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PROP Taste Sensitivity is Related to Visceral but Not Moral Disgust

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Abstract Taste perception and the emotion of disgust are both processed by the anterior insular cortex. A current debate in the emotion and disgust literature is whether visceral and moral disgust responses are fundamentally the same. The purpose of the present study was therefore to test whether visceral and moral disgust would be responded to similarly as a function of taste sensitivity. Several disgust questionnaires measuring different components of visceral disgust (core, pathogen, sexual) and moral disgust were administered along with a 6-*n*-propylthiouracil (PROP) taste sensitivity test. Individuals were categorized on the basis of their responses to PROP as super-tasters, tasters, and non-tasters. PROP taster status was used as an independent variable to assess responses on the various disgust questionnaires, and PROP scores were also correlated with the disgust-dependent measures. Results showed that super-tasters were more responsive to all visceral components of emotional disgust than tasters and non-tasters, and that taste sensitivity was positively correlated with disgust responsivity. However, taste sensitivity was not related to responses concerning moral disgust in any way. Results are discussed in terms of the proposed theoretical underpinnings of emotional disgust and the physiological and neuroanatomical foundations that may mediate different forms of it.

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Disgust is one of the six basic emotions—emotions that any healthy human no matter who they are, or where they are from can recognize and experience (Ekman and Friesen 1975). Each of the basic emotions has a specific facial expression, physical response, and mental state associated to it. When we are disgusted, our thoughts and feelings vary from mild negativity to overwhelming revulsion, but they all center around the urge to avoid that which is causing the feeling (Rozin et al. 2008). Physiologically, disgust reduces sweating, blood pressure, and heart rate and can trigger fainting, nausea, and vomiting (Levenson, Ekman & Friesen 1990; Page 2003). In the state of disgust, our face displays a highly specified set of muscle contortions: the mouth opens (the tongue may also extend), the nose wrinkles, and the upper lip retracts while the lower lip protrudes (Rozin et al. 1994). Even people who have been blind from birth make the same face of disgust as everyone else (Galati et al. 1997; Peleg et al. 2006).

Interestingly, the facial expression made when in the throes of emotional disgust is the same as that made when tasting bitter compounds (Ekman and Friesen 1975; Rozin et al. 1994). Correspondingly, it is widely held that the emotion of disgust originated from the oral rejection of bitter taste as a defense mechanism to protect against ingestion of poisonous or spoiled foods (Darwin 1872/1965; Rozin and Fallon 1987). It has been well established that the insula comprises the primary taste cortex and that the anterior insula in particular is responsible for the hedonic quality and intensity of taste and oral sensations (Kringelbach et al. 2004; Small 2010). The anterior insula

has also been shown to be the focal neurological site for disgust processing (Phillips et al. 1997; Wicker, et al. 2003; Wright et al. 2004). Processing and perception of taste and disgust thus share the same neurological substrate, although the degree of neurobiological overlap is not yet known.

Despite consensus regarding the evolution of disgust, there are diverging positions about what stimuli, beyond rotted food, trigger and engage this emotion. Disgust is variously defined as elicited by "core" triggers including food; bodily fluids; gore and death; and/or to sexuality (e.g., incest), disease (e.g., pathogens), and morality (e.g., cheating) (Rozin et al. 2008; Curtis et al. 2004; Oaten et al. 2009). Moreover, the degree to which one is disturbed by disgust (sensitivity) and the ease and tendency for one to become disgusted (propensity) are constructs that have been differentially examined in both subclinical and experimental populations (van Overveld et al. 2006; Cisler et al. 2009).

Most debated is whether responses to physical triggers of disgust, such as rotted food, gore, sexuality, and disease, are fundamentally the same as responses elicited by morally repugnant transgressions. In other words, is the emotional state elicited by news that a rich politician pilfered money intended for a homeless shelter within the same emotional constellation as the feeling elicited by seeing an unflushed bowel movement or tasting quinine? Several recent experiments have weighed in on both sides of the debate. Using fMRI, Borg et al. (2008) showed that some of the brain areas that were activated when men thought about pathogen disgust scenarios (eating their sister's scab), sexual disgust scenarios (watching their sister masturbate), and moral disgust scenarios (burglarizing their sister's home) were the same; for example, the amygdala. But this experiment also showed that though incestuous transgressions and burglary were rated as equally morally bad, incest elicited significantly more activation in the anterior insula than moral transgressions did. That is, compared with sexual and pathogen disgust, moral disgust elicits activation in both disparate and overlapping regions of the brain.

In another recent experiment, Chapman et al. (2009) gave participants quinine to taste and the muscular distortions of their face were recorded using electromyography. Next, participants played a $10 "ultimatum game" and facial expressions were recorded using electromyography again. Ultimatum games are frequently used in studies of behavioral economics and involve two participants pitted against one another where one is designated the role of "proposer" and the other the role of "receiver". The proposer offers various divisions of a certain sum of money and the receiver has the option to accept the proposer's offer and get some money, or reject the offer, and in so doing receive nothing. In the Chapman study (Chapman et al. 2009) "receiver" facial expressions to divisions of money that were fair ($5 for both the proposer and the receiver) were compared with very unfair divisions ($9 for proposer, $1 for receiver) and examined in relation to facial expressions made to quinine. Results showed that both the taste of quinine and very unfair propositions of monetary divisions elicited activation of the levator labii muscle region of the face, which raises the upper lip and wrinkles the nose. In other words, the facial expression participants made to bitter taste was similar to the face they made when there were cheated out of money. However, the emotion of anger is also triggered by being cheated and anger elicits activation of the levator labii region as well (Rozin et al. 1994).

Research proposing that moral and visceral disgust are not the same has convincingly argued that anger, and not disgust, is the primary emotion experienced during moral transgressions such as the ultimatum game (Rozin et al. 2009). Over a decade ago, Rozin et al. (1999) developed a tripartite model to explain when various violations would elicit either contempt, anger, and disgust and provided cross-cultural evidence that participants will pick the word "anger" or a picture of an angry face to denote their response to moral violations of autonomy, such as *seeing someone steal a purse from a blind person*. Recently, Horberg et al. (2009) further substantiated these findings and showed that anger, not disgust, was elicited by immoral acts that cause harm or injustice, such as taking advantage of someone to advance oneself. The difference between disgust and anger has also been assessed by colloquial language. Nabi (2002) showed that the common understanding of the word "disgust" reflects a combination of the conceptual meaning of disgust and anger, and that 75% of the time people use the word "disgust" to describe anger provoking events. My laboratory has also found that when considering various immoral acts, such as: *the man who just sold you his car lied about its condition and gave you fake contact details*, and asked to endorse how "angry", "disgusted", and "grossed out" they were by them, participants felt "angry" most strongly and almost never "grossed out," regardless of how disgust sensitive they were further demonstrating how the slang term "grossed out" specifically captures the construct of visceral disgust, where the word "disgust" does not (Herz and Hinds in preparation).

Considering the common oral-taste basis for emotional disgust and distaste, and the debate over the connection between moral and visceral disgust, it was of interest to understand whether taste sensitivity was related to disgust responsivity, and how moral disgust fit into this puzzle. I propose that because the anterior insula is highly involved in both taste perception and emotional disgust processing, individuals who have more intense taste experience will be more disgust reactive.

"Super-tasters", individuals who are homozygotes (PAV/PAV) at the TAS2R38 gene locus on chromosome 5, have a lifetime of more intense oral sensations including bitter,

mouth feel, and burn than individuals who are homozygous (AVI/AVI) at TAS2R38, "non-tasters". "Tasters" who experience moderate oral-taste sensations are presumed to be heterozygous (AVI/PAV) at this gene locus. I suggest that since super-tasters have a life-long history of stronger oral sensations than non-tasters, the anterior insula of super-tasters might be especially sensitized. As such, other stimuli which activate the anterior insula may be responded to more intensely as well. Thus, in the present experiment, it was hypothesized that disgust triggers would be responded to more strongly by super-tasters than tasters and non-tasters. Whether all triggers of disgust would be more awful for super-tasters, or whether responses to moral transgressions would differ from those involving visceral sources of disgust was an open question. Sex differences were also examined in relation to these topics because it has been shown that females generally have more intense disgust reactions than males (Aleman and Swart 2008; Davey 1994; Haidt et al. 1994). To address these questions, several questionnaires measuring various components of visceral and moral disgust were administered to male and female college students and taste sensitivity was examined in relation to the responses.

