Data-driven Investigations of Disgust

by

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Dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor
of Philosophy in the Department of
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ABSTRACT

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Abstract

Disgust features prominently in many facets of human life, from dining etiquette to spider phobia to genocide. For some applications, such as public health campaigns, it might be desirable to know how to increase disgust, whereas for things like legal and political decision-making it might be desirable to know how to suppress disgust. However, interventions in neither direction can take place until the basic structure of disgust is better understood. Disgust is notoriously difficult to model, largely due to the fact that it is a highly individually variable, multifactorial construct, with a great breadth of eliciting stimuli and contexts. As such, many of the theories which attempt to comprehensively describe disgust come into conflict with each other, impeding progress towards more efficient and effective ways of predicting disgust-related outcomes. The aim of this dissertation is to explore the possible contribution of data-driven methods to resolving theoretical questions, evaluating extant theories, and the generation of novel conceptual structures from bottom-up insights. Data were collected to sample subjective experience as well as psychophysiological reactivity. Through the use of techniques such as factor analysis and support vector machine classification, several insights about the approaching the study of disgust emerged. In one study, results indicated that the level of abstraction across subdivisions of disgust is not necessarily constant, in spite of a priori theoretical expectations: in other words, some domains of disgust are more

general than others, and recognizing as much will improve the predictive validity of a model. Another study highlighted the importance of recognizing one particular category of disgust elicitors (mutilation) as a separate entity from the superordinate domains into which extant theories placed it. Finally, another study investigated the influence of concurrent emotions on variability in disgust physiology, and demonstrated the difference in the representations of the structure of disgust between the level of subjective experience and the level of autonomic activity. In total, the studies conducted as part of this dissertation suggest that for constructs as complex as disgust, data-driven approaches investigations can be a boon to scientists looking to evaluate the quality of the theoretical tools at their disposal.

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1. Introduction[1]

Although it has enjoyed increased scientific and philosophical attention in recent years, disgust has been historically understudied compared to other so-called basic emotions, receiving relatively little empirical scrutiny until the 1980s (Rozin & Fallon, 1987). This delay may be explained by the fact that certain inherent features of disgust render it challenging to develop a comprehensive theoretical model of its function(s), psychological implementation, and biological and cultural substrates. Perhaps chief among these obstacles is the variability of things which can elicit disgust. Consider the fact that smelling a rotten banana peel, looking at a picture of a mutilated limb, and learning about the dishonest actions of a politician are all experiences that can be described as disgusting, despite sharing few prima facie characteristics otherwise. Whereas it might be argued that elicitors of other basic emotions fall into predictable categories with some recognizable relationship to the likely function of the emotion (e.g., snakes elicit fear because the function of fear is most likely to avoid immediate physical harm), the underlying categorical structure of disgust elicitors is much less intuitive. Any model of the basic nature of disgust must strain to provide a comprehensive theoretical account that accommodates this broad and diverse set of elicitors.[2] Put

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[1] Portions of the text of this introductory section have been published as a chapter in Hanna & Sinnott-Armstrong, 2018.

[2] In fact, Strohminger (2014) has suggested that the pursuit of such a model is a futile undertaking, and that disgust is better conceptualized as a "psychological nebula" rather than as something for which there might be a "grand unified theory."

simply, progress in the basic and applied science of disgust has been stymied by the fact that it is difficult to account for why so many different sorts of things evoke feelings of disgust.

A number of potential frameworks have been put forward to guide hypothesis generation in regard to disgust. At first, it seems as though many of the outstanding questions about disgust are best answered by modeling the emotion as a pathogen avoidance mechanism, and all its elicitors as sources of potential infection in one way or another (Curtis & Biran, 2001; Fessler & Navarrete, 2003; Oaten et al., 2009; Pizarro & Inbar, 2015). However, disgust has been found to be related to a number of things for which the connection to pathogen avoidance is less immediately apparent, such as judgments of unfairness (Chapman et al., 2009), incest (Fessler & Navarrete, 2004), or the abstract contemplation of one's own mortality (Goldenberg et al., 2001). Other theories presume that disgust is a multifunctional construct, grouping the documented disgust elicitors into functionally distinct superordinate classes. However, although these models do not agree on the best way to organize these classes. Some of these theories have proven empirically valuable, having been used to interpret data about disgust at the behavioral, neural, and physiological level (Harrison et al., 2010; Olatunji et al., 2008; Ottaviani et al., 2013; Schaich Borg et al., 2008). Nevertheless, these models appear to differ in fundamental and irreconcilable ways (Rozin & Haidt, 2013; Tybur et al., 2013), which could lead to differing predictions about disgust experience, the mechanistic

components of disgust, and the most meaningful way to categorize what kinds of things elicit disgust. Given the rapid accumulation of findings about disgust's psychiatric (Phillips et al., 1998), sociopolitical (Inbar et al., 2012), and ethical/moral import (Chapman & Anderson, 2013), it is crucial to resolve this apparent discrepancy and arrive at a meaningful theoretical framework for disgust.

1.1 Elicitor-based models of disgust

1.1.1 The symbol-based paradigm of disgust

The first wave of theoretical models of disgust largely focused on its symbolic mechanisms: that is, how disgust emerges from, and interacts with, representations of abstract concepts. For instance, an early account by Angyal (1941) suggested that the function of disgust is to avoid the "oral incorporation" of objects which carry the symbolic association of being "debasing [or] degrading…" in spite of (supposedly) not being dangerous or noxious (p. 397). Angyal and others (Kolnai, 1929/2004) further suggest that disgust is elicited by objects that represent the nexus of life and death: organic objects which are not quite alive (e.g., body products) or nonliving objects which are inextricably connected with animate beings (e.g., corpses or things which are decaying). Various symbol-based models propose that disgust is related to a symbolic association with inferiority (Angyal, 1941; W. Miller, 1997), as well as violations of culturally-mediated boundaries, categories, and hierarchies (Douglas, 1966; W. Miller, 1997), especially as concerns the abstract notion of the self (S. B. Miller, 2004).

Certain theories that emerged from the symbol-based paradigm persist in contemporary disgust research. In fact, the most influential contemporary model of the emotion, put forward by Rozin, Haidt, and McCauley (1993, 2000, 2008) (referred to as the cultural evolution model for the purposes of the current discussion), describes disgust function and elicitor structure largely in terms of symbols. Haidt and colleagues (1994) used an open-ended approach to source disgust elicitors from subjects, and organized these elicitors into qualitatively meaningful clusters: food, sex, body products, small animals, poor hygiene, body envelope violations (that is, an instance where the body envelope is either breached or has an abnormal shape), and death. The cultural evolution model grouped these disgust elicitor categories, along with an additional "interpersonal contamination" category, into four superordinate categories, each with its own specific symbolic function (see Table 47.1 in Rozin et al., 2008): core disgust, animal reminder disgust, interpersonal disgust, and moral disgust. The cultural evolution model presumes that although behavior, subjective experience, and physiology are essentially the same across all superordinate categories of disgust, the propensity to experience disgust varies between, and not within, domains. In other words, an individual is theoretically likely to be just as disgusted by one animal reminder elicitor as another, but responses to core disgust and animal reminder disgust should be independent.

The cultural evolution model has united several lines of psychological and anthropological scholarship in order to provide a theoretical grounding for speculations on the function of each superordinate category. The orogastric defense function outlined by Angyal (1941) is considered to be the "core" of the disgust response. As such, food, animals, and body products are considered to be elicitors of core disgust: food, because it is the immediate focus of the oral defense; animals, because certain small animals (like maggots) may be a cue to food spoilage; and body products, because they represent a contamination risk if they make contact with food. The other superordinate elicitor categories – animal reminder, interpersonal, and moral disgust – are presumed to be culturally elaborated exaptations of the existing core disgust response, taking advantage of the prepared architecture of core disgust and applying it to other objects which must be rejected.

In generating the category of animal reminder disgust, the cultural evolution model draws upon an analysis put forth by Becker (1973), which interprets psychological experience as being largely mediated by withdrawal from symbolic associations with death. Critically, Becker suggests that this withdrawal from death is accomplished by feelings of disgust. Having found an empirical relationship between fear of death and disgust sensitivity (Haidt et al., 1994), Rozin and colleagues build on the purported death-disgust link of Becker's account and suggest that certain things are disgusting because they remind us of our ultimate mortality. Elicitors directly related to

death (such as corpses) fall straightforwardly into this category. Further, the cultural evolution model maintains that anything that reminds us that we are animals will activate concepts of death, because we are aware that animals are mortal. Therefore, violations of the human-animal boundary – such as reminders of behavioral or physical attributes that are shared between human and non-human animals (e.g., sexual intercourse, viscera, etc.), or failures to engage in behaviors, which distinguish humans from animals (e.g., proper hygiene) – elicit disgust. In other words, the specific function of animal reminder disgust is to avoid psychological confrontations with our ultimate animal mortality. Intriguingly, Rozin and colleagues point out that core disgust elicitors can also serve as reminders of our animal nature (2008). Eating food, for instance, is a behavioral attribute that humans share with non-human animals. There are culturally defined norms about the proper way to eat, and observing a violation of these norms (e.g. someone eating in a sloppy way) often generates a disgust response. It is possible that the putative symbolic functional boundary between core disgust and animal reminder disgust is a somewhat permeable one.

The cultural evolution model also includes a superordinate category of interpersonal disgust, which functions to reduce the risk of contamination from other persons. Elicitors of interpersonal disgust include cues to the infectious illness, misfortune, moral taint, or strangeness of another person (Rozin et al., 1994). Notably, disgust responses to these cues are thought to be dependent on symbolic associations,

rather than rational concerns about potential infection. It is not reasonable to think that misfortune and moral taint can be transmitted interpersonally in the same way that germs are. It is more reasonable to attribute aversion to persons who are unfamiliar or who show signs of infectious illness to concerns about germ transmission; nevertheless, Rozin and colleagues found that this disgust held even when concerns about infection were assuaged (ibid). Rozin and colleagues marshal anthropological evidence to explain the contaminating character of interpersonal (as well as other categories of) disgust, suggesting that disgust complies with the law of contagion (Frazer, 1890/1959; Mauss, 1902/1972; Tylor, 1871/1974): once a disgusting object has come into contact with something, it imparts its disgusting character and pollutes the other object. In other words, interpersonal contamination disgust is an example of the way in which another person can represent a symbolic threat of pollution by infection, bad luck, immorality, or unfamiliarity.

Finally, the cultural evolution model claims that disgust can be elicited by immoral activity, such as cruelty or dishonesty. Drawing on anthropological work on culturally universal dissociations between foundations of morality (Shweder et al., 1997), Haidt and colleagues (1997) suggest that the function of moral disgust is to uphold an "ethic of divinity." The ethic of divinity stands in contrast to two other alleged divisions of moral reasoning: the ethic of autonomy, which centers on individual rights, and the ethic of community, which centers on the integrity of social roles within

the context of a hierarchy. The ethic of divinity is thought to be concerned with the soul (the spiritual self), and as such, disgust is thought to protect the body and the soul from physical and symbolic degradation, respectively.

Though influential, the cultural evolution model has been recently criticized for lacking both construct validity and a sound empirical basis, especially where the "reminder of animal nature" domain is concerned (see Tybur et al., 2009; Tybur et al., 2013 for a discussion); in short, given the fact that reminders of animal nature are not uniformly negative, the explanation of the function of elicitors in the animal reminder cluster is unsatisfying. Criticisms might also be levied at the psychometric instrument associated with the model, the Disgust Scale (DS)(-R) (Haidt et al., 1994; Olatunji et al., 2007). Initially, the DS was divided into subscales related to food, sex, body products, small animals, poor hygiene, body envelope violations, death, and a domain-general sense of sympathetic magic (i.e., feelings of contamination). Potential items related to moral violations demonstrated a low correlation with the total score, and as a result, the only remaining explicitly morally relevant items in the original DS were questions about sexual morality. There was no defined interpersonal contamination scale, perhaps because the elicitors of interpersonal contamination demonstrate an overlap with other categories. In the development of the revised form of the scale, items relating to sexual disgust elicitors demonstrated a poor fit to the three-factor solution (with factors for core disgust, animal reminder disgust, and domain-general contamination disgust), leading

to the dismissal of these items from the ultimate scale. Given that sex subscale items were not included in the analyses, the revised factor solution does not preclude the existence of a sexual domain distinct from the animal reminder domain, a dissociation that is suggested by other disgust researchers. The DS-R does show predictive validity in terms of behavior, physiology, and individual differences (Olatunji et al., 2008); however, due to the lack of interpersonal, sex, and moral items, the scale's internal validity cannot be used as support for the model itself.

1.1.2 Evolutionary theories and the adaptationist model of disgust

Although the cultural evolution model has maintained its dominance, in the early 1990s the symbol-based paradigm began to recede in favor of a paradigm that focuses more on the ultimate adaptive functions of psychological phenomena. The cultural evolution model does engage with questions of ultimate function in certain ways. It suggests that (1) disgust biologically evolved from distaste, a phylogenetically ancient response to chemosensory irritants; (2) infection risk most likely plays some role in core disgust as well as interpersonal disgust; and (3) moral disgust functions to reinforce the social order via socializing group members in the appropriate moral norms (Haidt et al., 1997; Rozin et al., 2008). However, in most ways, the cultural evolution model is much closer to a standard social science model (Tooby & Cosmides, 1992), wherein most or all psychological architecture is imputed by culture. This leaves open questions of evolutionary trajectory and adaptive significance.

Under the banner of this new paradigm, the adaptive function of disgust has been widely explained (barring some variation) as pathogen avoidance, a view which enjoys empirical support (Oaten et al., 2009). Curtis and Biran (2001) based such a claim on data from an international survey spanning Africa, Asia, and Europe, and go so far as to explain the relationship between disgust and morality as an expansion of the parasite avoidance mechanism. Specifically, they suggest that immoral acts are self-benefiting breaches of sociomoral norms, constituting a form of parasitism, and that disgust functions to condemn and avoid social parasites who perpetrate such acts. Pizarro and Inbar (2015) make a similar argument, claiming that the relationship between disgust and moral or political judgment is linked to the behavioral immune system (a suite of behavioral adaptations for disease avoidance; Schaller & