analysis was conducted using the same parameters as Study 1. Four hundred fifty-three participants: 228 (180 women; 48 men) undergraduate students (M_{age} = 21.57, $SD = 5.03$) living in the United States of America and 225 (66 women; 159 men) Amazon Mechanical Turk

[1] Mauchly's test of sphericity was significant. This suggests the error covariance matrix is not proportional to an identity matrix. Therefore, the Greenhouse-Geisser adjustment of degrees of freedom was performed. Subsequent Greenhouse-Geisser adjustments are indicated with a "†" symbol.

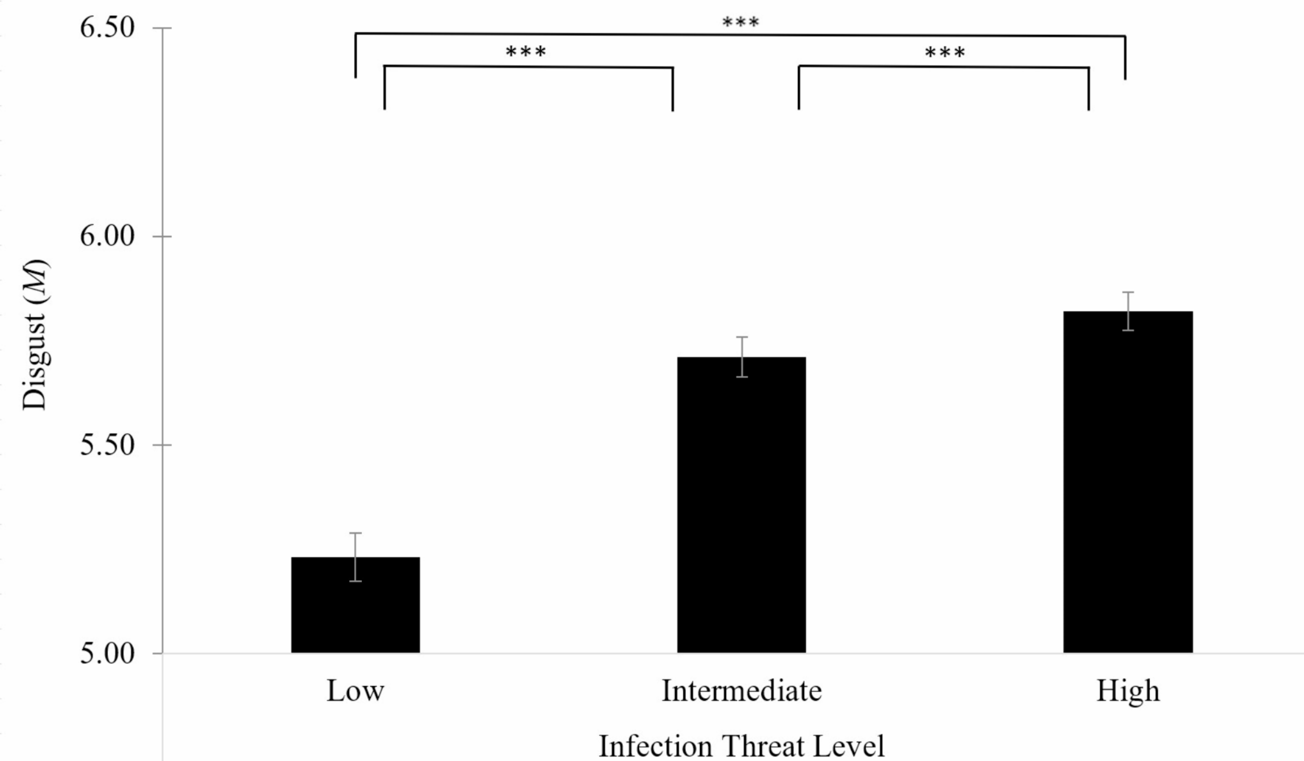

Fig. 1 Disgust as a Function of Relative Threat: 1st-Person Exposure. Note *** $p<.001$. Disgust was measured on a scale ranging from 1 (*not at all disgusting*) to 7 (*extremely disgusting*). Error bars indicate standard error. Figures displaying all individual data points are available in the supplementary materials

workers (M_{age} = 32.40, $SD=6.32$) living in India participated in Study 2. All participants were fluent in English. Undergraduate students were offered extra credit and MTurk workers were compensated for their participation. The study was approved by the Institutional Review Board at the University of Colorado, Colorado Springs and all participants provided informed consent prior to their participation.

