

Disgust as a Mechanism for Decision Making Under Risk: Illuminating Sex Differences and Individual Risk-Taking Correlates of Disgust Propensity

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The emotion disgust motivates costly behavioral strategies that mitigate against potentially larger costs associated with pathogens, sexual behavior, and moral transgressions. Because disgust thereby regulates exposure to harm, it is by definition a mechanism for calibrating decision making under risk. Understanding this illuminates two features of the demographic distribution of this emotion. First, this approach predicts and explains sex differences in disgust. Greater female disgust propensity is often reported and discussed in the literature, but, to date, conclusions have been based on informal comparisons across a small number of studies, while existing functionalist explanations are at best incomplete. We report the results of an extensive meta-analysis documenting this sex difference, arguing that key features of this pattern are best explained as one manifestation of a broad principle of the evolutionary biology of risk-taking: for a given potential benefit, males in an effectively polygynous mating system accept the risk of harm more willingly than do females. Second, viewing disgust as a mechanism for decision making under risk likewise predicts that individual differences in disgust propensity should correlate with individual differences in various forms of risky behavior, because situational and dispositional factors that influence valuation of opportunity and hazard are often correlated across multiple decision contexts. In two large-sample online studies, we find consistent associations between disgust and risk avoidance. We conclude that disgust and related emotions can be usefully examined through the theoretical lens of decision making under risk in light of human evolution.

Keywords: disgust, risk-taking, sex differences, individual differences, evolutionary psychology

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An expanding scientific literature on disgust implicates this emotion in a range of important human behaviors, from feeding and mating to moral and political judgments (reviewed by Tybur, Lieber-

man, Kurzban, & DeScioli, 2013). As the psychological literature on disgust grows, it can and should be integrated with theory and evidence from related fields of study. Notably, theories from the study of behavior in evolutionary biology are increasingly being applied toward understanding human emotions, including disgust. In this article we situate the investigation of disgust in the larger framework of the evolutionary study of decision making under risk. We apply this integrated approach to explain basic features of the demography of disgust, illuminating both broad sex differences and focused individual differences in the propensity to experience this emotion.¹

Disgust Functions to Regulate Exposure to Potential Harm in Particular Domains

In evolutionary biology, explanations at the level of proximate mechanism specify the design features of phenotypic traits—*how*

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¹ Some researchers use *disgust propensity* to describe the frequency and intensity of disgust experiences and *disgust sensitivity* for the cognitive component of the affective experience (see Olatunji et al., 2007 and Van Overveld et al., 2006). Here we do not make this distinction and use *propensity* for both phenomena.

traits work, in an engineering sense. Taking the vertebrate liver as an example, proximate explanations include descriptions of how this organ is physically connected to other bodily systems, information about the internal structure of the liver and its cells, and maps of the various metabolic and hormonal pathways influenced by the liver. In contrast, explanations at the level of ultimate function emphasize the contribution of traits to the survival and reproduction of the trait's bearer(s)—*why* a trait exists, that is, what problem or goal is addressed by the trait. For example, the liver detoxifies the blood and produces chemicals useful for converting food into energy, thereby keeping the body healthy and fueled to pursue other goals. Note that a single trait can have multiple ultimate functions (e.g., filtering blood *and* creating chemicals), and also that functions can be interpreted at various levels of hierarchical abstraction (zooming out to a higher level, livers are for maintaining health).

This multilevel explanatory approach can be productively applied to the study of behavioral traits (Mayr, 1961; Tinbergen, 1963). Mechanistically, we can ask: What neural, hormonal, and anatomical pathways produce the behavior? What cues from the environment inform the deployment of the behavior instead of an alternative action? Complementing such proximate questions, we can ask ultimate questions: What are the costs and benefits of this behavior, such that individuals who successfully deployed this behavior would have out-competed those who did not? A primary tool of evolutionary psychology is to leverage functional theories to better understand mechanisms. In this spirit, evolutionary psychological approaches to emotion (Gervais & Fessler, 2016; Holbrook, in press; Fessler & Gervais, 2010; Tooby & Cosmides, 1990, 2008) consider emotions to be psychological mechanisms (or suites of connected mechanisms) that function to coordinate psychological and physiological systems to produce behaviors (or other responses) in order to address adaptive challenges that recurrently confronted ancestral human populations.

Many investigators concur that disgust has been shaped by the adaptive challenges imposed by pathogens over evolutionary time (Oaten, Stevenson, & Case, 2009; Tybur et al., 2013). Despite individual and cultural variation in specific elicitors and responses to disgust, the human disgust system exhibits universal features that constitute continuities with homologous systems in other animals (Curtis, de Barra, & Aunger, 2011). The mechanistic input–output structure of many disgust responses is consistent with a pathogen-avoidance function: *Pathogen disgust* is often activated by substances that are likely to harbor harmful microbes (e.g., rotting food, feces, blood, mucous), and the behavioral, physiological, and cognitive outputs of the emotion appear well-designed to mitigate pathogen-related harm: motivation to avoid potentially contaminated substances, nausea and vomiting to expel ingested pathogens, up-regulation of the immune system to fight infection, and learning and memory processes to avoid future infection (Tybur et al., 2013; Curtis et al., 2011).

Despite the dangers that they pose, pathogens should not be avoided at all costs. This specific functional goal often trades off against other important functional goals, such as acquiring food or engaging in mating (Fleischman et al., 2015), and these tradeoffs need to be managed (Tybur et al., 2013). Thus, a higher-level specification of the function of the pathogen disgust system is that it serves to *regulate* exposure to potentially harmful pathogens rather than avoid them unconditionally. Correspondingly, at a

proximate level, the pathogen disgust system (or a superordinate mechanism regulating it) must not only coordinate pathogen-detection input processes and pathogen-avoidance behavioral output processes, but must also estimate and compare the net expected fitness values of various response options (e.g., approaching vs. avoiding a potentially contaminated food source, etc.) in order to determine whether deploying a disgust-mediated avoidance strategy is appropriate.

Summarizing the above, pathogen disgust can motivate behaviors (avoiding potentially contaminated resources) that reduce potential costs (those imposed by pathogens) but also reduce potential gains (e.g., acquiring calories) relative to alternative behaviors (e.g., approaching the potentially contaminated food; see Tybur & Lieberman, 2016). This harm-avoidant class of behaviors is, by definition, a form of risk avoidance: Risky behaviors are widely defined as those with higher outcome variance than available alternatives, where outcome variance considers the costs and benefits of both failure and success (Mishra, 2014). Thus, the conventional view—that pathogen disgust can function to reduce the harm of exposure to pathogens while also reducing potential benefits—implicates risk management as a higher-level functional characterization of the phenomenon.

Implications of the Risk Perspective on Disgust

Recognizing that disgust is involved in managing certain risk-relevant decisions affords the application of functional principles developed by evolutionary biologists in explaining risk-sensitivity in general. We first apply these principles to sex differences in disgust propensity, then use them to explore individual differences independent of sex; likewise, we begin by applying these principles to the case of pathogen disgust, then expand to other forms of this emotion.

Sex Differences in Disgust Propensity

If disgust regulates risk-sensitive decisions regarding pathogen exposure, this mechanism should produce outputs that fit within the broader and well-established pattern of men being more accepting of (most forms of) risk than women. Sex differences in violence (Daly & Wilson, 1988) and other types of risk-taking behavior (Byrnes, Miller, & Schafer, 1999) are well documented. At the level of ultimate function, these differences are explicable as an adaptive response to ancestral conditions characterized by a mild degree of *effective polygyny* (Wilson & Daly, 1985; Fessler, 2010). Effective polygyny describes a demographic pattern wherein variance in reproductive success is greater among males than among females. In terms of evolutionary game theory—in which reproductive success is the principal currency through which natural selection operates—these sex differences in reproductive variance can be rephrased as indicating that the payoff disparities between male winners and male losers in reproductive competition are greater than the disparities between their female counterparts. Because reproductive inequality was greater among ancestral men than women (Brown, Laland, & Mulder, 2009), ancestral men can be said to have been engaged in competition that had higher stakes relative to their female contemporaries. Higher stakes incentivize bigger competitive gambles, so natural selection under effective polygyny favored traits that enabled and motivated

greater risk-taking in males. As heirs to this evolutionary legacy, compared with women, contemporary men can thus be expected to be relatively indifferent to the costs of risk-taking, such as somatic harm, and to more intensely pursue the benefits that accrue to successful risk takers: reproductive opportunities, as well as the resources, power, and status through which such opportunities are obtained.

Selection pressures caused by effective polygyny provide a functional explanation for numerous sexually dimorphic traits, such as risky physiological development “decisions” across numerous taxa, including such phenomena as immune function, growth of ornaments and armaments, and senescence rates (e.g., Clutton-Brock, Albon, & Harvey, 1980; Daly & Wilson, 1983; Leutenegger & Kelley, 1977; Promislow, Montgomerie, & Martin, 1992; Puts, 2010; Wittenberger, 1978). Our proposal is simply to add disease-avoidance in general, and the human disgust response in particular, to a long list of sexually dimorphic traits related to risk acceptance. Hence, if disgust propensity reflects a risk-averse strategy, and if humans are heirs to an evolutionary history of effective polygyny that has made men generally more risk-prone than women, then women should display greater disgust propensity than men.

Prima facie convergent evidence of the plausibility of the above thesis derives from sex differences in phenomena linked to, but distinct from, disgust. Given the centrality in disgust of guarding the ingestive oral pathway (Fessler & Haley, 2006), with corresponding loss of appetite, nausea, and related gastrointestinal qualia (Rozin & Fallon, 1987), it is telling that women experience more postoperative nausea and vomiting (Gan, 2006), postchemotherapy nausea, motion sickness, and conditioned food aversions than men (Fessler & Arguello, 2004; Hickok et al., 2003; Klosterhalfen et al., 2005; Stockhorst et al., 2006). Reducing the likelihood that these patterns stem primarily from gendered cultural schemas (a topic to which we will return), parallel patterns occur in other mammals, as female rats show stronger conditioned “disgust” responses than males (Cloutier, Kavaliers, & Ossenkopp, 2017), and female Japanese macaques engage in more hygienic behaviors when foraging and handling food (Sarabian & MacIntosh, 2015). Likewise, with regard to the avoidance of contact-mediated pathogen transfer, female mandrills engage in less perianal allogrooming of conspecifics infected with gastrointestinal macroparasites than do males (C. Sarabian, personal correspondence, 15 June 2017).

Extending the Risk Framework From Pathogen Disgust to Sexual and Moral Disgust

Other forms of disgust do not demonstrate an input–output logic consistent with a pathogen-avoidance function. For example, people often report feeling disgusted by incest or violent aggression, despite there being no clear connection between such behavior and pathogen harm. Natural selection generally proceeds by modifying existing traits to serve new ultimate functions. In some cases, the old trait is entirely transformed into the new trait; for example, the terrestrial quadruped’s forelimbs were transformed into the bat’s wings. In other cases, in what is termed *serial homology*, an existing trait is duplicated and the duplicate is modified, such that the organism possesses both the older, ancestral trait and the newer, derived trait; for example, the snake’s fangs are modified

duplicates of its other teeth. It appears that some emotions constitute serial homologues, that is, the functional features of one form of the emotion afforded repurposing to serve other ultimate functions even as the original form was retained. Pathogen disgust motivates avoidance and diminishes appetitive drive, features that made it well suited for repurposing to guide the individual away from other types of hazard. Hence, disgust responses to sexual stimuli or moral violators can be understood as serial homologues of pathogen disgust, duplicates in which the eliciting conditions have been importantly altered, and which operate in parallel with the original pathogen-avoidance functions of disgust (Clark, 2010). Importantly, like pathogen disgust, these subsidiary forms operate in domains in which costs and benefit tradeoffs must be regulated. Correspondingly, considerations of decision-making under risk continue to apply in these areas as well.

Sexual disgust motivates avoidance of sexual contact with the disgust elicitor, a risk-averse strategy that forgoes benefits of sexual behavior (reproduction; alliance formation and maintenance) in order to avoid potentially larger costs of sexual behavior (Tybur et al., 2013), such as the opportunity and genetic costs of reproducing with a suboptimal mate. *Moral disgust* motivates avoiding those who violate social norms, perhaps protecting the morally disgusted individual from direct harm by the violator and/or from stigma-by-association (Neuberg et al., 1994) and higher-order punishment (punishment meted out to those who fail to punish norm violators, Kelly, 2011; Clark & Fessler, 2014). Whenever this cost mitigation also sacrifices benefits, such as from cooperation with norm violators, moral disgust too can be seen as a risk-avoidance strategy.

In sum, viewing the various forms of disgust as mechanisms for decision making under risk potentially sheds theoretical light on the demography of various forms of this emotion. Examining the role of sex in the demography of all three principal forms of disgust, in this article we present the first meta-analysis to investigate whether sex differences are a robust feature of the empirical record on disgust.

Evidence and Explanations for Sex Differences in Disgust

Evidence: Meta-Analysis of Sex Differences in Disgust

Method.

Literature search. We conducted an English-language literature search using the search terms “disgust,” “disgust sensitivity,” “disgust propensity,” and “disgust tendency” in PsycINFO and Google Scholar.

We did not pursue unpublished data on the assumption that, because sex differences are rarely the central focus of disgust studies, it is unlikely that the reason that relevant results were not published is the presence or absence of findings regarding sex differences in disgust propensity. Hence, because there is no reason to expect systematic “file-drawer” patterns focused on the issue of sex differences in disgust, publication bias is unlikely to distort our findings.

We included articles that assessed disgust propensity via established questionnaires, as well as articles that measured self-reported affective reactions toward disgust-inducing stimuli. We excluded articles that induced disgust via the recall method and

then measured disgust as a manipulation check, because in such measures disgust propensity is conflated with the ability to vividly recall past disgust experiences. Similarly, we excluded intergroup disgust measures, as these are confounded with attitudes toward outgroups. Finally, we did not include psychophysiological indices related to disgust-eliciting stimuli, because, notwithstanding evidence from a handful of studies suggesting a unique role for the levator labii superioris muscle of the face (Schienle, Stark, & Vaitl, 2001; Stark et al., 2005), disgust does not have a clearly established distinctive set of physiological markers (Bradley et al., 2001; Stark, Walter, Schienle, & Vaitl, 2005; Yartz & Hawk, 2002). Many of the studies that we included employed measures assessing reactions to discrete actual or hypothetical stimuli (e.g., “How disgusted are you/would you be by X?;” see detailed descriptions below). We take individual differences in the net intensity of the state reported in response to a given set of stimuli as indicative of a relatively stable underlying trait, allowing us to employ these results to explore sex differences in the propensity to experience disgust.

Final sample. Our final sample consisted of 90 articles, from which 258 effect sizes were extracted. We contacted authors if parameters needed for the meta-analysis were not reported in the article, except when these articles had eight or fewer men in their sample. The sample consisted of studies predominantly from the U.S., Canada, or Western European countries ($k = 234$) and other highly developed nations such as Australia, New Zealand, Israel, Korea, and Japan ($k = 14$). Only seven effect sizes were from less extensively developed countries such as Turkey, Slovakia, Brazil, and Bangladesh. One study included respondents from 30 countries (Tybur et al., 2016).

Disgust propensity measures in our sample include the following:

- The Disgust Scale (DS), developed by Haidt et al. (1994), includes 32 items in two formats: true/false questions about personal disgust-related experiences (e.g., “I never let any part of my body touch the toilet seat in public restrooms”) and 3-point ratings (*not disgusting*, *slightly disgusting*, or *very disgusting*) of stimuli (e.g., “You are about to drink a glass of milk when you smell that it is spoiled”). The authors’ claim that the scale investigates seven (or eight) domains of disgust has been challenged in subsequent work (e.g., Olatunji et al., 2007).
- The Disgust Scale—Revised (DS-R) dropped seven items from the original DS based on psychometric analyses (Olatunji et al., 2007). This scale captures three factors, challenging the original seven-domain (or eight-domain) interpretation.
- Questionnaire for Assessment of Disgust Sensitive (QADS) is the result of efforts to translate the DS for German-speaking populations and to improve the DS for psychometric and theoretical reasons (see Petrowski et al., 2010).
- The Disgust Propensity and Sensitivity Scale (DPSS; van Overveld et al., 2006) uses a 5-point Likert scale to assess the frequency (1 = *never* to 5 = *always*) of various disgust reactions. Items are intended to distinguish disgust propensity from disgust sensitivity.
- The Padua Inventory (PI; Burns, Keortge, Formea, & Sternberger, 1996; Sanavio, 1988) was designed to measure obsessive and compulsive symptoms. It includes a contamination-related subscale with disgust-relevant items (e.g., “I avoid using public toilets because I am afraid of disease and contagion.”)
- The Three Domain Disgust Scale (TDDS) was developed by Tybur et al. (2009) because of theoretical concerns about existing instruments. Participants rate how disgusting they find various items using a 7-point Likert scale. Items are drawn from three theoretically derived domains of adaptive challenges: pathogen threat (e.g., “Seeing some mold on old leftovers in your refrigerator”), sexual scenarios (e.g., “Finding out that someone you don’t like has sexual fantasies about you”), and moral judgment (e.g., “Deceiving a friend”).

These are all self-report measures. A critical assumption behind a meaningful sex comparison of any self-report scale is that the scale should measure the same construct for each sex. Method invariance (factor structure and loadings) across sex has been established in the two most commonly used disgust scales, the TDDS (Tybur et al., 2009) and the DS-R (Olatunji et al., 2007), so it seems likely that the similar effects observed among remaining measures also reflect real sex differences.

