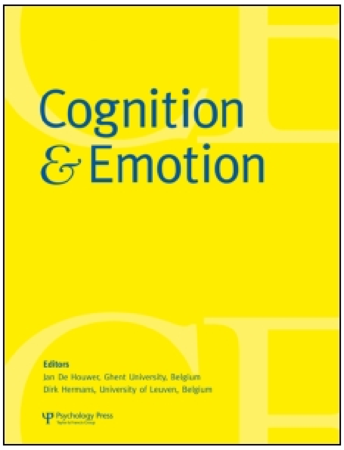

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A feel for disgust: Tactile cues to pathogen presence

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BRIEF REPORT

A feel for disgust: Tactile cues to pathogen presence

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One function of disgust is to act as a pathogen-avoidance system preventing contact with substances harbouring disease-causing organisms. Avoiding pathogens, however, requires systems for their detection. Whereas previous research on disgust has focused on visual and olfactory detection cues, one largely overlooked modality is touch. Here we examine whether tactile cues play a role in pathogen detection and activate the disgust response. Participants briefly touched and then rated stimuli varying along dimensions predicted to correlate with pathogen presence: moisture, temperature, and consistency. Results show that participants rated wet stimuli and stimuli resembling biological consistencies as more disgusting than dry stimuli and stimuli resembling inanimate consistencies, respectively. No main effect for temperature was found. We report on predicted interactions, the relationship between disgust ratings and perceived infection risk, and individual differences. Taken together, these data suggest that touch is an important modality providing information for disgust-related processes.

Keywords: Disgust; Disease avoidance; Touch; Pathogens.

Disgust is one of the basic emotions, elicited in response to a variety of acts and substances from faeces and fornication to stealing and spit (Curtis & Biran, 2001; Fessler & Navarrete, 2003; Rozin & Fallon, 1987). Over the past two decades, research on disgust has expanded, as have models to explain the heterogeneity of disgust elicitors (e.g., Haidt, McCauley, & Rozin, 1994; Rozin & Fallon, 1987; Schaller & Duncan, 2007; Tybur, Lieberman, & Griskevicius, 2009). A common theme across these models is the role disgust plays in protecting against infection from disease-causing agents. Here we focus on this pathogen-avoidance function of disgust and examine whether particular tactile cues regulate the disgust response.

For any mechanism to function as a pathogen-avoidance system it must include detection components that are sensitive to the properties associated with pathogen presence. Direct detection of pathogens, however, is not possible since most are invisible to the naked eye. For this

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reason, it is likely that evolution took advantage of cues—visual, olfactory, etc.—that correlated with pathogen presence in ancestral environments to shape the disgust system.

Although many studies have used a range of stimuli to induce disgust (e.g., Lerner, Small, & Loewenstein, 2004), only a few have explicitly investigated the particular features that render these stimuli disgusting. Of these, most have focused on visual and olfactory cues. For instance, Curtis, Aunger, and Rabie (2004) presented over 40,000 individuals from around the world with pairs of similar pictures, one displaying cues indicative of pathogen presence (e.g., a plate of fluid coloured red and yellow resembling biological fluids) and one that did not (e.g., a plate of fluid coloured blue, a colour atypical of biological fluids in the real world). They found that participants rated images displaying visual cues that correlate with pathogen presence as more disgusting than similar images without such cues present. Rozin, Millman, and Nemeroff (1986) likewise found that faeces-shaped fudge and plastic cockroaches elicited disgust despite the absence of actual pathogens, suggesting these stimuli still possessed cues that would have reliably indicated pathogen presence in ancestral environments. A handful of other studies have uncovered other visual cues signalling pathogen presence (e.g., skin rashes), though typically in the service of investigating dimensions associated with pathogen load such as symmetry or attractiveness and not disgust per se (e.g., Jones et al., 2004).

Additional lines of research have focused on the olfactory cues associated with the disgust response. Volatile compounds, such as ethyl- and methyl-mercaptan, can be found in faeces and are also released from decaying organic matter (Sato et al., 2002). Indeed, these odorous chemicals have been used in a variety of disgust experiments and are rated as quite unpleasant (e.g., Wicker et al., 2003). As another example, isovaleric acid, a product of the bacterium *Staphylococcus epidermis*, has a strong pungent smell and is responsible for body and foot odour (Ara et al., 2006). Such body odours, particularly when from a stranger, have been shown to activate the amygdala and insular regions of the brain, areas previously associated with disgust (Lundstrom, Boyle, Zatorre, & Jones-Gotman, 2008). Other studies on olfaction and disgust, while not primarily focusing on cues, have identified factors that contribute to the intensity of the disgust response, for instance the identity of the individual emitting the odour (e.g., kin vs. strangers; Stevenson & Repacholi, 2005).

Despite the range of work done on the cues eliciting disgust, one modality that has been largely overlooked is touch. Although researchers have acknowledged that particular tactile properties are associated with disgust (e.g., mushiness, stickiness, and sliminess; Curtis & Biran, 2001), no systematic research with which we are familiar has been conducted on reactions to these properties. Rather, research on touch and disgust has focused on how contact with disgusting items or other individuals renders previously non-disgusting objects as more disgusting (e.g., Morales & Fitzsimons, 2007; Rozin et al., 1986) or on how feelings of disgust are communicated between individuals via touch (Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006).

The sense of touch provides important information about the likelihood of pathogen presence. Over our species' evolutionary history, pathogen load would have correlated highly with the properties of warmth and moisture. Many pathogens thrive in dark, warm, moist environments, conditions ideal for rapid growth and multiplication (Winfield & Richards, 2003). Indeed, moisture content and temperature, along with pH, are the primary physicochemical predictors of microbial proliferation (Lovanh, Cook, Rothrock, Miles, & Sistani, 2007). Furthermore, because pathogens require biological hosts for survival, growth, and transmission, consistencies that are typical of biological objects may also elicit heightened disgust reactions. In nature, softer textures are often indicative of pathogen presence because pathogens break down biological tissues, particularly in plants, fruits, and meats.

Here we investigate the sense of touch and the extent to which moisture, temperature, and consistency influence the disgust response. Considering the conditions under which pathogens are likely to flourish, we made the following predictions: (i) wet stimuli would be perceived as more disgusting than dry stimuli; (ii) stimuli bearing resemblance to biological consistencies would be perceived as more disgusting than stimuli not resembling biological consistencies; and (iii) warm stimuli would be perceived as more disgusting than cold stimuli. We also made the following secondary predictions: (iv) greater levels of disgust would be elicited by stimuli possessing multiple properties typical of pathogen-friendly environments (e.g., warm and wet stimuli); (v) heightened disgust would be associated with greater perceptions that stimuli would make the subject sick; and (vi) individual differences in disgust sensitivity would modulate any observed effects. Specifically, we predicted that individuals more sensitive to disgust as measured by the Disgust Scale-Revised (DS-R; Olatunji et al., 2007) would be more reactive to stimuli with properties cuing higher pathogen load (e.g., moist stimuli). We also predicted that compared to males, females would be more sensitive to items eliciting disgust (e.g., Haidt et al., 1994). With these hypotheses in mind, we designed the following study.

METHOD

Participants

Fifty students (21 males, 29 females; ages 18–29 years, mean age = 21.1) were recruited from undergraduate psychology courses at a major university and participated in exchange for course credit.

Materials

We used two different types of stimuli, one selected for its resemblance to biological, animate consistencies (dough) and one for its resemblance to inanimate consistencies (rope). Although a number of different stimuli could have been chosen to represent each category, we selected these two stimulus types for their ability to hold moisture and to maintain temperature for the duration of the experiment. The dough mixture was made using 2 cups of flour, 2 cups of water, 1 cup of salt, and 1 tablespoon of cream of tartar, yielding a consistency similar to Play-Doh. Each dough stimulus was formed into a fist-sized ball. The rope was a large braided cotton rope cut into fist-sized segments.

We prepared 6 samples of each stimulus type that varied in temperature (cold, room, or warm) and moisture level (wet or dry): 1 cold/wet; 1 cold/dry; 1 room/wet; 1 room/dry; 1 warm/wet; and 1 warm/dry. Cold stimuli were chilled in a mini-refrigerator overnight. Before each participant arrived for the experiment, the two cold dough and rope samples were removed from the refrigerator and one of each stimulus type was submerged in water for 15 seconds to create the cold/wet stimuli and the other two were set aside as the cold/dry stimuli. Room temperature stimuli were prepared before the participant arrived; one of each stimulus type was submerged in room-temperature water for 15 seconds to create the room/wet stimuli and another set aside as the room/dry stimuli. A microwave was used to heat the warm stimuli just prior to participant arrival. Prior experimentation with heating the stimuli was done to ensure we produced warm stimuli of similar temperatures across participants. Pilot testing on research assistants ensured that items varied in temperature and moisture as intended and also that moisture and temperature conditions were similar for both dough and rope (e.g., the dough and rope were similarly wet, similarly cold, etc.) Surface temperature readings using an infrared digital thermometer (ThermoWorks Inc., IR-Mini; device error: $\pm$ 2%) were taken for a set of stimuli and are listed in Table 1. To prevent visual item recognition from affecting perception, each stimulus was concealed inside a small cardboard box.