Materials and procedure

Participants completed a Qualtrics survey about "Emotional Responses to Different Items." After providing informed consent, participants completed a task parallel to that described in Study 1. However, rather than participants being asked to imagine the depicted stimuli coming into contact with their hand, their foot, or the leg of a chair, participants were shown an image of a person sitting in a chair alongside each of the five stimuli and were asked to imagine the stimuli touching the hand of *the person in the image* (high infection threat), the person's foot (intermediate infection threat), or the leg of the chair that the person was sitting on (low infection threat). Each image was presented to each participant in all three conditions, resulting in 15 trials total. Trials were completely randomized, as in Study 1. Participants rated how disgusting it would be for the substance to touch the described body part or object (person's hand, person's foot, leg of chair) on a 7-point Likert type scale (1 = *not at all disgusting*; 7 = *extremely disgusting*). Participants then answered demographic questions and were debriefed.

Study 2 results

As in Study 1, we conducted a 2 (culture) × 3 (infection risk) mixed-model ANOVA with disgust ratings as the dependent variable. Again, we observed a significant main effect for infection threat level, $F(1.47^{\dagger}, 664)=472.47$, $p<.001$, $\eta p^2=0.51$ that was underpinned by the key effects predicted by the TDD hypothesis: post hoc comparisons revealed that participants rated the high threat condition ($M=5.54$, $SD=1.04$) as significantly more disgusting ($p<.001$) than the intermediate threat condition ($M=5.37$, $SD=1.03$), which they rated as significantly more disgusting ($p<.001$) than the low threat condition ($M=4.48$, $SD=1.51$).

Although the TDD hypothesis does not yield predictions regarding the effects of culture on disgust, we nonetheless report the relevant effects as part of the complete reporting of the mixed-model ANOVA. The main effect for culture was significant, $F(1, 451)=25.76$, $p<.001$, $\eta p^2=0.05$, which reflected participants from the United States ($M=4.89$, $SD=1.21$) reporting significantly less ($p<.001$) disgust than participants from India (M = 5.38, SD = 1.02). The interaction between culture and infection threat levels was also significant, $F(1.47^{\dagger}, 664) = 325.14$, $p < .001$, $\eta p^2 = 0.42$); participants from the United States reported lower disgust than participants from India in the low ($p < .001$) but not intermediate ($p = .510$) or high ($p = .120$) threat conditions (Fig. 2).

Study 3: Differentiating between different types of wounds

A wound may have various causes, ranging from a contagious disease to a run-in with a sharp object. Any wound on another person poses the threat of infection risk to oneself, as the wound creates a medium by which one could be exposed to another's potentially pathogenic bodily fluids. However, a wound on another person that is the result of a pathogenic infection poses a more severe infection threat than a wound resulting from an injury or surgical incision; the former poses the same threats as the latter *plus* the threat of the disease that caused the wound. Moreover, a wound resulting from pathogenic infection necessarily means that the person has an infectious disease, whereas a wound resulting from an injury does not. The Threat-Dependent Disgust hypothesis therefore predicts that people will react with disgust toward both types of breaks in the skin, but will respond with greater disgust toward those caused by pathogenic infection than those caused by a sharp object. In Study 3, we tested this prediction using samples from the United States and India.

Study 3 Method

Participants

An a priori power analysis was conducted using the same parameters as Study 1. Four hundred fifty-two participants: 217 (108 women; 109 men) Amazon Mechanical Turk workers (M_{age} = 39.76, SD = 12.13) living in the United States of America and 235 (58 women; 177 men) Amazon Mechanical Turk workers (M_{age} = 31.46, SD = 6.21) living in India participated in Study 3. All participants were fluent in English and were compensated for their participation. This study was approved by the Institutional Review Board at the University of Colorado, Colorado Springs and all participants provided informed consent prior to their participation.