Calculation of effect sizes. Whenever possible, we used the reported effect sizes (converting them to Cohen’s d if necessary). For articles that did not report effect sizes, we calculated Cohen’s d or Hedge’s g (Hedge, 1981), depending on the available information. The interpretation of both types of effects is the same, so for simplicity and consistency we have referred to all meta-analytic effect sizes as “ d .” We ran our meta-analysis using both Wilson’s (2015) and Field and Gillett’s (2010) SPSS macros and obtained identical results.

Most authors who used the TDDS (Tybur et al., 2009) report sex differences split by the three domains, whereas many authors who used the DS-R (Olatunji et al., 2007) or DS (Haidt et al., 1994) tended to report overall sex differences and only occasionally report scores split by the respective scales’ facets. Hence in Table 1, we report facets of the DS-R wherever possible, but the overall meta-analytic average score is comprised of the DS or DS-R (all), the three domains of TDDS, DPSS, QADS, Padua, and various self-designed scales, not facet scores of the DS or DS-R. In fact, for the older DS scale (Haidt et al., 1994), some facets are known to have low reliability (Haidt et al., 1994; Olatunji et al., 2007), although when averaged as an overall 32-item DS scale the scale reaches sufficient reliability. Hence, we do not report DS scores by facet.

Results. Per predictions, overall, women report greater disgust propensity than men: random effect $d = .54$, $\tau = .05$, 95% CI [.51, .57]. Women’s propensity for disgust was greater than men’s for all instruments. The results are displayed in Table 1 (see also Figure 1).

Publication bias. We plotted effect sizes of DS, DS-R, three subscales of TDDS, QADS, Padua, and self-designed scales against their standard errors; asymmetries in the resulting funnel plot are possible indicators of publication bias. There is a slight asymmetry when all effects are plotted (see Figure 1), but this is better explained by the large sex difference in TDDS sexual

Table 1
Effect Sizes Split by Scales Used to Measure Disgust Propensity

Disgust scale employed	k	d_{fixed}	95% CI		d_{random}	95% CI	
			LL	UL		LL	UL
DS or DS-R (all)	65	.52	.51	.54	.64	.59	.69
DS-R (core)	18	.58	.53	.62	.59	.45	.73
DS-R (contamination)	17	.37	.32	.41	.26	.14	.38
DS-R (animal reminders)	16	.47	.42	.51	.45	.36	.53
TDDS (pathogen)	28	.39	.37	.43	.41	.34	.47
TDDS (sex)	25	1.11	1.06	1.16	1.17	1.05	1.28
TDDS (moral)	24	.17	.13	.21	.20	.13	.27
DPSS	11	.33	.27	.40	.34	.27	.40
QADS	3	.71	.50	.91	.71	.50	.91
Padua inventory	7	.44	.33	.55	.45	.32	.59
Self-designed	44	.50	.48	.52	.45	.38	.53
Overall	258	.50	.49	.51	.54	.50	.57

Note. LL = Lower limit; UL = Upper limit; DS = Disgust scale (Haidt et al., 1994); DS-R = Disgust scale-revised (Olatunji et al., 2007); QADS = Questionnaire for the assessment of disgust sensitivity (Schienle et al., 2011); TDDS = Three domain disgust sensitivity (Tybur et al., 2009); DPSS = Disgust propensity and sensitivity scale (van Overveld et al., 2006). Positive d means that females display higher disgust propensity than males.

disgust relative to sex differences in other disgust domains (see Table 1) than by publication bias; when sexual disgust effect sizes are separated the resulting funnel plot is quite symmetrical (see Figure 1). This is consistent with our expectation that, because sex differences in disgust propensity are most often reported as peripheral findings, publication bias would not distort our meta-analysis (see Figure 2).

Are sex differences in disgust universal? The vast majority of this research has been conducted in the highly developed nations of the West, with samples often comprised of university undergraduates—features that necessitate caution when concluding that the pattern at issue is panhuman (Henrich et al., 2010). Nevertheless, while systematic research on disgust in small-scale traditional and semitransitional societies is largely absent, the corpus of work included in our meta-analysis includes results from 20 countries (Austria, Australia, Bangladesh, Belgium, Brazil, Canada, Finland,

Germany, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Slovenia, Sweden, Turkey, United Kingdom, and U.S.), plus a single study that included 30 countries (Tybur et al., 2016). Our reanalysis of Tybur et al.’s (2016) cross-cultural study revealed significant sex difference in the subsamples from 24 of 30 countries; among the exceptions (Singapore, U.S., Greece, Ireland, South Korea, and China), women generally reported higher pathogen disgust than men.

From the above analyses, it is reasonable to assume that the basic sex difference in disgust propensity is a species-typical feature of the mind. Complementarily, author DF’s experiences conducting ethnographic research in a small Bengkulu fishing village in Indonesia (see Fessler, 1995 for a general ethnographic overview), while not derived from quantitative data, suggest a sex difference there that is at least as dramatic as that found in cosmopolitan Western samples, and this despite the vastly greater

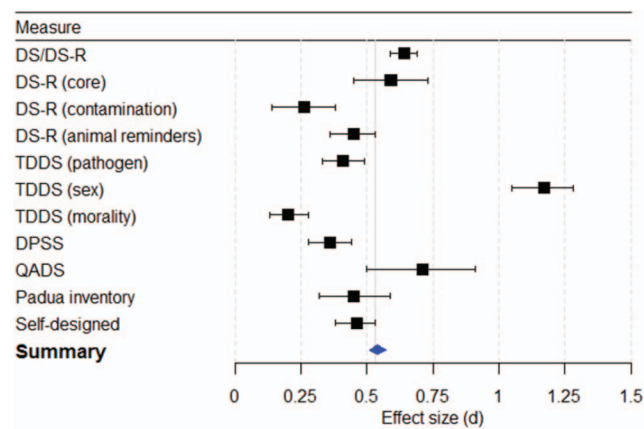


Figure 1. Forest plot of random effect sizes. Error bars represent 95% confidence intervals. Positive d means that women display higher disgust propensity than men. See the online article for the color version of this figure.

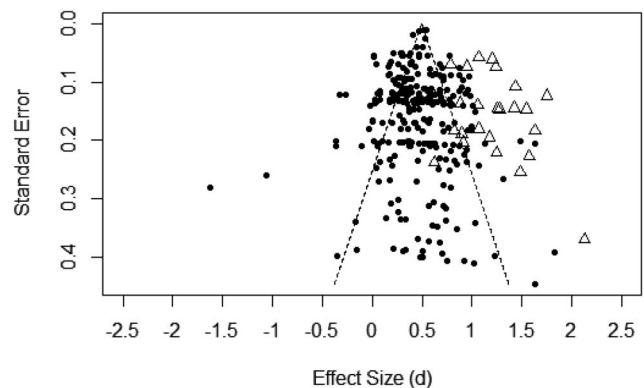


Figure 2. Funnel plot of standard error against effect size. Circles represent effect sizes from DS, DS-R, TDDS pathogen and morality subscales, QADS, Padua, and self-designed scales. Triangles represent TDDS sexual disgust subscale. Area bounded by the dotted lines represents the triangular 95% confidence region.

quodidian exposure to disgust elicitors typical of life in a small-scale rural community in a developing country. Likewise, while it is clear that cultural gender roles contribute to the observed patterns of disgust propensity (Skolnick et al., 2013), given its apparent ubiquity in our sample, it seems likely that gendered norms reflect an elaboration of an underlying sex difference, rather than the sole cause of said.

Existing Explanations: Why are Human Females More Disgust-Prone Than Males?

The sex difference in disgust propensity cries out for explanation, and its likely panhuman nature begs for a functional account. Having previously noted this pattern in a handful of findings, several authors have attempted this. Prokop and Jančovičová (2013) and Fleischman (2014) note that sex differences in sexual disgust are readily explained by differences in obligate parental investment. Because each reproductive act constitutes a far greater proportion of a woman's total reproductive potential than for a comparable man, women should be significantly more selective when choosing sexual partners. To the extent that sexual disgust functions to reduce the costs of pairings with biologically suboptimal mating partners (Fessler & Navarrete, 2004; reviewed by Tybur et al., 2013), women—for whom such costs are much higher—should exhibit much greater sexual disgust propensity than men. This explanation is consistent with voluminous evidence of a basic sex difference in sexual selectivity (Buss & Schmitt, 1993; Clark & Hatfield, 1989; Ellis & Symons, 1990; Hald & Høgh-Olesen, 2010; McBurney, Zapp, & Streeter, 2005; Schmitt, 2005; Schmitt et al., 2003), and with the massive effect size for sexual disgust in our meta-analysis. We therefore endorse this explanation, adding only that sex differences in decision making under risk complement and reinforce the pattern driven by sex differences in obligate parental investment (indeed, viewed from sufficient logical distance, these two explanations merge, as effective polygyny is itself a product of sex differences in obligate parental investment).