Design and procedure

A 2 (Consistency: rope, dough) $\times$ 3 (Temperature: cold, room, warm) $\times$ 2 (Moisture: wet, dry) within-subjects design was used, for a total of 12 stimuli presented per participant. Participants were tested

Table 1. *Temperature of stimuli*

	Cold (°F)	*Room (°F)*	*Warm (°F)*
Dough			
Wet stimuli	49.6	72.7	98.4
Dry stimuli	50.4	74.4	92.1
Rope			
Wet stimuli	59.6	74.3	91.4
Dry stimuli	60.4	75.3	87.6

individually and the order in which stimuli were presented was randomised across participants.

Upon entering the lab, participants were seated at a table and informed they would be touching a variety of items and asked to provide their reactions to each item. Participants first completed a short survey that included the Disgust Scale-Revised to measure disgust sensitivity (Olatunji et al., 2007). Next, the experimenter presented the participant with each stimulus, one at a time. Participants were instructed to face away and reach into the box and briefly touch the item inside. Immediately after touching each stimulus, participants were given a short questionnaire prompting them to rate their perceptions of the object on a 7-point Likert scale ranging from -3 to 3: (i) "Please rate how disgusting you found the item you just touched" (anchors: *not disgusting at all/extremely disgusting*; variable label: DISGUST); (ii) "How disgusting would it be to put this item in your mouth?" (anchors: *not disgusting at all—it wouldn't be a problem/extremely disgusting—I'd probably vomit*; variable label: MOUTH); We chose to use these modified anchors to avoid ceiling effects and to ensure that we obtained sufficient variance to conduct statistical analyses. (iii) "How willing would you be to touch this item again?" (anchors: *not willing at all/extremely willing*; variable label: TOUCH); and (iv) "Please rate how appealing you found the item you just touched" (anchors: *not appealing at all/extremely appealing*; variable label: APPEAL). The appealing question was included to ensure we measured aversions (after all people might find touching disgusting things enjoyable). A separate question asked participants: "How likely do you think the substance you touched would make you sick?" also rated on a 7-point Likert scale (anchors: *not likely at all/extremely likely*; variable label: SICKNESS). This question was included to measure subjects' perceived risk of infection. All questions were presented in a random order between stimuli. After the questionnaire was completed, the next box was presented until all twelve conditions were completed.

RESULTS

Measures of disgust were coded such that higher scores indicated greater aversion (less appeal). A repeated-measures analysis of variance (ANOVA) was used to test the effects of temperature, moisture, and consistency on each of the four measures of disgust. Though these items were highly intercorrelated (Cronbach's alpha = .80; Table 2), we opted to present the results separately for each variable. Similar results are obtained when the three disgust questions (DISGUST, TOUCH, and MOUTH) are compiled. We also examined all two-way interactions to determine the effects of multiple properties on disgust ratings. Post hoc analyses with false discovery rate adjustments were used to compare different categories of stimuli. This method is similar to the Bonferroni method of correction, but lowers the risk of committing Type II errors (Benjamini & Hochberg, 1995). All Ns = 50 and all ps are two-tailed unless otherwise noted. For brevity, we report results using the variable labels described above.

Strong support was found for our first hypothesis, that wet stimuli would be perceived as more

Table 2. *Correlations between measures of aversion*

	1	*2*	*3*	*4*
1. How disgusting (DISGUST)	1.00	.46***	.63***	.55***
2. How disgusting to put in mouth (MOUTH)		1.00	.41***	.38***
3. How willing to touch again (TOUCH)			1.00	.54***
4. How appealing (APPEAL)				1.00

Note: ***$p < .0001$; $N = 611$.

disgusting than dry stimuli. ANOVAs on each of the items showed large main effects for Moisture: DISGUST, $F(1, 49) = 178.12$, $p < .0001$, $\eta^2 = .20$; MOUTH, $F(1, 49) = 45.77$, $p < .0001$, $\eta^2 = .07$; TOUCH, $F(1, 49) = 94.19$, $p < .0001$, $\eta^2 = .13$; and APPEAL, $F(1, 49) = 112.74$, $p < .0001$, $\eta^2 = .15$. Across all measures, participants reported a greater aversion to the wet stimuli compared to the dry stimuli.