Methods

Participants

Participants were recruited from three large lecture courses in the Cognitive, Linguistic and Psychological Sciences department at Brown University. One hundred and sixty-two students (100 female, 62 male) consented to complete this experiment. The mean age of participants was 19.4 years. Participation was entirely voluntary and no inducement or compensation was given.

Materials

To assess responsivity to disgust, three disgust questionnaires were used. (1) An eight-item short form of the Disgust Scale (DS) (Inbar et al. 2009; Haidt et al. 1994) which predominately evaluates core disgust. Sample items include: *I might be willing to try eating monkey meat under some circumstances*, and *You see a bowel movement left unflushed in a public toilet.* For the first four items (e.g., "monkey meat"), participants use a 1–5 category scale anchored by 1 = "Strongly disagree (very untrue about me)", to 5 = "Strongly agree (very true about me)". For the next four items, (e.g., "bowel movement" item) participants use a 1–4 category scale (1 = not at all disgusting, 4 = extremely disgusting). The maximum obtainable score is 36 and the minimum is 8. (2) The Three Domain disgust scale (3D) (Tybur et al. 2009). The 3D scale was developed as an alternate to the traditional DS. It is the only published disgust test to date with a subscale that explicitly measures moral disgust. Two other subscales measure visceral disgust to sexuality and pathogens, respectively. There are seven items in each subscale; for example: *Having anal sex with someone of the opposite sex* (sexuality subscale); *Accidentally touching a person's bloody cut* (pathogen subscale); *A student cheating to get good grades* (morality subscale). Participants rate their response to each item using a 1–7 category scale (1 = not at all disgusting, 7 = extremely disgusting). (3) The Disgust Propensity and Sensitivity Scale Revised (DSPP-R) (van Overveld et al. 2006) which measures disgust reactivity with two eight-item subscales testing the likelihood of becoming viscerally disgusted—propensity (DPSS_P), and how bad disgust feels when visceral disgust is experienced—sensitivity (DPSS_S). Sample items include: *I avoid disgusting things* (propensity subscale), and *It scares me when I feel nauseous* (sensitivity subscale). Participants use a 1–5 category scale, (1 = never, 5 = always) to rate themselves on each item.

For the present study, taste sensitivity was measured by having participants assess 6-*n*-propylthiouracil (PROP). PROP is a standard biological assay used in evaluations of taste sensitivity (Bartoshuk et al. 1994; Lee, Prescott & Kim, 2008; Mennella et al. 2011; Tepper et al. 2010); however, it is not the only measure of taste sensitivity and other stimuli, such as "thermal taste" (sweetness from heat), have recently been recommended as possibly better assays (Green and George 2004; Lim et al. 2008). Nevertheless, PROP was considered an especially good measure for the present research because of its bitter taste, given that the human response to bitterness is presumed to be ontologically related to the emotion of disgust (Rozin et al. 2008). Note, however, that direct measurements of fungiform papilla were not taken in the present study, and that "taste sensitivity" as discussed here refers specifically to super-threshold PROP taste ability as a presumed correlate of individuals' fungiform papilla number and density (more PROP sensitive individuals express higher number and density of fungiform papilla; Delwiche et al. (2001); Duffy et al. 2004). PROP was administered as 1.6 mg saturated in round filter papers that were individually contained in small translucent envelopes (donated by Linda Bartoshuk's laboratory at the University of Florida, Gainesville). PROP taste sensitivity was measured with the General Labeled Magnitude Scale (gLMS; Bartoshuk et al. 2004). The gLMS is a vertical line scale partitioned into evenly distributed numerical increments of 0–100 with six semantic labels (barely detectable, weak, moderate, strong, very strong, and strongest imaginable sensation of any kind) fixed at empirically determined points on the scale.