While they offer a compelling explanation for the sex difference in sexual disgust propensity, sex differences in obligate parental investment cannot directly account for sex differences in disgust unrelated to sexual choosiness. What then explains sex differences in the central manifestation of this emotion, namely pathogen disgust?

Following Fessler et al. (2004), Fleischman (2014) proposes that sex differences in pathogen disgust derive in part from the pattern wherein inflammatory responses are downregulated during (and in anticipation of) pregnancy to facilitate maternal immune tolerance of the conceptus, with corresponding increases in disgust-mediated disease-avoidance behavior. Central to this compensatory prophylaxis hypothesis is the notion that escalated disease avoidance efforts, being costly, should be pursued only when needed to offset episodic increases in vulnerability to pathogens (Fessler & Navarrete, 2003). There indeed appear to be tightly periodic changes in disgust propensity linked to female reproductive physiology (Fessler et al., 2005; Fleischman & Fessler, 2011; Jones et al., 2005; but see Fessler & Navarrete, 2003). However, while compensatory prophylaxis may account for a system of carefully calibrated changes in women's disgust propensity, it does a poor job of explaining an overarching sex difference. It seems unlikely

that the overall sex difference is driven exclusively by women who participate in research while pregnant or in the luteal phase of the menstrual cycle (when compensatory prophylaxis is upregulated), because (a) among the populations that form the majority of the samples, pregnancy rates are low, and hormonal contraceptive use (which may reduce cyclical changes in disgust propensity—Jones et al., 2005) is high. Further, (b) the luteal phase constitutes less than half of the menstrual cycle, with the peak period of immunomodulation being far shorter. Additionally, sex differences in disgust likely precede sexual maturity (e.g., Muris et al., 1999; Stapley & Haviland, 1989). Lastly, and most damning for any attempt to explain sex differences in pathogen disgust in terms of susceptibility to infection, due to weaker immune responses, men suffer more severe infections than women from a wide variety of viruses, bacteria, fungi, and parasites (reviewed in Fish, 2008)—exactly the opposite of what would be expected if sex differences in disgust were driven by sex differences in vulnerability.²

Following Curtis et al. (2004) and Fessler et al. (2004), both Prokop and Jančovičová (2013) and Fleischman (2014; see also Oaten et al., 2009) argue that, because (due to lactation) women care for infants more than men do, it is adaptive for women to be more sensitive to cues of the presence of pathogens in order to shelter vulnerable offspring. Sex differences in disgust propensity that precede the onset of reproduction are explained in that girls generally care for immature kin more than boys, and thus derive similar inclusive fitness benefits from greater disease avoidance (Fessler et al., 2004). Nevertheless, given that prophylaxis is costly, and given that caretaking responsibilities for immature kin will vary, we might expect the system to adjust disease avoidance as a function of caregiving. However, Prokop and Jančovičová (2013) report that experimental elicitation of a caregiving context does not increase disgust responses. While their stimulus may have been insufficient to activate an increased disgust response, actual motherhood should constitute a definitive cue, yet mothers are no more reactive toward common disgust elicitors than nonmothers (Visconti, 2013) and may even be less disgust-prone than other women (Prokop & Jančovičová, 2016). When considering their own child, mothers do not differ from nonmothers regarding reactions to the given child's interactions with environmental contaminants (B. Visconti, personal communication, 17 June 2015; see Visconti, 2013)—precisely the domain in which the vulnerable-offspring hypothesis would predict an upregulation of disgust.

Rather than needing to be sheltered from pathogen sources, it is possible that infants benefit from some contact with pathogens: Infants' avid mouthing of inedible objects may be an adaptation to sample the local pathogen ecology while under the protection of maternal immune factors supplied in breastmilk (Fessler & Abrams, 2004). If so, we should not expect increased disgust-proneness as a function of motherhood, and might expect a decrease as regards the infant's interactions with the environment.

² Note that the sex difference in susceptibility to infection is entirely in keeping with our approach: among other pathways, androgens reduce immune function in favor of devoting resources to enhancing body size, muscularity, secondary sex characteristics, and aggression—all of which is ultimately driven by greater competition among males due to an effectively polygynous ancestral mating system (Zuk & McKean, 1996).

To summarize the above, sex differences in sexual disgust are well explained by existing functional accounts, but sex differences in pathogen disgust are not. Our solution is to view sex differences in pathogen disgust as a manifestation of higher-order sex differences in risk-taking. Note that, contra Fleischman (2014), we are not arguing that lower male disgust propensity is simply a by-product of other adaptations for male risk-proneness. Rather, we suggest that, because disease avoidance requires time, energy, and attention, given that ancestral women were better served by a wide variety of precautionary behaviors than were ancestral men, cost/benefit considerations favored the evolution of sex differences in pathogen disgust.

From Sex Differences to Other Individual-Difference Patterns

The sex difference in pathogen disgust is consonant with sex differences in other traits explicable in terms of greater female sensitivity to the possibility of hazards relative to opportunities, and greater male valuation of opportunities relative to hazards. Across cultures, women score higher than men on measures of subclinical anxiety (Baloglu et al., 2007; Ben-Zur & Zeidner, 1988; Costa Jr et al., 2001; McLean et al., 2011; Thorpe et al., 2003), clinical anxiety (Gater et al., 1998; McLean et al., 2011; Remes et al., 2016), neuroticism (Costa Jr et al., 2001), and pain responsiveness (Else-Quest et al., 2006; Mendrek et al., 2014), while the reverse is true of sensation seeking (Roberti, 2004).

The effective-polygyny explanation of sex differences in preferences for high-variance options hinges on sex being a stable, albeit crude, index of differences between individuals in the valuation of hazard and opportunity. Individual attributes other than sex may also influence such valuations, leading to associations between disgust propensity and other harm-avoidant traits. Indeed, within both sexes, many of the sexually dimorphic psychological traits discussed above are linked to disgust propensity: Disgust is correlated with anxiety and paranoid ideation, associations substantially mediated by the more general trait of harm avoidance (Olatunji et al., 2009; a characteristic that, in turn, is linked to pain responsiveness; Pud et al., 2004). Correspondingly, Pond et al. (2012) report that disgust propensity is negatively correlated with the use of violence. At the level of personality, reflecting shared genetic underpinnings (Kang et al., 2010), disgust propensity is positively correlated with neuroticism (Druschel & Sherman, 1999; Haidt et al., 1994; Tybur & de Vries, 2013; Tybur et al., 2009; Wilson et al., 2000). Like other forms of risk aversion (Mishra & Lalumière, 2011), disgust is negatively correlated with sensation seeking (Dvorak et al., 2011; Haidt et al., 1994). These patterns are consistent with the proposed link between the specific trait of disgust propensity and broader individual differences in the valuation of possible negative outcomes relative to possible beneficial outcomes. Accordingly, we expand our account to address patterns of individual differences in disgust beyond those predicted by biological sex.

Correlated Individual Differences in Disgust and Risk-Taking

Applying the Relative State Model to Disgust

Seeking to explain nuanced patterns of correlated risk-taking, Mishra, Barclay, and Sparks (2017) presented the *relative state*

model wherein risky behavior is influenced by the interaction of *need-based* and *ability-based* pathways.

Need-based risk-taking. The need-based pathway to risk, based on risk-sensitivity theory (Kacelnik & Bateson, 1997; Mishra, 2014; Mishra & Lalumière, 2010; Stephens, 1981), describes relatively disadvantaged individuals attempting to reach a desired goal state that is inaccessible via low-risk alternatives. The effective polygyny explanation for sex differences in risk-taking fits the need-based framework, in that it assumes that a stable feature of human history has been that men's higher-variance reproductive game necessitated higher-variance competitive tactics. A classic example of need-based risk-taking in animal behavioral ecology is when a starvation threshold necessitates foraging under predation risk. Oaten et al. (2009) similarly suggest that human disgust propensity should be downregulated when starvation looms; this logic extends to quotidian situations, as mere hunger suffices to downregulate disgust somewhat (Ainsworth & Maner, 2014; Hoefling et al., 2009; Curtis et al., 2011).

We suggest that the need-based pathway can also explain some correlated individual differences in disgust. Chronic disadvantage in access to resources (e.g., food) could cause a chronic need-based downregulation of disgust responses to resources at risk of pathogen contamination. Chronic disadvantage in mating competition could cause a need-based reduction in sexual disgust. Similarly, for those disadvantaged in status competition, reduced moral disgust could support taking advantage of opportunities for mutually beneficial interactions with norm violators despite the risks of higher-order punishment (i.e., low-status individuals may be more likely to pursue relationships with pariahs, etc.); conversely, prosocial punishment provides a risky path to status (Barclay, 2006) that could be facilitated by heightened moral disgust. These examples of hypothesized relationships between chronic disadvantage and various forms of disgust can be investigated in future work. Here, they simply illustrate how the functional logic of need-based risk-taking may be useful in constructing explanations of individual differences in various types of disgust.