Support was also found for our second hypothesis, that stimuli bearing resemblance to biological consistencies would be perceived as more disgusting than stimuli not resembling biological consistencies. On all three disgust-related questions, ANOVAs revealed the dough stimuli were perceived as more aversive than the rope stimuli: DISGUST, $F(1, 49) = 55.09$, $p < .0001$, $\eta^2 = .06$; MOUTH, $F(1, 49) = 31.63$, $p < .0001$, $\eta^2 = .05$; and TOUCH, $F(1, 49) = 10.26$, $p = .001$, $\eta^2 = .01$. No main effect for Consistency was found for APPEAL, $F(1, 49) = 0.26$, $p = .61$, $\eta^2 = .00$.

Contrary to our prediction, no support was found for the third hypothesis, that warmer stimuli would be perceived as more disgusting than colder stimuli: DISGUST: $F(1, 49) = 1.17$, $p = .31$, $\eta^2 = .00$; MOUTH: $F(1, 49) = 0.21$, $p = .81$, $\eta^2 = .00$; TOUCH: $F(1, 49) = 0.71$, $p = .49$, $\eta^2 = .00$. We raise possible explanations for this null result in the discussion.

Our fourth hypothesis was that stimuli possessing multiple cues to pathogen presence would be regarded as most disgusting. Indeed, we found an interaction between Moisture and Consistency for three of the four variables: DISGUST, $F(1, 49) = 7.88$, $p = .005$, $\eta^2 = .01$; TOUCH, $F(1, 49) = 8.43$, $p = .004$, $\eta^2 = .01$; and APPEAL, $F(1, 49) = 10.65$, $p = .001$, $\eta^2 = .01$. For each of these items, the wet dough stimuli were found to be significantly more disgusting than the wet rope stimuli, which in turn was significantly more disgusting than any of the dry stimuli. Additionally, for DISGUST, the dry dough was more disgusting than the dry rope (see Figure 1). No interaction was found for the MOUTH variable.

To determine whether the disgust ratings related to perceptions of how likely each stimulus would be to make the subject sick, for each subject we computed a correlation between their ratings of DISGUST and SICKNESS across all twelve boxes. We then averaged these correlations across participants and found a significant overall relationship, $r_{avg} = .70$, $p < .0001$. Next, we wanted to determine whether there were effects of moisture, consistency, and temperature on perceptions of how likely the stimuli would be to cause sickness. Based on our prior findings showing an effect of moisture and consistency, but not temperature, we expected to see a similar pattern with perceptions of SICKNESS. Indeed, an ANOVA revealed a main effect of Moisture: $F(1, 49) = 33.11$, $p < .0001$, $\eta^2 = .05$, and Consistency: $F(1, 49) = 23.36$, $p < .0001$, $\eta^2 = .04$, on SICKNESS with wet stimuli and stimuli resembling biological consistencies rated as more likely to make subjects

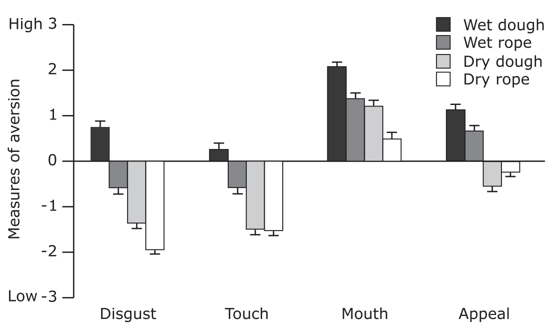

Figure 1. *Aversion ratings (M ± SE) of stimuli. In general, participants perceived wet stimuli to be more disgusting overall, less desirable to touch, more disgusting to put in their mouth, and less appealing than dry stimuli with the greatest intensity elicited by the wet dough and least intensity by the dry rope.*

sick than dry stimuli and inanimate consistencies, respectively. No main effect for temperature was found, $F(1, 49) = 0.36$, $p = .70$, $\eta^2 = .01$, nor were there any interactions.