Materials and Procedure

Participants completed a Qualtrics survey about "Emotional Responses to Different Images." After providing informed

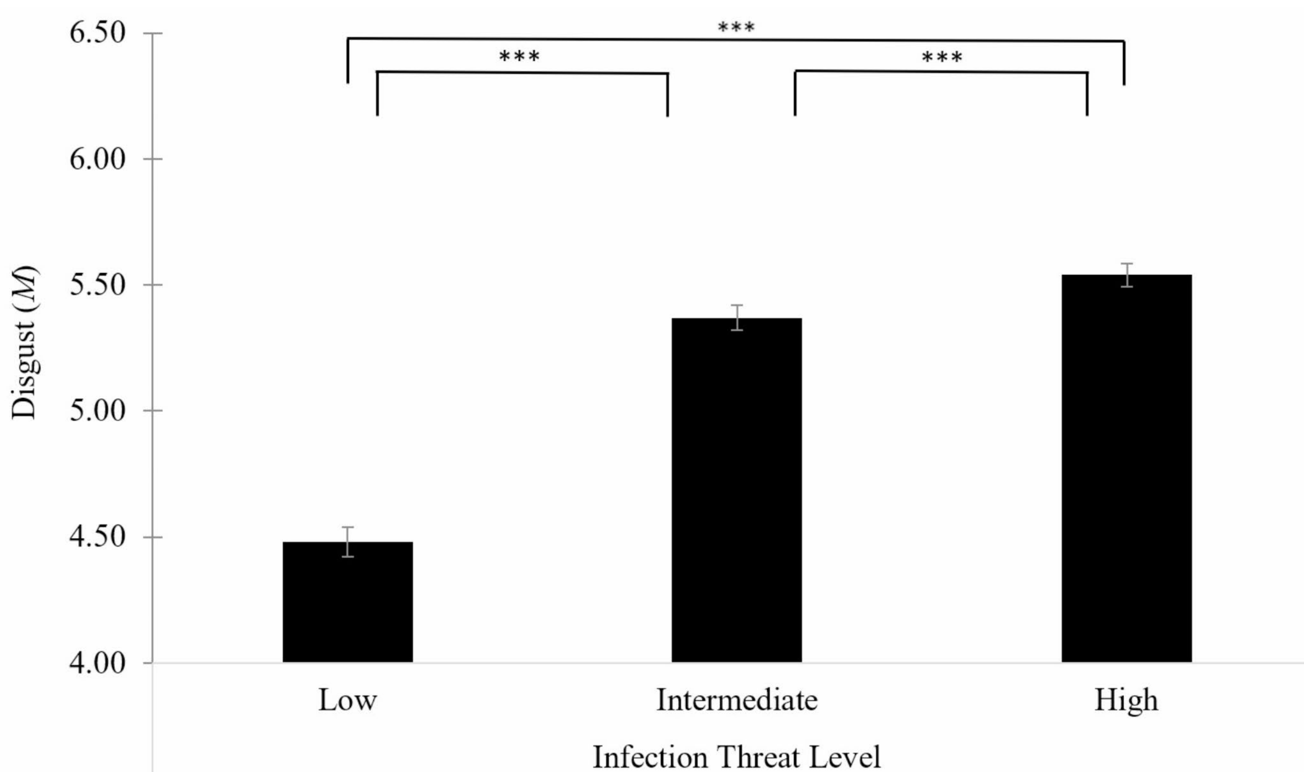

Fig. 2 Disgust as a Function of Relative Threat: 3rd-Party Exposure. Note *** $p < .001$. Disgust was measured on a scale ranging from 1 (*not at all disgusting*) to 7 (*extremely disgusting*). Error bars indicate standard error. Figures displaying all individual data points are available in the supplementary materials