Ability-based risk-taking. The ability-based pathway to risk describes individuals using competitive advantages to increase the probability of success and/or positive payoffs of risk-taking. If a given risky behavior has a higher expected return for some people because of differences in abilities, those advantaged people can be expected to use the behavior more. For example, stronger men more frequently engage in risky aggression in pursuit of resources, because their relative strength makes them more likely to win in agonistic conflicts (Archer, & Thanzami, 2009; Gallup, White, & Gallup, 2007), a pattern that, in turn, helps to explain sex differences in anger (Sell, Tooby, & Cosmides, 2009). Analogously, within each sex, individuals who are more vulnerable to infection engage in more behavioral prophylaxis, including greater disgust-proneness, with attendant costs (Conway et al., 2007; Fessler, Eng, & Navarrete, 2005; Fleischman & Fessler, 2011; Jones et al., 2005; Prokop & Fančovičová, 2011; Żelaźniewicz, Borkowska, Nowak, & Pawłowski, 2016); in other words, those advantaged with greater ability to cope with infection can afford to engage in behaviors that present infection risks, and thus they show lower disgust propensity.

In addition to the (potentially sizable) direct payoffs of ability-based risky behavior (e.g., resources gained by risky combat), costly signaling theory (Higham, 2013; Zahavi, 1975, 1990) sug-

gests an auxiliary indirect “revenue stream” available to ability-based risk takers. Observable behavior can reliably indicate the presence of socially relevant traits in the actor, which can in turn lead to favorable treatment of the actor by observers (Barclay, 2015; Bliege Bird, Smith, & Bird, 2001). For example, men who take conspicuous physical risks and thereby demonstrate their indifference to harm are regarded as more formidable, which in turn may attract allies and deter rivals (Fessler et al., 2014). A visible willingness to risk pathogen exposure may similarly earn a valuable reputation for indifference to harm (Fessler et al., 2004). Disgusting behavior entailing heightened risk may also serve as a signal of group loyalty, such as when disgust-eliciting ordeals are required of initiates in groups such as fraternities and sports teams (i.e., hazing; see Cimino, 2013). Lastly, behavioral indifference to potential pathogen exposure could signal strong physiological immune function, a desirable trait in mates (Fessler et al., 2004).

Mishra, Barclay, and Sparks (2017) argue that, because the embodied and situational factors that cause advantage (leading to ability-based risk-taking) and disadvantage (leading to need-based risk-taking) are often relevant to behavioral decisions in multiple domains, risk-taking often appears to be somewhat domain-general, that is, multiple forms of risk-taking tend to be correlated within individuals. We propose to add disgust to the list of risk-taking phenomena that exhibit such a degree of domain generality; thus, we expect various forms of disgust propensity to correlate somewhat with other forms of risk aversion. We explored this empirically in two studies.

Method

We first conducted a large Internet survey that included measures of disgust propensity and risk aversion. As we report below, the observed correlations were supportive of our hypothesis and the sizes of the effects were medium or large by modern social science standards (Gignac & Szodorai, 2016). The amount of variance explained by the observed correlations could be considered small in absolute terms, but this is to be expected if the domain-generality of risk-taking is driven by imperfect overlap between inputs to various decisions (Mishra et al., 2017). We next conducted a second large Internet study to confirm the replicability of the aforementioned results, and to generalize them using a second measure of disgust and an expanded harm avoidance measure. The instruments, data, and analysis code for the two studies, as well as the preregistration of methods and hypotheses for Study 2, are included in the electronic [supplementary materials](#) and are also publicly archived via the Open Science Framework (Sparks et al., 2016). Here, we summarize the relevant methods employed in both studies.

Study 1. Participants ($N = 1,026$) recruited via Amazon’s Mechanical Turk survey platform (Buhrmester, Kwang, & Gosling, 2011) completed methods that combined three studies in randomized order; the two studies irrelevant to this report investigated perceptions of attractiveness and formidability and are not discussed further.

The study included the Three Domain Disgust Scale (TDDS; see meta-analysis methods above for description; Tybur et al., 2009) and the Domain Specific Risk-taking Scale (DOSPERT; Blais & Weber, 2006; Weber et al., 2002). The DOSPERT is a widely employed measure of risk tendency; participants use a Likert scale

to rate their likelihood of engaging in various risk behaviors in a wide variety of scenarios. We also included three original items intended to assess harm-avoidance behavior (i.e., avoidance of large fitness costs) as a subset of the more general risk-acceptance/avoidance patterns (i.e., acceptance/avoidance of outcome variance, whether driven by costs, benefits or both) assessed by the DOSPERT. These items asked how often (1 = *very rarely or never* to 5 = *extremely often*) people tend to lock their doors, jaywalk, and use seatbelts. Finally, participants were asked how much money they would like to bet on a coin toss; such a wager could be considered risky behavior.

After eliminations for largely incomplete responses, finishing in less than 5 min, or failing one of two simple attention checks, the final sample was $n = 941$ (53.9% male; $M_{\text{age}} = 31.3$, $SD = 11.4$).

Study 2. Participants from the United States ($N = 530$) were recruited from Mechanical Turk and asked to complete the TDDS and DOSPERT. We also included a second disgust measure that focuses on pathogen disgust (Curtis, Aunger, & Rabie, 2004), soliciting Likert responses (1 = *not at all disgusting* to 7 = *extremely disgusting*) about the intensity of disgust response to visual—rather than textual—stimuli. We also included a different set of novel harm-avoidance items, intended to survey a wider variety of harm-avoidance situations (e.g., buying insurance, approaching a new neighbor’s dog, etc.) and to solicit the participants’ likely responses to specific scenarios rather than general tendencies (e.g., “You are going to drive a short distance through a residential neighborhood. The drive will take 3 min and your speed will be under 25 mph. Would you use your seatbelt?;” see [supplemental material](#) for full list of items). The TDDS, visual disgust measure, and harm avoidance items were presented in random order, followed by the DOSPERT and finally by standard demographic items and an honesty check.

After eliminations for finishing in under 5 min, largely incomplete responses, and admittedly dishonest responding, the final sample was $n = 473$ (221 men, 246 women; six did not indicate sex $M_{\text{age}} = 36.5$, $SD = 11.9$).

Hypotheses. We expect disgust propensity and other forms of risk avoidance to correlate positively, hence we predicted a negative relationship between our disgust measures (TDDS and Curtis scale) and risk-taking (DOSPERT, wager). We expected our novel harm-avoidance items to correlate negatively with DOSPERT scores and positively with disgust propensity. Disgust motivates a specific profile of risk aversion—accepting small costs to avoid potentially larger costs—and our novel harm-avoidance items were designed to assess similar risk aversion in other domains, so we tentatively expected that the disgust-harm avoidance correlation would be stronger in absolute terms than the disgust-DOSPERT correlation. Last but not least, per the logic detailed earlier, we expected sex differences on these measures, consistent with our meta-analysis results.

Results

Scales. All Curtis pathogen-relevant items were rated as more disgusting than their pathogen-irrelevant counterparts (see [supplemental material](#)), and formed a reasonably reliable scale ($\alpha = .79$). The TDDS full scale and subscales had good reliability, as did the full DOSPERT ($\alpha > .80$ in both studies). The full DOSPERT can be interpreted as a generalized risk propensity measure (Mishra &

Lalumière, 2011); analyses of the subscales should be interpreted with caution because of their lower reliabilities. Our novel harm avoidance measures showed weak reliability (α s < .50), hence our results for these scales should be interpreted cautiously (see [supplemental material](#) for item-by-item analyses). Scale and subscale reliabilities are reported in [Table 2](#).

Sex differences. [Table 3](#) shows sex differences in risk-taking, harm avoidance, and disgust propensity. Women reported higher disgust on all available measures in both studies. The effect sizes for Curtis pathogen disgust and TDDS pathogen-disgust subscale are similar, suggesting that they successfully assay the same phenomenon, as intended. Consistent with sex differences previously reported for the DOSPERT (Figner & Weber, 2011), women in both studies reported less risk-taking than men on all subscales, with the exception of social risk-taking. Against expectations, there was no sex difference in the wager measure employed in Study 1. However, consistent with predictions, our novel harm avoidance items for both studies showed higher harm avoidance among women.

Summarizing these results, the observed sex differences were overall consistent with our hypotheses and with the results of our meta-analysis.