Our last hypothesis was that individual differences in disgust sensitivity would modulate observed effects. Using scores on the Disgust Scale–Revised (Olatunji et al., 2007), we computed for each subject an index of disgust sensitivity. We found that disgust sensitivity as measured by the DS-R positively correlated with a participant's average rating of DISGUST across stimuli, $r_{avg} = .36$, $p = .009$. Indeed, regression analyses revealed that disgust sensitivity predicted DISGUST, $\beta = .18$, $t(48) = 4.48$, $p < .0001$; MOUTH, $\beta = .23$, $t(48) = 5.84$, $p < .0001$; TOUCH, $\beta = .30$, $t(48) = 7.63$, $p < .0001$; and, marginally, APPEAL ($p = .09$). The positive relationship between disgust sensitivity as measured by the DS-R and our DISGUST variable raised the question of whether perceived sickness mediates this link. However, we did not find a significant correlation between disgust sensitivity as measured by the DS-R and SICKNESS ($r = .19$, $p = .19$).

With respect to sex differences, only the MOUTH item showed a significant effect of Gender, $F(1, 49) = 8.04$, $p = .005$, $\eta^2 = .01$. Consistent with previous findings (e.g., Haidt et al., 1994), females ($M = 1.45$; $SD = 1.50$) found it more disgusting to put the stimuli in their mouths than did males ($M = 1.08$; $SD = 1.86$). No other variables showed significant gender effects.

DISCUSSION

This study investigated the tactile side of disgust and found that moisture and consistency had robust effects on measures of disgust. Wet stimuli were rated to be significantly more disgusting (and less appealing) than dry stimuli. Similarly, participants found the dough stimuli to be more disgusting than the rope, reported being less likely to touch dough stimuli again, and indicated they would be less likely to put the dough in their mouth. The interaction effects we report indicate that moisture augments the effect of consistency. That is, the effects of consistency are greater for the wet stimuli than the dry stimuli, with the wet dough eliciting the highest levels of disgust. These data support the hypothesis that perceptual information regarding moisture and consistency, two cues indicative of pathogen presence, are taken as input by emotive procedures that regulate the disgust response.

In this study, the strongest effects were found for moisture. For instance, our manipulation of moisture showed stronger effects on DISGUST ($\eta^2 = .20$) than did our manipulation of consistency ($\eta^2 = .06$). Water is a key ingredient for life and it is possible this dimension trumps all others in the assessment of pathogen presence. It is also possible that moisture was more effectively manipulated in our study. We suspect that different manipulations of consistency—ones that better capture the animate/inanimate distinction—would yield similar results as was found for moisture in this experiment. Properties bearing resemblance to living organisms, which host a multitude of communicable pathogens, should elicit higher levels of disgust compared to inanimate matter, which is less likely to host and sustain communicable pathogens.

Contrary to our predictions, we did not find any effects for temperature. There are multiple reasons why this might have occurred. First, object temperature might not be a dimension that is taken as input to assess pathogen presence. Rather, evolved pathogen-detection systems might be more tied to environmental climate rather than object-specific temperatures. That is, perhaps our pathogen sensitivities and corresponding disgust sensitivities are calibrated based on whether one is, for instance, in the tropics where pathogens flourish versus in the tundra where they do not. Indeed, there is recent evidence suggesting that disgust sensitivities vary with environmental conditions (Schaller & Murray, 2008). Thus, temperature might influence disgust sensitivity in the predicted direction, but on a more macro level. Another reason why we might not have found any effects of temperature is due to the range of temperatures we used. Our warm stimuli ranged from approximately 88°F to 98°F and our cold stimuli ranged from approximately 50°F to 60°F. Had we selected a more extreme range of cold temperatures (as we were close to the upper bound for the warm stimuli), we might have found a larger effect of temperature. In a previous pilot of this study, however, in which stimuli were frozen in a freezer (not just chilled in the refrigerator) versus warmed in a microwave, we still did not see any effect of temperature. Certainly, future experiments more tightly controlling temperature range can further illuminate whether this dimension is of importance in perceiving pathogen presence within the local environment.