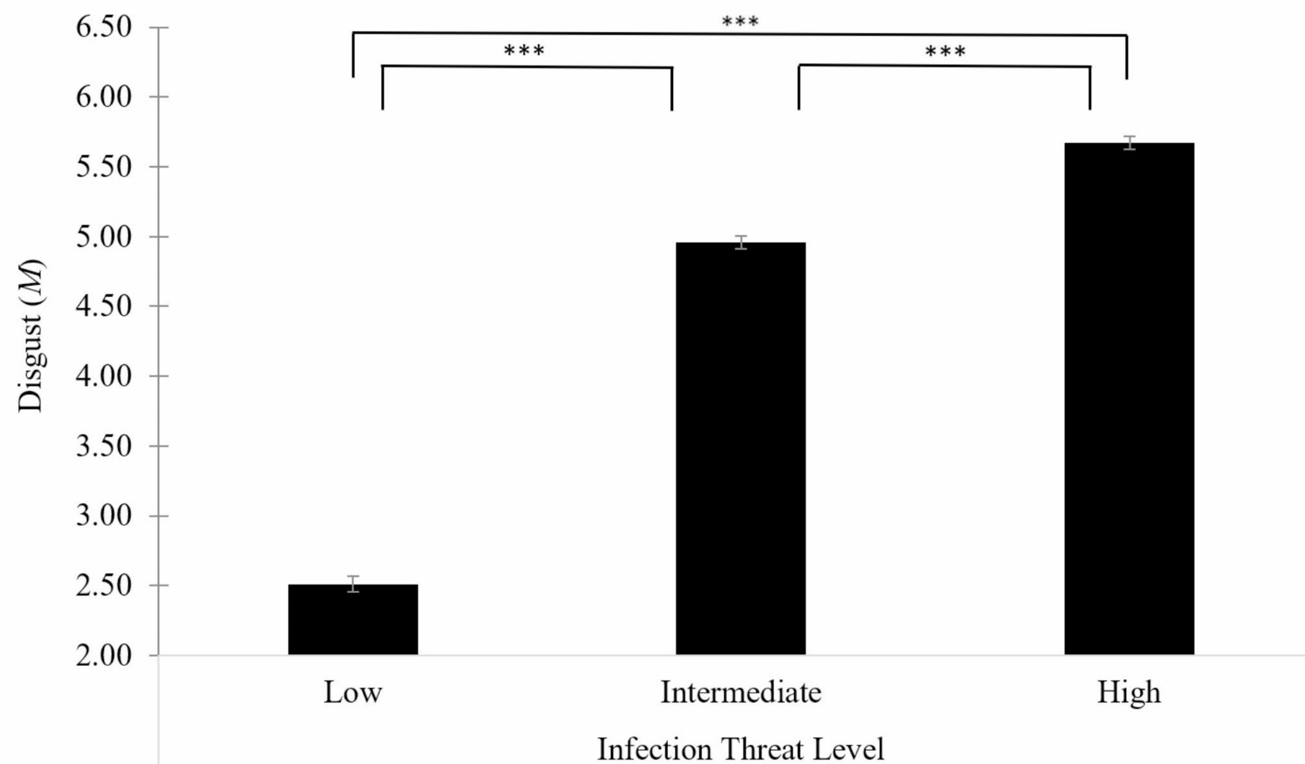

Fig. 3 Disgust as a function of relative threat: varying wound types. Note *** $p<.001$. Disgust was measured on a scale ranging from from 1 (*not at all disgusting*) to 7 (*extremely disgusting*). Error bars indicate standard error. Figures displaying all individual data points are available in the supplementary materials

consent, participants viewed a series of five images of skin sores caused by diseases or parasites (i.e., high infection threat), five images of surgical incisions (i.e., intermediate infection threat), and five images of healthy skin without sores or cuts (i.e., low infection threat). The wounds were approximately the same size across all images containing sores and cuts. The images were zoomed in or cropped so that the bodily location of the skin patch was not apparent, and the size of the lesion was held constant. Each participant viewed these images in a random order, with order of presentation randomized anew for each participant. After seeing each image, participants rated how disgusting they were on a 7-point Likert-type scale (1 = *not at all disgusting*; 7 = *extremely disgusting*). Participants then answered demographic questions and were debriefed.

Study 3 results

As in Studies 1 and 2, we conducted a 2 (culture) × 3 (infection risk) mixed-model ANOVA with disgust ratings as the dependent variable. Once again, we observed a significant main effect of infection threat level, $F(1.38^{\dagger}, 622)=815.37$, $p<.001$, $\eta p^2=0.64$, which was underpinned by the key results predicted by the TDD hypothesis: post hoc comparisons revealed that participants rated the high threat condition ($M=5.67$, $SD=1.13$) as significantly more disgusting ($p<.001$) than the intermediate threat condition ($M=4.96$, $SD=1.34$), which they rated as significantly more disgusting ($p<.001$) than the low threat condition ($M=2.51$, $SD=1.74$).