Procedure

Each participant performed the experiment while seated among the rest of the volunteers from their class at the end of a lecture. The experimenter was introduced and briefly explained that the present study was part of a larger research project investigating sensory perception and emotion, and that in the present experiment the sense of taste was being explored. No further background was given, and no mention of "sensitivity" as a factor of interest was made. Participants were told that they would be answering several emotion questionnaires and that they were free to opt out of the study at any time, or decline from answering any questions that they were uncomfortable with. It was further explained that after completing the questionnaires they would then taste "something" and rate their experience of it. The experimental use of PROP was briefly discussed and the envelope containing the PROP paper that each participant would receive was shown. Volunteers were told that individuals vary widely in their sensitivity to this substance, that responses are genetically determined, that some people do not perceive the compound at all, and that variations of sensitivity are "normal". No indication as to what PROP might taste like if they could perceive it was offered. An explanation of the gLMS and non-taste examples of how it is used to measure the intensity of various experiences was then given. For example, the light from a candle seen from a distance on a dark night would be "barely detectable," and staring directly into the sun would be an example of "the strongest imaginable sensation of any kind". Volunteers did not undergo any explicit practice trials with the gLMS before testing began. After these instructions were given, the experimenter asked if anyone else wished to leave and the final group of participants remained.

Participants first read and signed a Brown University IRB approved consent form. Questionnaire packets which in order contained the DS, 3D, DSPP-R, and gLMS, were then distributed along with the PROP filter paper envelopes. Participants were instructed to complete the questionnaires in order and that there were no right or wrong answers. When participants got to the last page with the gLMS they were told to open the envelope and taste the filter paper inside by briefly placing it on their tongue, and then to mark an "X" on the gLMS scale location that corresponded to their experience of the sensation. Peppermint candies were handed out to participants for relief after the PROP test.

Results

All participants fully completed all of the instruments. To examine taste sensitivity in relation to disgust responsivity, participants' self-rating on the gLMS to the PROP taste challenge was both correlated with their scores on the disgust questionnaires and used to allocate participants to taster groups. For analyses involving PROP taster status as an independent variable, participants were allocated to three taster groups on the basis of their responses on the gLMS following the methods employed by Lee et al (2008) and after discussions with taste researchers who recommended that taster status cutoffs reflect that "tasters" would be the dominant group (John Prescott, personal communication November 24, 2009; Linda Bartoshuk, personal communication November 24, 2009). Accordingly, in the present study, participants who rated their experience of PROP between 50 and 100 (very strong–strongest imaginable) were categorized as super-tasters (ST). Participants who rated their experience between 0 and 15 (barely detectable–weak) were categorized as non-tasters (NT), and participants who rated their experience between these two poles were categorized as tasters (T). This allocation resulted in 51 super-tasters (39 female, 12 male), 74 tasters (39 female, 35 male), and 37 non-tasters (22 female, 15 male).

Between subjects ANOVAs with taster status (super-taster, taster, and non-taster) and sex (female, male) as independent variables were performed on the dependent measures from the three questionnaires: DS, 3D_Pathogen, 3D_Sexuality, 3D_Morality, DPSS_Propensity, and DPSS_Sensitivity. Where post hoc comparisons were performed, Newman-Keuls tests were used. In addition, correlations between PROP intensity scores and the responses given on each of the disgust-dependent measures were examined.

A significant main effect of sex showing that females scored higher than males was found for every disgust measure except DPSS_Sensitivity. The results are summarized in Table 1. Females did not give higher self-ratings on the gLMS to the PROP taste challenge than males did (M (female)=44.4, SEM=2.81; M (male)=38.9, SEM=3.42), F (1, 158)=1.06, p=0.30. Importantly, sex did not interact with taster status for any of the dependent measures.

A significant main effect of taster status was obtained for overall core disgust sensitivity (the DS test), F(2, 156)= 8.68, p<0.01. Post hoc comparisons revealed that super-tasters (M=25.12, SEM=0.53) were more sensitive to disgust than tasters (M=21.85, SEM=0.53) and non-tasters (M=20.62, SEM=0.61). Non-tasters did not differ reliably from tasters. Responses on the DPSS_R also showed a significant main effect as a function of taster status on the propensity subscale (DPSS_P), F (2, 156)=7.27, p<0.01. Post hoc comparisons revealed that super-tasters (M=25.00, SEM=0.58) had a higher propensity to become disgusted than tasters (M=22.58, SEM=0.47) and non-tasters (M= 21.05, SEM=0.57). Tasters did not differ from non-tasters. The sensitivity subscale (DPSS_S) did not yield any statistically reliable findings, F(2, 156)=0.24, p=0.79.

Table 1 Sex differences on dependent measures of disgust

	DS_T[a]	3D_S[a]	3D_P[a]	3D_M[b]	DPSS_P[a]	DPSS_S
Female	23.8±0.4	32.9±0.7	32.7±.06	32.6±0.8	23.7±0.4	18.8±0.5
Male	20.7±0.5	22.1±0.9	29.6±0.8	29.5±1.3	21.8±0.5	17.4±0.5
F_Stat	$F(1, 156)=8.95$	$F(1, 156)=75.83$	$F(1, 156)=5.65$	$F(1, 156)=4.84$	$F(1, 156)=7.00$	$F(1, 156)=3.13$

Means±the standard error of the mean (SEM) are given for each disgust-dependent measure

DS_T Disgust Scale Total, *3D_S* Three Domain Sexuality subscale, *3D_P* Three Domain Pathogen subscale, *3D_M* Three Domain Morality subscale, *DPSS_P* Disgust Propensity, *DPSS_S* Disgust Sensitivity

[a] Significant at 0.01

[b] Significant at 0.05

Figure 1 illustrates the results for the Three Domain disgust scale. As can be seen, significant main effects were obtained for the sexuality subscale, $F(2,156)=3.39$, $p<0.05$, and the pathogen subscale, $F(2,156)=5.26$, $p<0.1$. Post hoc comparisons showed that for measures of sexual disgust, super-tasters were more reactive than tasters and non-tasters. Tasters also scored higher than non-tasters ($M=28.23$, SEM=1.06 vs. $M=25.51$, SEM=1.4) but due to the large variance in scores the difference was not statistically reliable. For pathogen disgust, however, all taster groups were statistically different from each other (super-tasters $M=34.39$, SEM=0.81; tasters $M=31.14$, SEM=0.71; non-tasters $M=28.40$, SEM=0.97). Super-tasters were most sensitive to pathogen disgust triggers, and tasters were more sensitive than non-tasters. Most notably, however, there were no differences in the responses obtained between the taster groups on the morality subscale, $F(2,156)=0.61$, $p=0.55$.

Participants' self-rated scores on the gLMS to the PROP challenge were also correlated with the disgust-dependent measures. Table 2 summarizes the results. Significant positive correlations between sensitivity to PROP and responsivity to disgust triggers were found for every dependent measure except for the morality subscale of the 3D and the DPSS_S sub-test. Indeed a "zero" correlation between responses to moral transgressions and PROP sensitivity was obtained.

Discussion

The present study showed that responsivity to the visceral components of emotional disgust, such as body products, disease, and sexuality were related to individual differences in PROP taste sensitivity. Super-tasters were more responsive to these disgust triggers than tasters and non-tasters. There was also a trend for tasters to be more responsive on these measures than non-tasters. Indeed it appears that taste sensitivity linearly corresponds with visceral disgust sensitivity as correlations revealed that the higher one's PROP sensitivity the greater one's responsiveness on all measures of visceral disgust. These findings support the hypothesis

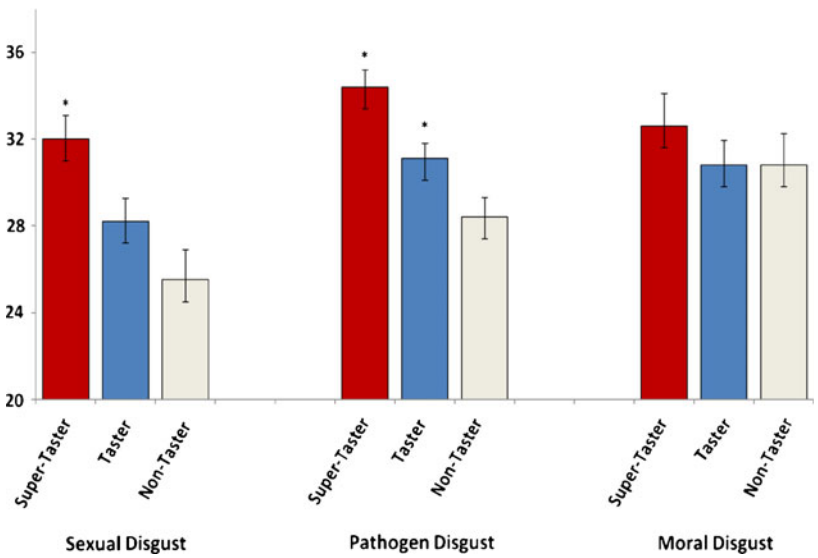

Fig. 1 Disgust reactivity as a function of taster status on the subscales of the Three Domain disgust questionnaire

Table 2 Pearson correlations between self-ratings of PROP taste sensitivity and disgust-dependent measures

	DS_T[a]	3D_S[a]	3D_P[a]	3D_M	DPSS_P[a]	DPSS_S
PROP	r=0.27	r=0.19	r=0.22	r=0.00	r=0.27	r=0.05

[a] Significant at 0.05

that PROP taste sensitivity and visceral disgust responsivity are fundamentally connected. Importantly, data from the pathogen subscale of the 3D questionnaire showed that super-tasters were statistically more sensitive to pathogen disgust triggers than tasters who were in turn were more responsive than non-tasters. A widely held view is that the primary function of the emotion of disgust is to promote avoidance of disease (Curtis et al. 2004; Oaten et al. 2009). Thus, the present finding that the strongest disgust–PROP sensitivity effects were found for the measure that singularly reflects disease-disgust may be of special significance.

By contrast, this study found that responses to moral disgust triggers were not related to PROP taste sensitivity. Results from the moral subscale of the 3D were equivalent among the three taster groups and there was no correlation whatsoever between taste sensitivity and the responses participants gave to items on the 3D_moral subscale. This shows that moral disgust and visceral disgust are different and that moral disgust is not related to the oral or bitter taste foundations of the basic disgust response.

It was surmised that greater responsivity to visceral disgust could be the result of a lifetime of increased activation by oral sensations to the anterior insula, such that the insula becomes sensitized and thus other stimuli that activate the insula (e.g., disgust) are reacted to more strongly. Accordingly, super-tasters may have greater sensitization through taste than tasters, and tasters more sensitization than non-tasters. This supposition was born out to some degree by the present data as a sometimes statistically reliable trend differentiated the three taster groups on disgust responsivity. However, neuroimaging was not performed in the present study and there is no other direct neurobiological evidence as yet that anterior insula activity in response to disgust and taste directly correspond. Therefore, it cannot be definitively established that the anterior insula is the neurological link between these responses. More pertinent still, it not known what the relation of PROP sensitivity in particular is to anterior insula activity and how its relation to bitter taste perception, or overall taste sensitivity, may relate to neurobiological cross-talk or sensitization. Nevertheless, it has been shown that another sensation, pain, which is processed by the anterior insula is differentially reacted to as a function of PROP taste sensitivity. Erden et al. (2007) found that PROP taste sensitivity was positively correlated with the degree of pain experienced by surgery patients from venepuncture and propanol intravenous injection. Similarly, Small and Apkarian (2006) showed that patients with chronic back pain gave more intense ratings to taste sensations than control subjects. Thus, there is evidence that taste sensitivity can correspond to increased sensation of other insula-based experiences. Direct tests examining the connection between specific sensations, emotions, and anterior insula activation are now needed.

Only one other study to date has examined individual differences in emotional responsiveness in terms of PROP taste sensitivity. Macht and Mueller (2007) found that super-tasters had more intense anger responses to watching a rape scene from the movie *Pretty Woman* than did tasters and non-tasters. However, sadness from watching a death scene in *The Champ* did not differ by taster status. The authors proposed that heightened taste sensitivity may correspond with heightened emotional arousal which occurs in the emotion of anger but not sadness. Disgust and other arousing emotions, such as fear and joy, however, were not assessed.

