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Review

Exploring the Emotion of Disgust: Differences in Smelling and Feeling

Lorenzo D. Stafford [1,*], Diana S. Fleischman [1], Nicholas Le Her [1] and Thomas Hummel [2]

[1] Centre for Comparative & Evolutionary Psychology, Department of Psychology, University of Portsmouth, Portsmouth PO1 2DY, UK; diana.fleischman@port.ac.uk (D.S.F.); nicholas.her@myport.ac.uk (N.L.H.)
[2] Department of Otorhinolaryngology, TU Dresden, Dresden 01307, Germany; thummel@mail.zih.tu-dresden.de
* Correspondence: lorenzo.stafford@port.ac.uk

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Abstract: Disgust evolved to motivate humans away from disease cues and may heighten discernment of these cues. Disease cues are often best perceived through our sense of smell, however very few studies have examined how eliciting disgust influences smell intensity or valence. In two novel experiments we investigated how domains of disgust induction influence odor perception. In experiment 1 participants (n = 90) were randomly allocated to one of two kinds of Disgust Induction (DI): Pathogen (DI-P), Moral (DI-M) or a Control (DI-C), followed by an evaluation of three affectively distinct odors (disgust-related, neutral, liked). Using a modified procedure in experiment 2, participants (n = 70) were again randomly assigned to one of the three disgust induction conditions, but here they evaluated one (disgust-related) odor during disgust induction. In experiment 2 we also measured feelings of disgust and anger. In experiment 1, surprisingly, we found overall ratings of odor disgust were lower in the DI-P compared to other groups, whereas in experiment 2, odor disgust was higher in the DI-P versus the DI-M/DI-C conditions, which also differed from each other. We also found that whereas feelings of disgust were higher in DI-P, in contrast, anger was higher for those individuals in the DI-M condition. These findings suggest that compared to a Control condition, inducing state Pathogen and Moral disgust lead to higher perceived odor disgust, whereas feelings of disgust/anger yield divergent effects. The work here also demonstrates that methodologies utilizing odor perception (disgust) can be a useful addition to measuring changes in state disgust.

Keywords: disgust; emotions; evolutionary psychology; odor

1. Introduction

Disgust can be separated into three different domains [1,2], each having a distinct adaptive function: protecting the individual from possible infection or the consumption of food that may cause harm (pathogen disgust); assessing potential mates and avoiding sexually transmitted infection, thereby maximizing reproductive success (sexual disgust) and punishment and avoidance of social transgressors, e.g., cheating (moral disgust). We call the first two, pathogen and sexual disgust, "disease avoidant disgust" collectively. One issue in this taxonomy in the research is that it is unclear whether moral disgust is related to sexual or pathogen disgust and therefore can be considered as a form of disgust [3] Evidence that moral disgust (e.g., elicited by reading about someone stealing) is in any way related to pathogen disgust (e.g., seeing pictures of rotting food) is contested.

A few studies have provided evidence that moral disgust and pathogen disgust are related. In one study, a bitter tasting beverage (thought to induce disgust) increased the harshness of

subsequent moral judgments compared to a sweet or neutral beverage [4,5] The idea here is that disgust at bitter tasting food can be an indicator of food contamination, and is linked to the original function of the emotion of disgust [2]. If moral disgust is exacerbated by a bitter beverage, this implies that moral disgust shares an affective component with the original oral incorporation disgust [4]. Tasting a bitter beverage and being treated unfairly in an ultimatum game activate the same facial muscles (levator labii), which was interpreted as further evidence for the shared affective foundations of pathogen and moral disgust [3].

However, there is evidence that counters the claim that moral disgust is related to disease avoidance disgust. For instance, one study found taste intensity to 6-n-propylthiouracil (PROP) bitterness, a taste associated with plant toxins, is related to pathogen and sexual but not moral disgust sensitivity [6]. Hence, if moral disgust was really related to these more physical forms of disgust, this would have predicted an association between bitter taste intensity and moral disgust. Other work has shown that exposure to moral transgressions induces anger more than disgust [7]. Thus, previous literature has not found a consistent association between disgust and morality that one might expect if moral disgust was a domain of disgust.