Regarding the effects of culture – about which the TDD hypothesis does not yield any specific predictions – there was a main effect of culture, $F(1, 450)=19.86$, $p<.001$, $\eta p^2=0.04$; participants from the United States ($M=4.17$, $SD=1.47$) reported significantly less ($p<.001$) disgust than participants from India ($M=4.58$, $SD=1.28$). The interaction between culture and infection threat levels was also significant, $F(1.38^{\dagger}, 622)=9.98$, $p<.001$, $\eta p^2=0.02$). Participants from the United States reported significantly lower disgust than participants from India in the low and intermediate threat conditions (both ps $<.001$) but not in the high threat condition ($p=.898$) (Fig. 3).

General discussion

We tested the Threat-Dependent Disgust (TDD) hypothesis across three studies, each of which included samples from the United States and India. In all three studies, we found that people were more disgusted by high infection threats than by intermediate infection threats, and were in turn more disgusted by intermediate infection threats than by low infection threats.

Specifically, in Study 1, we found that people were more disgusted by pathogens on their hand than the same pathogens on their feet, which they in turn found more disgusting than the same pathogens on the leg of a chair. In Study 2, we found that the same pattern applied to pathogens on other people – that is, participants found pathogens on another person's hand to be more disgusting than the same pathogens on that person's foot, which they in turn found to be more disgusting than the same pathogens on the leg of that person's chair. In Study 3, we found that people were more disgusted by wounds caused by disease than similarly sized wounds caused by surgical incision, which they in turn found more disgusting than normal skin with no wounds. Notably, all of the findings across all three studies supported the Threat-Dependent Disgust hypothesis.

Prior research has primarily demonstrated that pathogenic stimuli elicit more disgust than non-pathogenic stimuli (e.g., Curtis et al., 2004; cf. Stark et al., 2005). The current studies systematically demonstrate that people respond differentially not only to threats vs. non-threats, but also to threats of greater magnitude compared to threats of lesser magnitude (see also Prokop et al., 2023). This more fine-grained, non-binary response is key because it enables an organism to calibrate its degree of disgust and behavioral avoidance to the level of threat, thereby avoiding the costs of insufficient or excessive disgust. The current results contribute to the existing literature on disgust by providing evidence that the disgust system assesses and responds to the threat level of an infection risk in a more fine-grained manner than has been previously demonstrated.

We would like to be clear about what we are and are not suggesting. We are not claiming that the level of expressed disgust will *always* correspond precisely to the relative level of pathogen threat. There are many contexts in which this correspondence will not be true, and many reasons why such a pattern will not always hold. One reason is that disgust needs to be downregulated or suppressed in certain instances even when there is an objective pathogen threat; for example, when caring for one's offspring (e.g., Al-Shawaf et al., 2016; Case et al., 2006). Similarly, disgust and behavioral avoidance may be downregulated toward people high in social value to us, including those high in social status or who are our friends (e.g., Al-Shawaf et al., 2019; Tybur et al., 2020). Second, some objective pathogen threats do not contain cues observable to the human eye (e.g., Norton et al., 2021), and in such cases we would not expect disgust to systematically track threat level. Relatedly, the *dose* of the pathogen may predict the degree of threat posed, but in many cases, there won't be enough—or any—observable cues to distinguish different doses with the naked eye. Third, as per Error Management Theory (Haselton & Nettle, 2006), disgust is expected to be overinclusive and triggered by *non*-pathogenic stimuli that exhibit cues that overlap with pathogenic stimuli (Al-Shawaf et al., 2018; Kupfer & Le, 2018; Park et al., 2003). Fourth, even if disgust systematically tracks relative threat level in many cases, this does not mean the relationship between threat level and disgust will be linear; there may be threshold effects such that extremely low threat levels do not activate any disgust response, ceiling effects such that extremely high threat levels do not activate greater disgust than high threat levels, or other sources of non-linearity in the relationship between disgust and threat level. For all of these reasons, we do not expect that the level of expressed disgust will always correspond precisely to the relative level of pathogen threat.