Correlated individual differences in disgust, risk-taking, and harm avoidance. [Table 4](#) displays correlations between risk propensity, as measured by the DOSPERT index, and several measures of disgust propensity. All of the relationships are in the predicted negative direction with confidence intervals that exclude zero. Study 2 replicated the results of Study 1, and the Curtis pathogen disgust measure that was added for Study 2 displays a similar relationship with risk-taking as does the TDDS pathogen-disgust measure. The correlation between the full TDDS and the full DOSPERT was $r = -.29$ in both studies; the magnitude of this relationship is in the 75th percentile of effect sizes in modern individual-differences research (Gignac & Szodorai, 2016). [Table 4](#) also displays the correlations between harm avoidance and disgust propensity. All of the relationships are in the predicted positive direction with confidence intervals that exclude zero. Item-by-item analyses are reported in the [supplementary material](#). Post hoc analyses show that these relationships are similar when women and men are analyzed separately (see [supplemental material](#)), indicating that the correlations are not simply caused by sex differences.

Table 2
Scale Alphas

(Sub)scale	Study 1	Study 2
TDDS (all)	.90	.91
Moral	.91	.95
Sexual	.85	.87
Pathogen	.83	.84
Curtis		.79
DOSPERT	.85	.86
Ethical	.66	.70
Financial	.75	.80
Health/safety	.63	.65
Recreational	.82	.82
Social	.63	.69
Harm avoidance 1	.21	
Harm avoidance 2		.43

Table 3
Women Report More Disgust, More Harm Avoidance, and Less Risk-Taking

(Sub)scale	Study 1			Study 2		
	<i>d</i>	95% CI		<i>d</i>	95% CI	
		LL	UL		LL	UL
TDDS (all)	.59	.45	.72	.69	.50	.88
Moral	.18	.05	.31	.28	.10	.46
Sexual	.79	.65	.92	.91	.72	1.11
Pathogen	.40	.27	.53	.40	.21	.58
Curtis				.39	.20	.57
DOSPERT	.53	.40	.66	.63	.44	.81
Ethical	.49	.36	.62	.42	.24	.61
Financial	.57	.43	.70	.45	.27	.64
Health/safety	.38	.25	.51	.50	.31	.68
Recreational	.35	.22	.47	.60	.41	.78
Social	-.04	-.16	.09	.01	-.17	.19
Wager	.02	-.11	.15			
Harm avoidance 1	.24	.12	.37			
Harm avoidance 2				.22	.04	.40

Note. LL = Lower limit; UL = Upper limit; TDDS = Three domains of disgust scale (Tybur et al., 2009); Positive *d* means that females display higher disgust propensity or less risk-taking than males.

Discussion

Risk-taking is widely reported to exhibit some degree of domain generality, arguably because the same stable individual differences and/or situational factors are common inputs to risk-sensitive decision mechanisms across contexts (reviewed and modeled by Mishra et al., 2017). Viewing disgust propensity as a mechanism of risk aversion leads to the straightforward prediction that disgust will be associated with other forms of risk aversion, particularly given that many forms of risk aversion are correlated. Consistent with the view of disgust as a mechanism for avoidance of risk and harm, we observed negative relationships between disgust propensity and self-reported risk-taking, and positive relationships between disgust propensity and harm avoidance, effects that replicated in two studies and generalized across distinct measures.

We offer these results as an initial proof-of-concept that theories addressing individual differences in risk-taking can be usefully applied to the topic of disgust. Our first-pass investigation of the relationship between disgust and other forms of risk-taking interpreted the full DOSPERT scale as a general measure of risk attitude (Mishra & Lalumière, 2011). This approach intentionally blurred the distinction between various types of behavioral risk-taking that likely stem from distinct psychological mechanisms, based on the assumption that common inputs to decisions in different domains are likely to produce domain-general patterns of risk-taking (Mishra et al., 2017). The DOSPERT is an appropriate research tool for such purposes because it is a widely used and well-validated instrument surveying a wide variety of risky scenarios. It would be reasonable to hypothesize that risk-taking in certain domains will be more highly correlated with disgust phenomena than risk-taking in other domains. To test such textured hypotheses about the relative sizes of correlations between specific domains, evolutionarily informed domain-specific risk scales (e.g., Kruger, Wang, & Wilke, 2007; Wilke et al., 2014) may be especially useful. Additionally, measuring real behavior would be an excellent improvement over self-report methods.

Table 4
Correlations Between Measures of Disgust, Risk Propensity, and Harm Avoidance

(Sub)scale	Disgust and risk propensity						Disgust and harm avoidance					
	Study 1			Study 2			Study 1			Study 2		
	<i>r</i>	95% CI		<i>r</i>	95% CI		<i>r</i>	95% CI		<i>r</i>	95% CI	
		LL	UL		LL	UL		LL	UL		LL	UL
TDDS index	-.29	-.35	-.22	-.29	-.37	-.20	.16	.10	.22	.34	.26	.41
Sexual	-.33	-.39	-.28	-.32	-.41	-.23	.11	.17	.24	.25	.15	.33
Moral	-.17	-.24	-.10	-.18	-.26	-.10	.10	.04	.16	.22	.13	.31
Pathogen	-.17	-.23	-.10	-.16	-.24	-.06	.10	.03	.16	.32	.24	.40
Curtis pathogen				-.11	-.19	-.03				.23	.14	.33

Note. LL = Lower limit; UL = Upper limit; TDDS = Three domains of disgust scale (Tybur et al., 2009).

Our novel harm avoidance measure was intended to identify subsets of risk-sensitive behavior that would be most closely related to disgust. The results were consistent with our general framework in that harm avoidance and disgust were positively correlated, but we did not find clear support for our prediction that disgust would show a stronger relationship to harm avoidance than to more general risk attitudes. Our harm avoidance scales showed poor internal reliability, suggesting that further development of theory and measurement instruments will be needed.

General Discussion

Disgust is widely argued to motivate avoidance of harm from pathogens and perhaps other sources. This functional perspective implicitly treats disgust as a mechanism of decision-making under risk, but the study of disgust has not previously been integrated with theory and evidence from the evolutionarily informed study of risk-taking. We have explored two implications of the disgust-as-risk-aversion perspective. First, sex differences in pathogen disgust propensity, clearly evident in our meta-analysis of published studies, and replicated in our two new studies, can be added to the list of sex differences in risk-sensitive decisions that are parsimoniously explained by our species' history of effective polygyny. Second, individual differences in various forms of disgust propensity correlate with other individual differences in general risk aversion.

Implications for the Study of Disgust

Our theoretical arguments have focused most directly on pathogen disgust, but we found that several forms of disgust show robust sex differences. Heightened female disgust propensity in the domain of sexual behavior can be parsimoniously attributed to cost disparities associated with differences between female and male reproductive physiology. Beyond this, however, within each sex, sexual disgust propensity was negatively associated with risk-taking and positively associated with harm avoidance. Thus, theories about individual differences in risk-taking may be useful for predicting and explaining variation in both pathogen and sexual disgust. Moral disgust also shows a slight sex difference. This is speculatively interpretable as a harm-avoidance strategy. For example, Sparks and Barclay (2015), having found that women condemn thievery and deception more strongly than men, speculated that this may

be because women are generally more vulnerable to harm from such tactics. Moral disgust also correlates with risk attitudes and harm avoidance in a manner that resembles the other forms of disgust, suggesting shared inputs to decision-making across these diverse domains of behavior. However, a full consideration of moral disgust—and morality more generally—is beyond the scope of the current article.

We hope that this work inspires further theoretical and empirical advances in the study of disgust. Here we have focused on the functional and mechanistic levels of analysis, but the risk lens can also be applied to potentially illuminate the development of disgust propensity across the life span. Many risky behaviors are especially prevalent among young, low-status men; decline with status- and fitness-relevant achievements such as marriage and fatherhood; and increase when those achievements are reversed, as with the loss of a spouse (reviewed by Daly & Wilson, 1990; Fessler, 2010; Wilson & Daly, 1985). This would suggest that younger men may show lower disgust propensity than older men, and post hoc analyses show such trends in our data. However, perhaps owing to general declines in neural responsiveness with age (Fessler et al., 2003), some empirical reports suggest the opposite (Curtis et al., 2004; Fessler et al., 2003; Quigley et al., 1997). This question should be examined in future work.

Our approach to disgust derives from an evolutionary, functional, and modular view of emotions. However, while consistent with such an approach, our results do not in themselves prove the veracity of this view. Proponents of constructivist views of emotion could conceivably construe our findings as indicating that “disgust” arises out of the conjunction of risk aversion and cultural schemas of contaminants and the appropriate gendered reactions to them. We have noted several observations from nonhuman animals suggesting that the patterns that we have documented are not unique to humans. We expect that, as data on disease avoidance in nonhuman species accumulates, evidence of both sexual dimorphism and individual differences will build, and such evidence will harmonize with our findings regarding both human sexual dimorphism and individual differences in risk-proneness. We view findings of this type as revealing phylogenetic continuity in the evolved mechanisms underlying the set of experiences termed “disgust.” Hence, if our expectations in this regard are fulfilled, doubt will be cast on the applicability of strong versions of constructivism to this case.

Implications for the Study of Emotion More Broadly

The intersection between affect and risk-taking behavior is a broad area of study, offering many opportunities to integrate theory and evidence across the behavioral sciences. The relative state model, previously applied primarily to risk-taking in the realm of social behavior, can in principle be usefully applied to the study of mechanisms involved in the production of any behavior that has different outcome variance than alternative behaviors. Here we applied this framework to predict and explain patterns of individual differences in a fairly narrow phenomenon. From a higher-level cost/benefit perspective, various forms of disgust can be interpreted as risk-management mechanisms to the extent that they motivate behaviors that incur some expense in order to reduce a risk of harm. This risk-differentiated pattern likely holds for other emotional experiences beyond disgust—fear, anxiety, and pain seem to motivate behaviors that mitigate potential harm at the cost of foregoing opportunities. Still other emotional mechanisms produce risk-accepting behavior, that is, the pursuit of benefits despite the potential for harm. For example, anger motivates the use (or threat) of violence, which can produce rewards (e.g., captured resources, vanquished rivals, or the deterrence of future transgressions) at the cost of potential somatic or reputational damage. Likewise, sexual arousal motivates acceptance of sexual opportunities as well as the associated risk of disease transmission. And so on. Other emotional experiences (e.g., happiness) have no clear relationship with risky outcomes; our perspective does not apply to these cases.

Our framework predicts that the broader suite of affective experiences that motivate and enable costly avoidance of different types of harm should show similar demographic patterns to those we report for disgust. A full review is beyond our present scope, but, as noted above, fear, anxiety, worry, and pain do indeed seem to be more pronounced among women (Else-Quest et al., 2006; Feingold, 1994; Fillingim et al., 2009; Keogh, 2012; McLean & Anderson, 2009; McLean et al., 2011), as do related processes such as attention to others' disgust (Kraines, Kelberer, & Wells, 2016). Similarly, emotions that motivate risk-taking, such as anger, should show reversed patterns (Fessler et al., 2004; Sell et al., 2009). Further, individual differences in disgust are correlated with differences in anxiety (Olatunji et al., 2009) and the negative relationship, noted earlier, between disgust propensity and violent behavior (Pond et al., 2012) hints that individual differences in disgust propensity may be negatively correlated with the propensity to experience emotions that cause risky violent behavior, such as anger.

We have highlighted high-level functional similarities and corresponding demographic patterns among various emotions, but this should not be mistaken for a claim that these experiences are functionally or mechanistically identical—there are clearly differences at some levels of analysis (Holbrook, 2016). For example, pathogen disgust and fear seem to have different input-output logic, suggesting domain-specific specialized functions. Common behavioral outputs of fear—for example, freezing, fleeing, and opening the eyes wide to maximize visual awareness—seem quite different from the behavioral outputs of pathogen disgust—measured withdrawal, nausea/vomiting, and “squishing” the face to restrict access to nose, mouth, and eyes

(reviewed by Tybur et al., 2013)—suggesting that the types of threats posed by many fear-inducing stimuli, such as predators or aggressive conspecifics, require different rapid-response mitigation tactics than do contaminants. Domain-specific harm mitigation responses are not limited to behavior: Experimental exposure to sets of images comprised mostly of pathogen-relevant threats (e.g., corpse, vomit, dirty toilet) activates oral immune responses, but exposure to a set of images primarily suggesting violent threats does not (Stevenson et al., 2011). Hence, pathogen disgust and fear can be differentiated at the mechanistic level of input-output logic (at least partially—some stimuli may activate both emotions) and at a low functional level: Pathogen disgust serves to regulate exposure to potentially harmful microbes whereas fear serves to regulate exposure to a different (but possibly partially overlapping) class of potential harms. Likewise, there may be a harm avoidant emotion, called the “heebie-jeebies” in colloquial English, that functions to protect us from skin parasites and which possesses an input-output logic empirically distinguishable from both disgust and fear (Blake et al., 2017). The possible phylogenetic relationship among various forms of disgust discussed above—that related but distinct mechanisms evolved through a process of serial homology—may apply to the broader suite of harm-avoidance mechanisms.

Howsoever sharp or blurry the distinctions between emotions such as disgust and fear at the level of input-output mechanisms or low-level functional specificity, from a high-level functional view, because all of these emotions are often implicated in risk-differentiated behavior, we should expect similar epidemiological patterns. We look forward to further tests of this broad prediction. Such tests would bear on interesting mechanistic questions about the extent to which various processes that produce risk-differentiated outputs involve integrated or partitioned information-processing architecture—for example, to what extent (if any) do pathogen disgust, fear of snakes, and anger at transgressors derive from overlapping neural machinery? Tybur et al. (2013) suggest that the information-processing architecture of the disgust response involves coordination of several distinct mechanisms, including midlevel processing mechanisms that assign values to the various payoffs implied by the detection of relevant cues. We take no position on whether a single valuation mechanism is shared by several emotions, or if each emotion system has its own unique valuation mechanism. In either case, the selection pressures imposed by our species' history of effective polygyny should be expected to have shaped the relative valuations of opportunity and hazard differently for men and women, and the valuations implicit in the outputs of various emotion systems should be correlated due to stable individual differences.

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SUPPLEMENTARY MATERIALS

to

Disgust as a Mechanism of Decision Making Under Risk

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Study 2 Scale Validation

In Study 2, we employed the pathogen disgust measure introduced by Curtis et al. (2004). This measure uses seven matched pairs of images. Each pair consists of a pathogen-relevant stimulus and a similar, but pathogen-irrelevant stimuli. Replicating Curtis et al (2004), we found that for each pair, the pathogen-relevant image was rated as more disgusting (Table S1). Thus in the main text, our analyses were based on a composite of the ratings of the pathogen-relevant images.

Table S1.

Paired t tests of disgust items

	Raw effect	<i>p</i> value	<i>df</i>
pair a	1.62	3.18E-66	469
pair b	1.46	2.29E-68	470
pair c	0.44	2.32E-22	469
pair d	2.92	2.99E-138	467
pair e	1.55	9.51E-85	468
pair f	0.51	3.54E-09	466
pair g	1.66	1.41E-56	471

Note: Raw effect is difference (on 7-point scale) in disgust rating for pathogen-relevant and paired pathogen-irrelevant image. Pairs are labeled as in Curtis et al. (1994). *p* values and degrees of freedom (*df*) are from directional Welsh's *t* tests.

Harm Avoidance Items

Below are the lists of items used in each study.

Study 1

Please rate how often, in your daily life, you tend to do the following

[1 = *Very Rarely or Never*; 5 = *Extremely Often*]

1. Ride in a car without using a seatbelt
2. Check that the door is locked before going to bed
3. Jaywalk in light traffic

Study 2

1. You are going to drive a short distance through a residential neighborhood. The drive will take 3 minutes and your speed will be under 25 mph. Would you use your seatbelt? (Assume the car does not automatically make an annoying noise that stops when the seatbelt is buckled.)

[1 = *Definitely not use seatbelt*; 5 = *Definitely would use seatbelt*]

- 1a. Do you have a driver's license?
2. You are spending three months away from home in a large city for a special opportunity (e.g. temporary project for your employer, taking courses towards a degree). The city has some crime problems, but the apartment building where you

are living seems fairly safe. Some of your neighbors lock their doors when they leave, and some do not. How often would you lock your door?

[1 = *never lock door*; 5 = *always lock door*]

3. While staying in the large city (as above), your daily commute is a walk from your apartment to work/class. It takes 15 minutes if you walk through a poorer neighborhood, or 30 minutes to take a longer route through a wealthier neighborhood. How often would you take the longer route?

[1 = *never take the long route*; 5 = *always take the long route*]

4. You accept a new job that offers you an increased income and the option to buy elite health insurance that will give you access to the best medical care available at a reasonable market price. If you decline the elite insurance, your new income will be 50% more than your current income. If you accept the elite insurance, your new income will be 40% more than your current income. How likely are you to accept the elite insurance?

[1 = *would definitely decline*; 5 = *would definitely accept*]

5. Do you try to keep emergency supplies on hand? Examples include
- first aid kits in your home, car, office, athletic bags, camping gear, etc.
 - fire extinguishers in home, office, etc.
 - water, blankets, jumper cables in your vehicle
 - matches, candles, batteries, etc in places where electrical power might be disrupted
 - other supplies specific to your location/situation

[1 = *I always try to keep emergency supplies*; 5 = *I never try to keep emergency supplies*]

6. Some people wear helmets when they ride a bike; others don't. Even if you don't ever ride a bike, would you say that you are a helmet person or a no-helmet person?