The olfactory system plays a central role in disgust perception and avoidance [8–10], even more so than taste. Our sense of smell is frequently used to detect foods that are spoiled, long before they have the opportunity to enter our oral cavity and in this way act as an early warning system of disgust avoidant behavior. Even at the time of ingestion, the vast majority of what we perceive as taste, actually comes from our sense of smell in terms of flavor [11,12]. Moreover, since humans perceive only five different tastants (salty, sour, sweet, bitter, umami), but a virtually infinite number of odors [13], our ability to learn and discern what is disgusting/unpleasant rests more on our olfactory than gustatory system.

The aim of the present study was therefore twofold: (1) To explore the use of our sense of smell as the outcome measure of state disgust; (2) To understand how integrated, moral disgust is with more physical forms of disgust. To examine this issue, participants were first induced into either a moral or pathogen disgust state or a control using scenarios and pictures similar to previous research [14].

Following this, participants' perceptions of three different odors (disgust-related, neutral, liked) were tested. The rationale for using three affectively different odors was to understand whether disgust induction yields alterations that are specific to disgust-related odors and also similar to related taste research where three different tastants were presented [4]. Finally, participants completed the three domains of disgust (TDD) questionnaire [1]. We expect that induction into a disgust state will heighten disgust intensity, making us more wary of other cues to disgust and promoting avoidance of such sources [15,16]. If moral disgust induction activates the same disease avoidance system as pathogen disgust, there should be equivalent levels of perceived disgust/unpleasantness of the disgust odor. In contrast, differences in perceived disgust/unpleasantness between these two conditions would be suggestive of divergent systems of disgust avoidance.

2. Experiment 1

2.1. Method

2.1.1. Participants and Design

Ninety female university staff and students participated in the study and were aged between 18 and 55 years (M = 28.8 years, SD = 10.2 years). The study was advertised on the University's website as examining factors that influence our sense of smell and participants were requested to email the researcher to express interest. Only female non-smokers were invited to participate in the study. The study protocol was given ethical approval from the department's ethics committee (British Psychology Society guidelines). The study used a mixed design where participants (Table 1) were randomly allocated to one of two kinds of Disgust Induction (DI): Pathogen (DI-P), Moral (DI-M) or

a Control (DI-C), followed by an olfactory test for three different odors (Disgust/Neutral/Liked). Hence, Disgust Induction was a between-subjects factor, Odor was a within-subjects factor. The main dependent variables were the ratings for the three odors.

Table 1. Mean (SE) Participant Characteristics (Exp 1).

	Group			
	Control (n = 30)	**Moral (n = 30)**	**Pathogen (n = 30)**	
				Group Differences
Age	28.3 (1.9)	28.3 (1.9)	29.7 (1.8)	F < 1, NS
Anxiety	8.0 (0.6)	6.1 (0.5)	7.6 (0.5)	F = 3.54, p = 0.03
Depression	2.6 (0.5)	2.0 (0.3)	2.6 (0.2)	F < 1, NS
Hunger	36.8 (4.3)	37.5 (5.1)	44.3 (4.9)	F < 1, NS

2.1.2. Materials

Disgust Induction

For each of the three disgust inductions (Pathogen, Moral, Control) two news extracts followed by a relevant photograph were used. The news items were described as "taken from the BBC news" (though some were in fact fictional). In the Pathogen condition, one item described in vivid detail, some distasteful scenes from a recently released (in fact fictional) film, which was modeled on the "The Tin Drum", used in previous work [17]. The associated photograph was of an animal corpse riddled with maggots.

For the Moral condition, one news story described members of a family found guilty of defrauding vulnerable people; the photograph was of the convicted female family member. The content for the Control condition was partly based on a previous study [14], with one of the news stories describing the attempt of two male table tennis enthusiasts to break the world record for the longest game; the photograph depicted one of the table tennis players "in action". The stimuli were developed and presented using E-Prime (v1.1.1.4). The structure for each induction was the same: 1. Instructed to read two brief news items that would be followed by a picture associated to that news item; 2. First news item; 3. Fixation cross (1 s); 4. Presentation of first Picture (10 s); 5. Second news item; 6. Fixation cross (1 s); 7. Presentation of second Picture (10 s). Apart from the fixation cross and picture presentations, participants advanced at their own pace, to ensure they read news items completely.