However, these caveats notwithstanding, we still expect disgust to track relative threat level in many situations. In particular, we expect disgust to respond in this manner rather than acting like a binary on/off switch that simply turns on in the presence of pathogens and off in their absence. To our knowledge, this is the first set of studies to show that disgust does indeed appear to track relative threat level in a systematic way, at least across the three levels we tested here (low, intermediate, and high pathogen threat). This opens the door to future studies that can further investigate how fine-grained this response is, as well as what boundary conditions and threshold effects it may be subject to.

Operationalizing threat level

In crafting the three studies presented here, we encountered questions about how best to manipulate the level of pathogen threat. Here, we discuss various potential operationalizations of threat level, along with their respective advantages and disadvantages.

One possible way to operationalize threat level is to use different amounts of the same disease vector. However, it is difficult to determine the relative risk of a disease vector based on its quantity. For example, one cannot safely infer that 10 g of feces poses a threat that is exactly two times greater in magnitude than that posed by 5 g of feces. This may be one reason why prior research suggests contagion beliefs are "dose-insensitive", such that people exhibit a strong aversion toward objects that have only briefly come into contact with a contaminant, and that this response does not appear to increase with more exposure (Apicella et al., 2018; Rottman & Young, 2019; Rozin & Nemeroff, 1990; 1995).

A second possibility is to manipulate the likelihood that a disease vector will enter the body. This is the approach we employed in Studies 1 and 2. This method provides a reliable means of varying the *relative* level of threat, as threat systematically increases with the probability that pathogens will enter the body.

A third option is to use different disease vectors that pose varying levels of threat, which is the approach we employed in Study 3. However, this approach may only be valid for a certain subset of disease vectors; in some cases, it may be very difficult to confidently ascertain the relative threat level posed by different disease vectors. For example, do feces on one's hand pose a greater threat than a cockroach on one's hand, or vice versa? The answer to this question is unclear and likely depends on a variety of factors, such as the specific type of pathogens that these vectors harbor, a variable that may not be linked with any noticeable cues to the human observer. However, although one cannot readily determine the relative risk of feces vs. cockroach (for example), one *can* confidently assert that the threat posed by skin wounds caused by infectious disease is greater than the threat posed by wounds caused by surgical incision (all else equal). This is because the infection-caused wound—which contains visible cues—poses the same threat as the incision-caused wound (exposure to the wounded person's bodily fluids) *plus* the threat of the disease that caused the wound in the first place.

A fourth possibility is to vary other features of the same disease vector that are statistically reliably correlated with different relative levels of threat while holding constant features such as mass and likelihood of entering the body. For instance, foods and other organic compounds contain discernable cues of increasing bacterial load as they progress through different stages of decomposition. These cues may indicate increasing relative levels of threat. Research that examines how disgust responses vary as a function of these cues is an important line of inquiry for future research.

The foregoing considerations point toward two key points. First, it is challenging to operationalize the level of pathogen threat with precision, and disgust researchers must therefore be careful in the operationalizations we employ. A second crucial point is that it in research like the current studies, it is not necessary to know the *absolute* degree of pathogen threat; to validly test the central hypothesis of a threat-dependent disgust response, what is critical is to know the *relative* degree of threat.

Even so, a possible line of future inquiry would be to come up with novel ways of testing the threat-dependent disgust hypothesis while assessing both the absolute and relative degree of pathogen threat as well as measuring participants' perception of the degree of threat. This could inform our understanding of the precise relationships between absolute, relative, and perceived levels of threat.

Limitations, future directions, and conclusion

Our studies were limited in several ways. First, we included only three levels of pathogen threat in each study (low, intermediate, and high). Future researchers may wish to test the TDD hypothesis with more than three levels of pathogen threat to investigate precisely how finely grained the disgust response is. A related issue is that it is unclear exactly what shape we should expect this relationship to take. It may be linear across multiple levels of threat, or there may be threshold effects, ceiling effects, or other forms of nonlinearity at different levels of pathogen threat. This is worth investigating in future research.

Second, the exact magnitude of pathogen threat present in the current studies' stimuli was not directly measured and cannot be known. However, for reasons discussed above, we suggest that it is *relative* threat level, not absolute threat level, that is the key variable of interest—and relative threat level can indeed be ascertained (e.g., feces on one's hand poses a greater threat than feces on the leg of a nearby chair).