[1 = *definitely no helmet*; 5 = *definitely helmet*]

7. A nearby pharmacy is offering free flu shots. It will take you about 30 minutes to go get a shot. You're busy but you could rearrange your schedule without major problems. Would you go get the flu shot?

[1 = *definitely would not*; 5 = *definitely would*]

8. Today you hear that a few people became ill last week after eating at your favorite restaurant. You call the restaurant to ask about the situation, but you only get the standard recorded message stating the usual hours of operation. You had made plans to eat there tonight. Would you cancel your plans?

[1 = *definitely would not cancel*; 5 = *definitely would cancel*]

9. Yesterday there was a violent terrorist attack at an entertainment event (e.g., sports match, music concert) in a large European city, killing 30 people and injuring many more. The group that organized the attack claims it will soon attack more events, including in the U.S. Today you happen to win a raffle for free tickets to a big event next weekend that you think you'd enjoy. Would you go to the event?

[1 = *definitely would not go*; 5 = *definitely would go*]

10. Some people put a lot of effort into learning about healthy eating. For example, they read articles and books on the subject, or they consult with experts (e.g., medical doctors, professors, etc.), or they keep careful records of their own eating. Other people put their efforts into other things and don't go out of their way to learn about healthy eating. Do you put much effort into learning about healthy eating?

[1 = *definitely do not*; 5 = *definitely do*]

11. New neighbors move in next door to you. Every morning, they let out their dog, a pit bull, into their front yard. You've read that pit bulls can be dangerous, but they say that their dog is friendly. The dog pokes his nose through the fence as you walk by. Would you reach your hand over the fence and pat his head?

[1 = *definitely not*; 5 = *definitely yes*]

- 11a. Would you pat a dog with a friendlier reputation, like a golden retriever?

[1 = *definitely not*; 5 = *definitely yes*]

Supplemental Analyses

As reported in the main text, our harm avoidance scales showed low internal reliability. We nevertheless reported analyses based on composites of these scales and interpreted the results with caution. For completeness, we report item-by-item analyses here that correspond to the scale-based analyses in the main text.

Table S2 shows a trend towards more female harm avoidance in both studies, consistent with our hypotheses. Tables S3 and S4 reports item-by-item correlations between harm avoidance items and our risk and disgust measures. Many of the items significantly correlate as expected, and no correlations are significantly reversed from our predictions. We also predicted that the harm avoidance correlations with disgust would be stronger than the correlations between risk and disgust. This hypothesis was not supported. On an item-by-item basis, some of the harm avoidance correlations with disgust are of a similar magnitude to the risk-disgust correlations.

Table S2

Trends towards more female harm avoidance

item	<i>d</i>	95% CI	
		LL	UL
Study 1			
lock door	0.17	0.04	0.29
jaywalk	0.16	0.03	0.29
seatbelt	0.12	0.00	0.25
Study 2			
skip event	0.23	0.05	0.41
healthy eating	0.17	-0.01	0.36
elite insurance	0.17	-0.01	0.35
long route	0.16	-0.02	0.34
cancel dinner	0.13	-0.05	0.31
emergency			
supplies	0.10	-0.09	0.28
seatbelt	0.06	-0.13	0.24
bike helmet	0.06	-0.13	0.24
pitbull	0.03	-0.16	0.21
lock doors	-0.02	-0.20	0.16
flu shot	-0.14	-0.32	0.05

Note: LL: Lower limit; UL: Upper limit Positive *d* indicates greater female harm avoidance.

Table S3

Study 1 Correlations between Harm Avoidance Items, Risk Propensity, and Disgust

Item	df	DOSPERT		TDDS-Sexual		TDDS-Moral		TDDS-Pathogen	
		r	p	r	p	r	p	r	p
jaywalk	938	-0.33	<0.00001	0.18	<0.00001	0.07	0.01495	0.06	0.03394
seatbelt	939	-0.29	<0.00001	0.08	0.00846	0.07	0.01174	0.02	0.22910
lock									
door	938	-0.17	<0.00001	0.07	0.02128	0.05	0.06962	0.09	0.00178

Note: TDDS: Three domain disgust sensitivity (Tybur et al., 2009); DOSPERT: Domain Specific Risk Taking Scale (Blais & Weber, 2006; Weber et al., 2002).

Table S4

Study 2 Correlations between Harm Avoidance Items, Risk Propensity, and Disgust

item	df	DOSPERT		TDDS- Sexual		TDDS- Moral		TDDS- Pathogen		Curtis Pathogen	
		r	p	r	p	r	p	r	p	r	p
seatbelt	467	-0.26	<0.00001	0.01	0.43744	0.10	0.01593	-0.02	0.68548	-0.05	0.84337
skip event	470	-0.25	<0.00001	0.28	0.00000	0.04	0.18623	0.26	<0.00001	0.23	<0.00001
pet pitbull	471	-0.25	<0.00001	0.23	0.00000	0.10	0.01471	0.19	0.00002	0.12	0.00517
cancel dinner	470	-0.16	0.00023	0.20	0.00001	0.15	0.00079	0.34	<0.00001	0.24	<0.00001
lock doors	471	-0.15	0.00048	-0.05	0.84546	0.05	0.16197	0.08	0.05075	0.01	0.40106
bike helmet	470	-0.14	0.00080	0.10	0.01833	0.09	0.02977	0.00	0.47666	0.06	0.10939
long route	470	-0.12	0.00483	0.17	0.00009	0.11	0.00634	0.23	<0.00001	0.16	0.00027
flu shot	470	-0.09	0.02785	0.01	0.41635	0.10	0.01548	0.07	0.06645	0.06	0.08715
emergency supplies	470	-0.02	0.36575	0.04	0.21667	0.10	0.01951	0.10	0.01196	0.06	0.11310
healthy eating	469	0.04	0.77711	0.08	0.03967	0.13	0.00239	0.05	0.12527	0.12	0.00454
elite insurance	471	0.05	0.87912	0.01	0.39736	0.00	0.51052	0.07	0.07364	-0.01	0.54800

Note: TDDS: Three domain disgust sensitivity (Tybur et al., 2009); DOSPERT: Domain Specific Risk Taking Scale (Blais & Weber, 2006; Weber et al., 2002); Curtis Pathogen scale (Curtis et al., 2004).

Finally, in the main text we reported observed correlations between disgust measures and the DOSPERT and between disgust measures and harm avoidance. Tables S5 and S6 show the same correlations within each sex. The patterns of correlations are similar for men and women, indicating that the overall correlations are not simply caused by sex differences.

Table S5

Sex –split correlations between measures of disgust and risk propensity

	Study 1			Study 2		
	<i>r</i>	95% CI		<i>r</i>	95% CI	
		LL	UL		LL	UL
WOMEN						
TDDS index	-0.28	-0.37	-0.18	-0.31	-0.42	-0.18
sexual	-0.31	-0.39	-0.22	-0.34	-0.44	-0.22
moral	-0.20	-0.30	-0.11	-0.20	-0.32	-0.07
pathogen	-0.13	-0.23	-0.03	-0.18	-0.31	-0.03
Curtis						
Pathogen				-0.13	-0.25	0.00
MEN						
TDDS index	-0.20	-0.28	-0.10	-0.13	-0.26	0.01
sexual	-0.23	-0.30	-0.14	-0.12	-0.26	0.02
moral	-0.12	-0.20	-0.02	-0.10	-0.22	0.02
pathogen	-0.11	-0.20	-0.02	-0.05	-0.18	0.07
Curtis						
Pathogen				0.00	-0.12	0.12

Note: TDDS: Three domain disgust sensitivity (Tybur et al., 2009); DOSPERT: Domain Specific Risk Taking Scale (Blais & Weber, 2006; Weber et al., 2002); Curtis Pathogen scale (Curtis et al., 2004).

Table S6

Sex –split correlations between measures of disgust and harm avoidance

	Study 1			Study 2		
	<i>r</i>	95% CI		<i>r</i>	95% CI	
		LL	UL		LL	UL
WOMEN						
TDDS index	0.17	0.08	0.27	0.33	0.22	0.44
sexual	0.19	0.10	0.28	0.23	0.10	0.35
moral	0.12	0.03	0.21	0.24	0.12	0.35
pathogen	0.09	-0.01	0.20	0.29	0.17	0.41
Curtis						
Pathogen				0.26	0.14	0.38
MEN						
TDDS index	0.10	0.01	0.17	0.31	0.20	0.43
sexual	0.09	-0.01	0.18	0.21	0.09	0.35
moral	0.07	-0.02	0.14	0.18	0.04	0.32
pathogen	0.06	-0.02	0.14	0.32	0.18	0.44
Curtis						
Pathogen				0.19	0.05	0.33

Note: TDDS: Three domain disgust sensitivity (Tybur et al., 2009); Curtis Pathogen scale (Curtis et al., 2004).

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