A hotly debated topic in the morality and emotion literature is whether oral rejection and moral offenses are essentially linked. Some evidence has suggested that they are (e.g., Chapman et al. 2009), while others propose that the connection is merely metaphorical and that the emotions actually felt are anger and/or loathing (Bloom 2004; Horberg et al. 2009; Rozin et al. 1999). The present results support the contention that oral and moral rejections are not coupled. However, the items in the 3D_Morality subscale (e.g., *A student cheating to get good grades*) may not be sufficiently egregious to elicit a true disgust response. Moreover, the moral transgressions in the 3D questionnaire all relate to stealing, cheating, and lying type transgressions and like the Borg et al. (2008) "burglary" example are all non-visceral violations. Perhaps moral transgressions that include a physically violating component, such as violent crime or sexual misconduct, would induce a visceral disgust response and then taste sensitivity would be relevant. Notably, a recent study that examined the relationship between bitter taste and morality found that priming participants with the taste of bitter intensified judgments of moral wrongness for violations that included visceral disgust transgressions such as "eating your dead dog" and cousin incest, among other non-visceral violations (Eskine et al. 2011), which lends some support to the idea that moral violations that involve visceral disgust may link to taste perception. It is now of interest to specifically determine how and if moral transgressions that *do not* involve visceral violations (e.g., stealing) compare to moral violations that do involve visceral transgressions (e.g.,

murder and incest), with respect to taste sensitivity, and bitter taste in particular.

Notably, in the present study taste sensitivity was measured by PROP. PROP is not the only measure of taster sensitivity but it was of interest in the present study because it elicits bitter taste which is the proposed ontological origin of the emotion of disgust and induces the same facial expression as disgust. This is also why taste sensitivity was always tested last—so that it would not prime emotional disgust and thus confound the questionnaire data. Unknown, however, is whether responding to the prior questionnaires could have influenced the way that participants evaluated PROP using the gLMS. Despite instructions to reserve the top point of the scale for the "strongest imaginable sensation of any kind" participants who were alerted to their disgust sensitivity and/or who were aroused by disgust from completing the questionnaires may have been driven to use higher points on the gLMS to express their PROP responses than they would have in isolation. The degree to which emotional arousal and prior use of different rating scales influences responses made to PROP and/or use of the gLMS is an empirical question worthy of research. It would also be of interest to know if participants had been allocated to taster groups by a different taste method (e.g., thermal taste) whether the same results would have been obtained, or if bitter taste in particular is the critical assay in studies of disgust. Further research examining disgust reactivity as a function of different measures of taste sensitivity and tastant perception (e.g., bitter vs sour vs salty vs sweet) are now needed. A final caveat with respect to taste sensitivity and the present data is that since genetic testing was not performed, individual TAS2R38 allele classification in relation to taster status designation is unknown.

Women in the present study were generally more disgust reactive than men, which is a consistent finding in disgust research (Aleman and Swart 2008; Haidt et al. 1994). Moreover, there were more female than male participants in the present sample and therefore it could be claimed that statistical comparisons were thusly compromised. The unequal number of male and female participants in this study was due to the self-selection method of participant recruitment coupled with the fact that there were more female than male students enrolled in the classes from which volunteers were drawn. Since relatively large sample sizes were obtained with both sexes, and sex did not interact with any of the disgust-dependent variables, it is argued that the statistical analyses for the main findings of this research were not problematically confounded.

The sensitivity subscale (DPSS_S) of the DPSS_R questionnaire did not yield significant effects in the present study. The DPSS-R test is typically used to assess disgust-relevant phobias (e.g., blood and spider). In the present study, overall scores on this subscale were uniformly low (M=18 out of a maximum score of 40). Thus, the items in this scale (e.g., *It scares me when I feel nauseous*) appear to be of little relevance to the undergraduate population tested here. Nevertheless, the propensity subscale (DPSS_P) did yield significant results as function of taster status, showing that the likelihood of becoming disgusted was higher for super-tasters than tasters and non-tasters, a finding that supports the data obtained on the DS and pathogen and sexuality subscales of the 3D questionnaire. That is– responsivity to visceral disgust triggers is related to PROP taste sensitivity.

The present results showed that the emotional disgust response to cues of strange food, body products, infection, contamination, and inappropriate sexuality appear to be linked through oral sensation, while moral transgressions do not. Moral disgust and visceral disgust may therefore only be linked through the conceptual motivation to avoid and reject. That is, both violations of the body (e.g., accidentally touching a person's bloody cut) and violations of justice (e.g., a student cheating) involve rejecting the source, but the commonality ends there. The feelings of "disgust" that arise from justice violations are therfore metaphorical and linguistically emphasizing expressions of "rejection" rather than reflecting true sensations of nausea. To validate this explanation and further investigate this topic, research assessing visceral and non-visceral moral violations and the neuroanatomy and physiology that mediates these experiences is now needed.

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