Odors

The study used three affectively different odors (Disgust: Thai fish sauce; Neutral: N-butanol; Liked: Isoamyl acetate, which smells of banana/pears) chosen on the basis of pilot testing, where individuals rated the odors on ratings of disgust; which confirmed higher disgust ratings for the Thai fish sauce. Concentrations for the odors were: Thai fish sauce (50 mL undiluted); N-butanol (2 mL/50 mL distilled water); Isoamyl acetate (2 mL/50 mL mineral oil). The odorants were kept in separate 250 mL (polyethylene) squeeze bottles with brown tape around the bottom of each bottle used to disguise the color of the liquid. After smelling each odor, participants used 100 mm Visual Analogue Scales (VAS) anchored "not at all" and "extremely" followed by the relevant word. The following words within the context of a sentence verifying the question were centered above each line in the following order: "disgusting", "intense", "pleasant". The order for presenting the three odors was counterbalanced.

Disgust Sensitivity Measurement

All participants completed the Three Domains of Disgust, a 21-item questionnaire (TDD, [1]). The TDD measures individual sensitivity to pathogen, sexual and moral disgust as separate domains. The scale consists of 21 items—7 for each domain—for which participants responded on a

7-point Likert-like scale ranging from "not at all disgusting" to "extremely disgusting". Examples of pathogen disgust items were "Stepping on dog poo" and "Standing close to a person who has body odor"; examples of sexual disgust were "Hearing two strangers having sex" and "Bringing someone you just met back to your room to have sex"; and examples of moral disgust were "Stealing from a neighbor" and "Forging someone's signature on a legal document". Some words were adapted to be more applicable to English society—such as "poop" to "poo". Scores for each domain ranged from 0–6, and was the average of scores for the particular domain's items. Higher scores pertained to higher disgust sensitivity. The TDD has been shown to have high levels of reliability, Cronbach's alpha for each factor (pathogen: 0.83, sexual: 0.86, moral: 0.89, [1]).

2.1.3. Procedure

Participants were tested in the Department of Psychology, between 12 and 4 pm in a large well-ventilated room. Participants were instructed to consume only water an hour before the session. On arrival, participants completed the Hospital Anxiety and Depression Scale (HADS) [18]. Next they completed the disgust induction followed by the counterbalanced evaluation of the three different odors. Finally, they completed the disgust sensitivity questionnaire (TDD), and were given a full debriefing and paid five pounds for participation. The study duration was approximately fifteen minutes.

2.2. Data Analyses

In order to facilitate clearer comparisons between odor disgust and pleasantness, the data for the latter were reverse scored, meaning higher ratings were indicative of greater unpleasantness. Preliminary analyses revealed significant group differences for HADS anxiety (Table 1), $F(2, 87) = 3.54$, $p = 0.03$, $\eta^2 = 0.08$, with higher levels of anxiety in the DI-M compared to both Control ($p = 0.01$) and DI-P ($p = 0.05$), who did not differ from each other ($p = 0.55$). To control for these baseline differences, ANCOVA was used in all subsequent analyses. For the odor ratings, separate repeated measures ANCOVAs were conducted for disgust, intensity and unpleasantness, using the within-subjects factor of Odor (Disgust, Neutral, Liked), and the between-subjects factor of Disgust Induction (Control/DI-M/DI-P) and the covariate of anxiety ratings.

2.3. Results

2.3.1. Odor Ratings

For the disgust ratings, there was a main effect of Odor, $F(2, 172) = 14.31$, $p < 0.001$, $\eta^2 = 0.14$, with as expected, higher ratings for the Disgust ($M = 63.4$, $SE = 2.6$) associated odor compared to both neutral ($M = 37.9$, $SE = 2.3$) and pleasant ($M = 18.4$, $SE = 2.3$) odors, with all odors differing from each other ($ps < 0.001$). We also found a main effect of DI, $F(2, 86) = 7.02$, $p = 0.001$, $\eta^2 = 0.14$, where surprisingly, there were lower ratings of disgust across all odors for those in the Pathogen ($M = 31.4$, $SE = 2.8$) compared to both Moral ($M = 43.4$, $SE = 2.9$) and Control ($M = 45.0$, $SE = 2.9$) conditions (both $ps < 0.01$), who did not differ from each other ($p = 0.70$).

Additionally, against prediction, there was no DI × Odor interaction ($F < 1$), and no differences in the disgust ratings for the disgust odor between conditions ($F < 1$) (Figure 1).

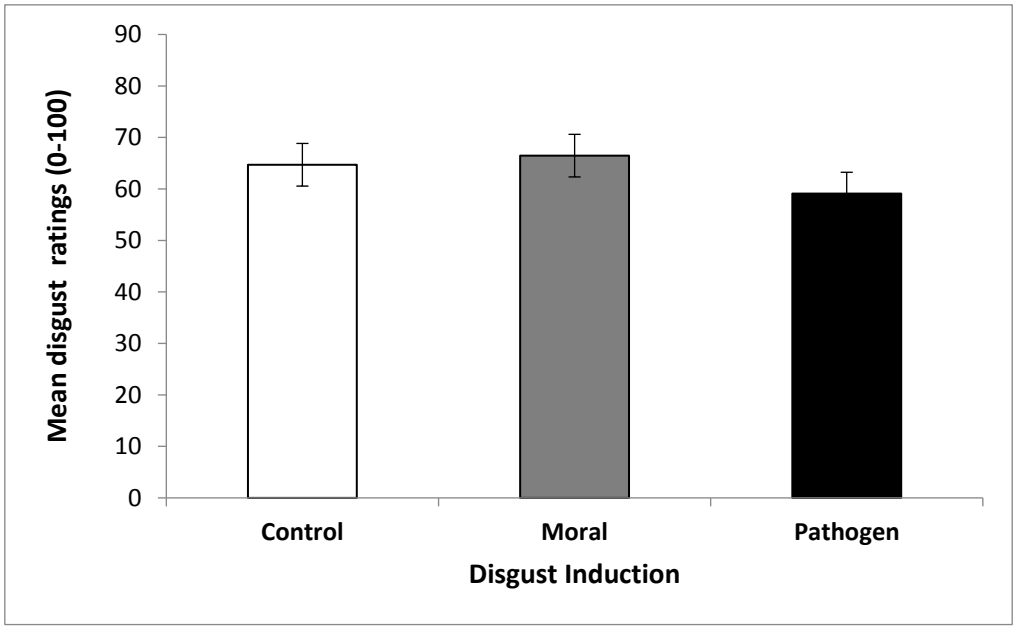

Figure 1. Mean (±SE) disgust ratings for disgust odor, dependent on disgust induction (Experiment 1).

For unpleasantness ratings, there were main effects of Odor, $F(2, 172) = 9.54$, $p < 0.001$, $\eta^2 = 0.10$ and DI, $F(2, 86) = 3.84$, $p = 0.03$, $\eta^2 = 0.08$, which were qualified by a DI × Odor interaction, $F(4, 172) = 2.81$, $p < 0.03$, $\eta^2 = 0.06$. In order to examine the nature of this interaction, we completed separate RM ANCOVAs for each Group; which revealed that for the Pathogen group only, lower unpleasantness ratings for the disgust versus neutral odor (Figure 2). There were no differences in ratings for the disgust odor between conditions ($F < 1$).

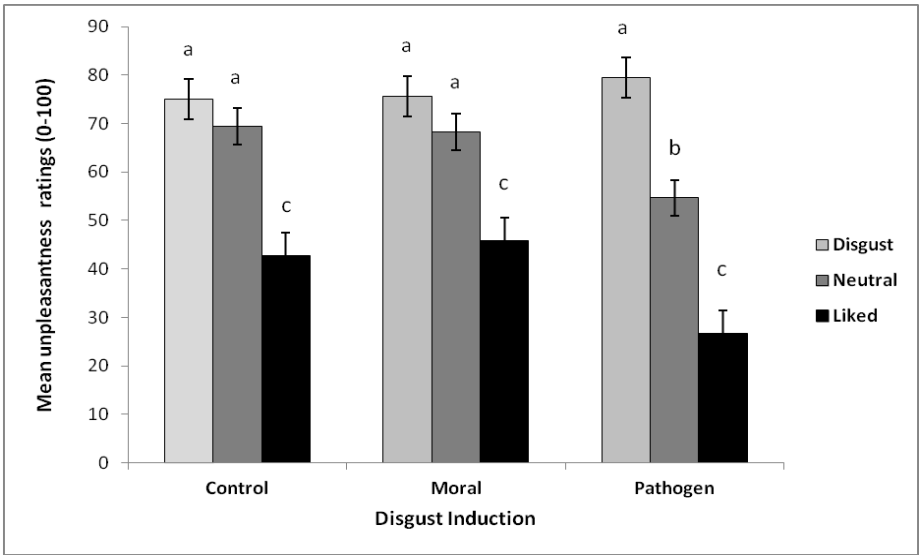

Figure 2. Mean (±SE) unpleasantness ratings dependent on odor and disgust induction (Experiment 1). Note: Letters refer to analyses within each induction group, where mean values denoted by different letters are significantly different from each other: $p < 0.001$.

Due to the unexpected pattern of findings, we also analyzed the above data with the additional factor of Odor order but since none of the significant interactions included DI Group, they are not included here. Additionally, to understand whether the pattern of main findings (Odor disgust/unpleasantness) may have been different when not controlling for Anxiety, we repeated the analyses without this control (ANOVA rather than ANCOVA) and this did not change the significance or direction of these findings.

2.3.2. Disgust Sensitivity—TDD

There were no differences in any of the TDD measures of disgust between the three induction conditions (all Fs < 1.5, Table 2).

Table 2. Mean (SE) Disgust Sensitivity (TDD) (Exp 1).

	Group		
	Control (n = 30)	**Moral (n = 30)**	**Pathogen (n = 30)**
TDD (Moral)	31.9 (0.8)	30.6 (0.9)	30.9 (1.2)
TDD (Sexual)	26.4 (1.4)	27.7 (1.3)	24.4 (1.3)
TDD (Pathogen)	30.9 (1.2)	24.4 (1.3)	26.9 (0.9)

2.4. Discussion of Study 1

Contrary to our prediction there were no differences in disgust (or unpleasantness) ratings for the disgust odor between induction conditions. Moreover, we also found *lower* levels of disgust reported for all three odors in the Pathogen versus Moral and Control groups. In trying to account for these findings, on the one hand they could be taken as evidence of habituation to being in a disgust state, i.e., initially disgust-related stimuli are not perceived as harmful to the organism and therefore become down regulated. Else it could be due to the nature of the induction paradigm where for instance, individuals in the DI-P group having been exposed to a rather unpleasant scenario and associated images are unconsciously comparing these to the odors in the subsequent odor test. This raises the question of whether an alternative method of disgust induction would produce clearer findings. We examined this in experiment two by administering the olfaction ratings for only the disgust odor during the induction, hence reducing the time between induction and odor ratings. Administering only the disgust-related odor in study two further avoids time lag and any decrease in disgust induction from smelling the neutral and pleasant odors. Finally, as the connection between moral and disease avoidant disgust is contested [3,7] we explored whether pathogen or moral disgust induction led to differences in feelings of disgust and anger. We predict higher ratings for odor disgust and feelings of disgust in the pathogen versus moral induction and in contrast, higher ratings of feelings of anger in the moral compared to pathogen induction.

3. Experiment 2

3.1. Method

3.1.1. Participants and Design

Seventy female students were recruited from the University of Portsmouth, aged between 18 and 30 years (M = 20.9 years, SD = 1.78 years). The study was advertised on the University's Participant Pool website as a study "Investigating factors affecting smell". Only female non-smokers were invited to participate in the study.

The study used a between-subjects design: participants were randomly allocated to one of two disgust inductions (DI): Moral (DI-M), Pathogen (DI-P) and Control (DI-C), completing the olfactory test for disgust-related odor. The main dependent variables were the ratings for the odor and feelings of disgust and anger.

3.1.2. Materials

Odor

We used only the disgust-related odor from experiment one. To avoid possible floor/ceiling effects of disgust ratings, we completed a mini-study in order to find the optimum concentration of Thai fish sauce to distilled water dilution. Participants (N = 22) were presented with three separate 250 mL (polyethylene) squeeze bottles containing different concentrations of the odor (40 pct, 20 pct,

10 pct) in a counterbalanced order. On the basis of these findings the concentration of 40 pct fish sauce to water dilution was selected for the main study.

Odor and Emotion Ratings

All ratings were completed on a visual analog scale as in experiment one. In addition to the ratings of unpleasantness and disgust in experiment one, participants also rated how "disgusted" and "angry" the odor made them *feel.*

3.1.3. Procedure

The same disgust induction using photos as articles was used as in experiment one. In this experiment, participants rated the disgust odor during the induction procedure.

This was followed by completion of the emotion ratings and finally the disgust sensitivity questionnaire (TDD), and participants were then given a full debriefing.

3.2. Data Analyses

As in Experiment one, the odor pleasantness data were reverse scored, meaning that higher ratings were indicative of greater unpleasantness. The data for the odor ratings and feelings of disgust and anger were analyzed separately using univariate ANOVAs with the factor of Disgust Induction (DI) Group (Control, Moral, Pathogen). We also completed bivariate correlations between disgust sensitivity (TDD-P, TDD-M) and odor perception, feelings of disgust; this was completed separately for each DI group.

3.3. Results

3.3.1. Odor Test

Analyses revealed an effect of DI on odor disgust, DI, $F(2, 67) = 9.64$, $p < 0.001$, $\eta^2 = 0.22$, where as predicted, ratings were higher in the Pathogen compared to Moral and Control conditions with the latter two also differing from each other (Figure 3).

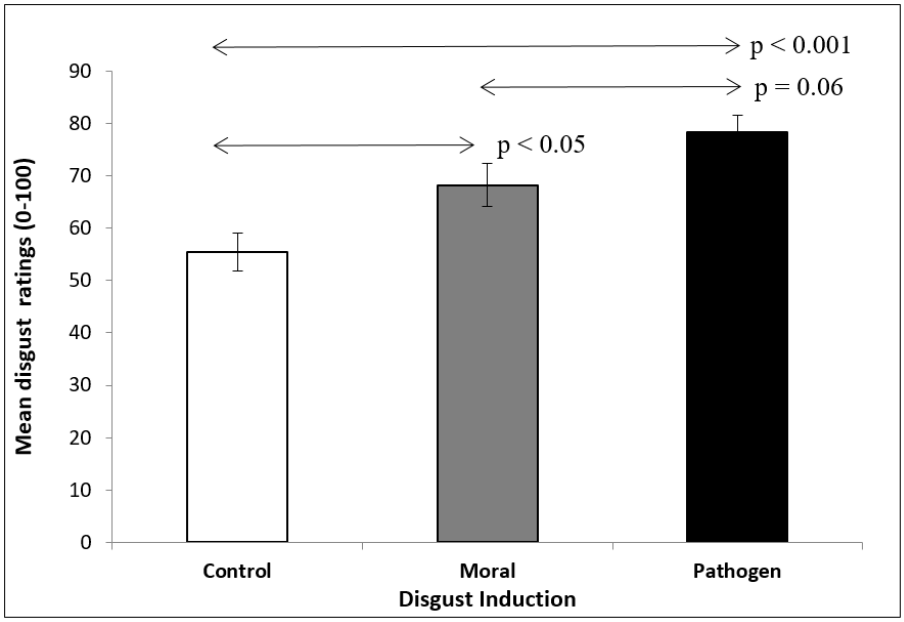

Figure 3. Mean (±SE) disgust ratings dependent on disgust induction (Experiment 2).

Similarly, the ratings for unpleasantness also revealed a significant effect of DI, $F(2, 67) = 3.72$, $p < 0.05$, $\eta^2 = 0.10$, with higher ratings for the Pathogen versus Moral ($p = 0.09$) and Control ($p < 0.01$),

the latter two not differing from each other ($p > 0.35$). For odor intensity, there was an effect of DI, $F(2, 67) = 7.05$, $p < 0.01$, $\eta^2 = 0.17$, with higher ratings for the Pathogen compared to both Moral and Control conditions ($p < 0.05$), the latter two not differing significantly ($p > 0.1$).

3.3.2. Effects on Emotion

In terms of feelings of disgust, we found an effect of DI, $F(2, 67) = 7.41$, $p = 0.001$, $\eta^2 = 0.18$, with as expected, higher ratings for Pathogen compared to both Moral and Control conditions ($p \leq 0.01$), who did not differ from each other ($p > 0.2$) (Table 3). For feelings of anger, there was an effect of DI, $F(2, 67) = 16.90$, $p < 0.001$, $\eta^2 = 0.34$ and interestingly as theorized, higher ratings for the Moral compared to both Pathogen and Control conditions ($p < 0.001$), which did not differ from each other ($p > 0.44$).

Table 3. Mean (SE) Participant Characteristics and Effects on Emotion (Exp 2).

	Group		
	Control (n = 24)	**Moral (n = 23)**	**Pathogen (n = 23)**
Age	21.0 (0.5)	20.7 (0.3)	20.9 (0.3)
Odor Disgust	55.4 (3.6)	68.2 (4.1)	78.2 (3.3)
Odor Unpleasantness	77.0 (2.4)	81.7 (4.6)	90.4 (3.2)
Odor Intensity	48.7 (4.4)	57.8 (3.9)	69.1 (3.1)
Feelings of Disgust	44.1 (4.1)	50.1 (4.4)	65.7 (3.7)
Feelings of Anger	12.9 (1.9)	35.2 (3.3)	16.1 (3.4)
TDD (Moral)	29.7 (1.2)	25.7 (1.1)	24.7 (1.3)
TDD (Sexual)	17.5 (1.6)	21.5 (1.5)	22.6 (1.5)
TDD (Pathogen)	30.2 (1.0)	26.0 (1.2)	29.7 (1.0)

3.4. Disgust Sensitivity—TDD

For the TDD measures of disgust, we found a significant effect of DI for TDD-Pathogen, $F(2, 67) = 4.46$, $p = 0.015$, $\eta^2 = 0.12$, where disgust sensitivity was significantly lower in the Moral group compared to both Pathogen and Control (both $ps < 0.05$), with the latter two not differing from each other (Table 3). Additionally, there were differences in TDD-Moral, $F(2, 67) = 5.06$, $p = 0.009$, $\eta^2 = 0.13$, where moral disgust sensitivity was higher in the Control group compared to both Pathogen and Moral (both $ps < 0.05$). TDD-Sexual was marginally significant, $F(2, 67) = 3.05$, $p = 0.054$, $\eta^2 = 0.08$, with higher sexual disgust sensitivity in the Pathogen versus Control group ($p < 0.05$); no other comparisons were significant.

Correlations

To explore the relationship between disgust sensitivity and perception of the disgust-related odor, we completed correlations separately for each DI group, between odor/emotion ratings and TDD-P and TDD-M; restricting our analyses to these two (TDD) dimensions since there was no sexual induction condition in our study. Findings demonstrated that for those in the Pathogen disgust induction, there were significant positive associations between TDD-P and odor disgust and feelings of disgust (Table 4). There were no significant correlations for TDD-P in either of the remaining DI groups and none of the correlations for TDD-M were significant. This suggests that for individuals in the Pathogen induction group only, increases in odor disgust and feelings of disgust were associated with higher pathogen disgust.

Table 4. Bivariate correlations Between TDD-P (Pathogen Disgust), Odor and Emotion Ratings for Pathogen Disgust Induction Only (n = 23) (Study 2).

		1	2	3	4	5	6
1.	TDD-P	1	0.52 *	0.34	0.46 *	0.60 **	0.15
2.	Odor Disgust		1	0.70 **	0.78 **	0.69 **	0.33
3.	Odor Intensity			1	0.46 *	0.66 *	−0.15
4.	Odor Unpleasantness				1	0.64 *	0.26
5.	Feelings of disgust					1	0.21
6.	Feelings of anger						1

* $p < 0.05$; ** $p < 0.01$.

3.5. General Discussion

In Experiment two, we found that participants in a Pathogen Disgust condition rated a fish sauce odor as more disgusting compared to both Moral and Control conditions. We also found that participants reading about a moral transgression (DI-M) rated the fish sauce smell as significantly more disgusting than control participants. These findings are consistent with disgust as a disease avoidance mechanism [15,16], where increases in state disgust invoke behavior to reduce the threat of contamination. In experiment one, we did not find a difference in disgust ratings of the disgust odor between conditions; however in experiment two, when the disgust state was induced closer to the time of odor rating, and only one odor was rated, we observed a clear pattern of heightened disgust for the odor, compared to control. In experiment one we speculated that the delay in odor ratings, and multiple odor ratings could have neutralized the disgust induction. We see the predicted effects of the disgust induction in experiment two, which had no delay. Alternatively, disgust priming may only adaptively heighten disgust intensity for a brief window of time, which once subsided causes a down regulation of disgust avoidance and thereby explains the diminished disgust perception. This makes sense from an evolutionary perspective and there is also evidence from the olfactory literature. Research has shown that an unpleasant odor yielded the earliest OERP (olfactory event-related potentials), but repeated presentations led to decreases in amplitude; these delays were accompanied by initially high ratings of unpleasantness which then reduced, i.e., became less unpleasant [19]. This is consistent with a down regulation of response to an initially unpleasant odor. Work has also shown that the same part of the brain (left insula) is activated by both smelling and also imagining an unpleasant odor [20]. This is particularly relevant to pathogen priming, as it suggests that in experiment one, those subjects induced into a pathogen disgust state (including viewing pictures of a maggot ridden animal corpse) would to some degree also imagine the associated smell, thus invoking activity of the left insula. However, when later confronted with the odors to evaluate (also utilizing the left insula), the disgust avoidance had already passed its rapid response phase and was in a state of declining responsiveness, thereby explaining the lower overall ratings of disgust.