Third, these studies may be limited by sampling and cultural biases. Although we recruited participants through different platforms (MTurk and undergraduates at the University of Colorado, Colorado Springs) and from different cultures, we only obtained samples from two countries (the United States and India). Future research would do well to test the threat-dependent disgust hypothesis in a more global context.

Nonetheless, the current studies are important as a proof of concept for threat-dependent disgust: the current studies are the first to demonstrate, in any culture, that the magnitude of the disgust response systematically tracks relative threat level. These novel findings suggest that, as hypothesized, the disgust system discriminates between differing degrees of infection threat and responds in a more fine-grained fashion than research has previously demonstrated.

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Data availability All data are available upon request.

Declarations

Conflicting interests The authors declare that there is no conflict of interest.

References

Al-Shawaf, L., & Lewis, D. M. G. (2013). Exposed intestines and contaminated cooks: Sex, stress, & satiation predict disgust sensitivity. *Personality and Individual Differences*, *54*, 698–702.

Al-Shawaf, L., Lewis, D. M. G., & Buss, D. M. (2015). Disgust and mating strategy. *Evolution and Human Behavior*, *36*(3), 199–205.

Al-Shawaf, L., Conroy-Beam, D., Asao, K., & Buss, D. M. (2016). Human emotions: An evolutionary psychological perspective. *Emotion Review*, *8*(2), 173–186. https://doi.org/10.1177/1754073914565518

Al-Shawaf, L., Lewis, D. M. G., & Buss, D. M. (2018a). Sex differences in disgust: Why are women more easily disgusted than men? *Emotion Review*, *10*(2), 149–160. https://doi.org/10.1177/1754073917709940

Al-Shawaf, L., Lewis, D. M. G., Ghossainy, M. E., & Buss, D. M. (2018b). Experimentally inducing disgust reduces desire for short-term mating. *Evolutionary Psychological Science*, *5*, 267–275.

Al-Shawaf, L., Lewis, D. M., Wehbe, Y. S., & Buss, D. M. (2019). Context, environment, and learning in evolutionary psychology. In Encyclopedia of evolutionary psychological.

Apicella, C. L., Rozin, P., Busch, J. T. A., Watson-Jones, R. E., & Legare, C. H. (2018). Evidence from hunter-gatherer and subsistence agricultural populations for the universality of contagion sensitivity. *Evolution and Human Behavior*, *39*(3), 355–363. https://doi.org/10.1016/j.evolhumbehav.2018.03.003

Case, T. I., Repacholi, B. M., & Stevenson, R. J. (2006). My baby doesn't smell as bad as yours. *Evolution and Human Behavior*, *27*(5), 357–365. https://doi.org/10.1016/j.evolhumbehav.2006.03.003

Curtis, V. (2013). *Don't look, don't touch, don't eat: The science behind revulsion*. The University of Chicago Press. https://doi.org/10.7208/chicago/9780226089102.001.0001

Curtis, V., & Barra, M. (2018). The structure and function of pathogen disgust. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*, 20170208. https://doi.org/10.1098/rstb.2017.0208

Curtis, V., & Biran, A. (2001). Dirt, disgust and disease: Is hygiene in our genes? *Perspectives in Biology and Medicine*, *44*(1), 17–31. https://doi.org/10.1353/pbm.2001.0001

Curtis, V., Aunger, R., & Rabie, T. (2004). Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society B: Biological Sciences*, *271*(4), 131–133. https://doi.org/10.1098/rsbl.2003.0144

Haselton, M. G., & Nettle, D. (2006). The paranoid optimist: An integrative evolutionary model of cognitive biases. *Personality and Social Psychology Review*, *10*(1), 47–66. https://doi.org/10.1207/s15327957pspr1001_3

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world? *Behavioral and Brain Sciences*, *33*, 61–135. https://doi.org/10.1017/S0140525X0999152X

Kupfer, T. R., & Le, A. T. D. (2018). Disgusting clusters: Trypophobia as an overgeneralised disease avoidance response. *Cognition and Emotion*, *32*(4), 729–741. https://doi.org/10.1080/02699931.2017.1345721

Lieberman, D., Billingsley, J., & Patrick, C. (2018). Consumption, contact and copulation: How pathogens have shaped human psychological adaptations. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1751), 20170203. https://doi.org/10.1098/rstb.2017.0203