In line with the prediction that disgust tracks perceptions of infection risk, we found both a direct relationship between disgust ratings and perceptions of how likely the substance would be to make the subject sick, and main effects of moisture and consistency on perceptions of sickness risk. This pattern is consistent with a model of pathogen avoidance in which cues indicating pathogen presence (e.g., moisture and consistency) are taken as input by a system that assesses the probability of infection/sickness risk, which, in turn, activates the disgust response. A viable alternate explanation, however, is that subjects might not have interpreted our survey question as intended. Although our survey question asking about sickness was thought to assay infection risk, it is possible that subjects interpreted this question as asking about disgust and not infection risk/sickness per se, or that asking about sickness activates concepts of disgust. Thus, the data showing an effect of moisture and consistency on our sickness variable might instead be replications for the pattern found for our disgust variable. If this were true, we should have seen a significant correlation between disgust sensitivity and sickness in the same way that we observed a significant correlation between disgust sensitivity and our disgust variable. But we did not. Nevertheless, inclusion of additional questions directly assaying infection and illness likelihood would better assess the link between pathogen cues, perceived infection risk, and disgust.

Regarding sex differences, the only sex difference we observed was on ratings of how disgusting it would be to put the stimuli in one's mouth. Females reported being more disgusted than did males. Although this finding is consistent with previous literature showing an effect of gender on disgust (e.g., Curtis et al., 2004; Haidt et al., 1994), we were surprised that this was the only sex difference in our data—even moisture, the dimension for which we found the largest effect, did not show an effect of gender. Future studies might incorporate additional tactile properties associated with disgust to see if males and females are more similar in their assessments via this modality.

Future studies might address other issues raised by the current investigation. Our stimuli were selected based on their ability to hold moisture and heat and thus were not perfectly matched on a variety of dimensions (e.g., smoothness). For instance, the surfaces of the dough stimuli were smoother than the rope stimuli and could explain why the dough was perceived to be more aversive. In the wet condition, however, rope was rated as much more disgusting than the dry dough, so it is unlikely that smoothness alone was driving the disgust effect found. Likewise our stimuli were roughly the same size, yet differed in shape with the dough being round and the rope being cylindrical. Although it is unlikely that these particular shapes affected disgust, it would be prudent in future studies to control for this factor. Last, we did not control for the possible odours of the stimuli. Whereas the rope did not have any detectable odour, the dough stimuli had a slight odour. This produced a faint smell of dough in the room where the experiment was conducted. We attempted to address this concern by keeping the room well-ventilated and asking participants to turn their heads away while touching the stimuli, thus reducing the influence of smell on their disgust ratings. Any slight odour that did remain would have been present when the participant touched both dough and rope stimuli making it unlikely that smell could explain the effects we found. Nevertheless, selecting stimuli that could be manipulated without causing odour, or otherwise controlling for odour via a question or nose plugs, would be desirable in future studies.

Future studies might also collect reactions to a wider range of stimuli than those used here. In this study, we chose to use objects that were easily manipulated in terms of temperature and wetness. Additional studies might select more mucoid, slimy and viscous textures—textures rated as highly disgusting—to examine the range of tactile properties associated with the disgust response. Moving forward in the investigation of tactile cues to pathogen presence, it would also be important to collect perceived wetness and temperature ratings. Though pilot testing indicated that our wet conditions were equally wet, warm conditions equally warm, etc., psychological assessment of these properties would allow even greater confidence in interpretations of results.

A last consideration is sample selection. We explored tactile disgust on a sample of college undergraduates. It would be very interesting to conduct a similar study in more culturally diverse samples as well as younger and older samples to see whether sensitivity to cues to pathogen presence change over the lifetime. In addition, it would be interesting to investigate the perception of tactile cues to pathogen presence in various clinical samples such as those with animal phobias (Davey et al., 1998) and obsessive-compulsive disorder (Sprengelmeyer et al., 1997).

In closing, tactile information has been used to investigate a range of phenomena such as object recognition (Klatzky, Lederman, & Metzger, 1985), co-operation (Kurzban, 2001), and emotion communication (Hertenstein et al., 2006). Here we demonstrate that much like cues derived from other modalities such as vision and olfaction, tactile cues, specifically moisture content and consistency, regulate intensities of disgust, an emotion proposed to function as a pathogen avoidance system (Curtis & Biran, 2001; Rozin & Fallon, 1987; Schaller & Duncan, 2007). Such findings, coupled with past work, suggest that a comprehensive view of disgust requires consideration of the multiple input and output modalities used for emotion processing and communication. In this way, we will have a more complete feel for disgust.

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