The other main finding of experiment two was that those in the pathogen disgust condition rated their feelings of disgust as substantially higher than both moral and control conditions but in contrast anger was higher in the moral compared to other conditions. This is consistent with our prediction and with previous literature showing that pathogen cues elicit disgust whereas moral transgressions elicit anger more than disgust. In contrast, a previous field study found that being exposed to a foul odor led to individuals making more severe moral judgements [21], which suggested that increases in pathogen disgust state can influence moral judgments. It is, however, unclear from that study alone, precisely how different types of disgust induction (moral, pathogen) influence disgust responses. Chapman and colleagues [3], found that disgust facial muscles were activated both by being treated unfairly in an ultimatum game and tasting a bitter beverage. Our very different methodology supports some shared affective mechanism for disgust and response to moral transgression. We found that reading about a moral transgression (DI-M) increased disgust ratings for a disgusting smell relative to a control but not as much as the pathogen prime (DI-P).

The observed differences in TDD correlations between disgust inductions were (Exp 2) interesting. Hence, it was only in the pathogen disgust induction group that we see clear associations between odor disgust/feelings of disgust and TDD-P. Although TDD is a measure of disgust sensitivity [1] i.e., disgust as a trait, since these measures were obtained after the disgust induction/odor task, the findings could be interpreted as a combination of disgust induction condition plus smelling the disgust-related odor as influencing the TDD-P scores. Alternatively, it could be that those with habitually higher levels of trait pathogen disgust (TDD-P) made higher ratings of odor disgust/feelings of disgust. Though we cannot be certain of the direction of effects here, however since participants were randomly allocated to disgust induction group, any substantial group differences would seem unlikely. Since this association was found only in the DI-P group, it would appear more likely that this induction was the main driver in the associations observed.

Humans have evolved an efficient behavioral disgust avoidance system to protect us from potentially harmful stimuli. It has been theorized that this originated from a low level system of distaste to bitter substances to a more complex mechanism of disgust behavioral responses [22], including the capability of learning vicariously what environmental stimuli might present increased risk of contagion. We propose here that as part of this evolution, our sense of smell is one of the central components of this disgust avoidance system. Though taste also plays an important role in disgust, for instance via the oral rejection response, it would seem that a system able to protect a potential threat even coming into close proximity to be a more adaptive defense system. This is nicely exemplified by research where odors emitted by the same persons after being given endotoxin (causes inflammation response) or placebo were subsequently rated as less pleasant and healthy by naïve judges [23]; Additionally, in a subsequent study using the same procedure, the faces of individuals given endotoxin were rated as less desirable, with further reductions when rated with the sick (inflammatory) body odor [24]. This suggests that our sense of smell helps navigate ourselves away from unhealthy individuals. Reflecting on why there is still an overemphasis of the taste system in disgust theory is possibly due, in part, to the linguistic origins of disgust = distaste, which is in turn out of synch with what we now know about taste and smell [9]: most of what we think of as belonging to taste in fact originates from the olfactory system.

Reflecting on the limitations of the current study, since we tested only females, it is uncertain whether similar findings would apply for males. The rationale for testing only females was based on the finding from other research [25] that females have generally higher levels of disgust than males and indeed higher sensitivity to odors [26], which would have potentially confounded the findings unless a much larger balanced study was used. It also needs to be acknowledged the influence of pregnancy and menstrual cycle on disgust perception [27,28], which should be considered in future work. In terms of the timing of the measure of disgust sensitivity (TDD), the rationale for completing these at the end of the study was to avoid any influence on the main measures of odor/feelings of disgust, i.e., answering the sorts of questions in the TDD may well have heightened disgust intensity and thereby affected the study. However, in order to obtain trait measures of disgust sensitivity, future work could look at obtaining these prior to the day of testing.

In summary, we found that inducing individuals into a Pathogen disgust state, surprisingly led to lower overall odor disgust (experiment one), but using a different methodology (experiment two), we found higher disgust ratings in both pathogen and moral groups compared to control.

Additionally, while feelings of disgust were higher for the Pathogen versus Moral disgust induction, the reverse was true for feelings of anger. These findings suggest that while both pathogen and moral inductions in state disgust lead to heightened odor disgust, in contrast feelings of disgust yield effects only in the pathogen group.

Ethical Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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Informed Consent: Informed consent was obtained from all individual participants included in the studies.

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