Norton, J. O., Evans, K. C., Semchenko, A. Y., Al-Shawaf, L., & Lewis, D. M. G. (2021). Why do people (not) engage in social distancing? Proximate and ultimate analyses of norm-following during the COVID-19 pandemic. *Frontiers in Psychology*, *12*, 648206. https://doi.org/10.3389/fpsyg.2021.648206

Park, J. H., Faulkner, J., & Schaller, M. (2003). Evolved disease-avoidance processes and contemporary anti-social behavior: Prejudicial attitudes and avoidance of people with physical disabilities. *Journal of Nonverbal Behavior*, *27*(2), 65–87. https://doi.org/10.1023/A:1023910408854

Prokop, P., Fančovičová, J., Šramelová, D., Thiebaut, G., Méot, A., & Bonin, P. (2023). Mouth proximity influences perceived disgust of visual stimuli. *Personality and Individual Differences*, *207*, 112146. https://doi.org/10.1016/j.paid.2023.112146

Rottman, J., & Young, L. (2019). Specks of dirt and tons of pain: Dosage distinguishes impurity from harm. *Psychological Science*, *30*(8), 1151–1160. https://doi.org/10.1177/0956797619855382

Rozin, P., & Nemeroff, C. (1990). The laws of sympathetic magic: A psychological analysis of similarity and contagion. In J. W. Stigler, R. A. Shweder, & G. Herdt (Eds.), *Cultural psychology: Essays on comparative human development* (pp. 205–232). Cambridge University Press. https://doi.org/10.1017/CBO9781139173728.006

Rozin, P., Nemeroff, C., Horowitz, M., Gordon, B., & Voet, W. (1995). The borders of the self: Contamination sensitivity and potency of the body apertures and other body parts. *Journal of Research in Personality*, *29*(3), 318–340. https://doi.org/10.1006/jrpe.1995.1019

Rozin, P., Haidt, J., & McCauley, C. R. (2008). Disgust. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.), *Handbook of emotions* (3rd ed., pp. 757–776). Guildford.

Ryan, S., Oaten, M., Stevenson, R. J., & Case, T. I. (2012). Facial disfigurement is treated like an infectious disease. *Evolution and Human Behavior*, *33*(6), 639–646. https://doi.org/10.1016/j.evolhumbehav.2012.04.001

Stark, R., Walter, B., Schienle, A., & Vaitl, D. (2005). Psychophysiological correlates of disgust and disgust sensitivity. *Journal of Psychophysiology*, *19*(1), 50–60. https://doi.org/10.1027/0269-8803.19.1.50

Tybur, J. M., Lieberman, D., Kurzban, R., & DeScioli, P. (2013). Disgust: Evolved function and structure. *Psychological Review*, *120*(1), 65–84. https://doi.org/10.1037/a0030778

Tybur, J. M., Inbar, Y., Aarøe, L., Barclay, P., Barlow, F. K., De Barra, M., & ežejl, I. (2016). Parasite stress and pathogen avoidance relate to distinct dimensions of political ideology across 30 nations. *Proceedings of the National Academy of Sciences*, *113*(44), 12408–12413.

Tybur, J. M., Lieberman, D., Fan, L., Kupfer, T. R., & de Vries, R. E. (2020). Behavioral Immune Trade-Offs: Interpersonal value relaxes Social Pathogen Avoidance. *Psychological Science*, *31*(10), 1211–1221. https://doi.org/10.1177/0956797620960011

van Leeuwen, F., & Jaeger, B. (2022). Pathogen disgust sensitivity: Individual differences in pathogen perception or pathogen avoidance? *Motivation and Emotion*, *46*(3), 394–403. https://doi.org/10.1007/s11031-022-09937-2

van Leeuwen, F., Jaeger, B., & Tybur, J. M. (2023). A behavioural immune system perspective on disgust and social prejudice. *Nature Reviews Psychology*, *2*(11), 676–687.

White, K. P., Al-Shawaf, L., Lewis, D. M. G., & Wehbe, Y. S. (2023). Food neophobia and disgust, but not hunger, predict willingness to eat insects. *Personality and Individual Differences*, *202*, 111944.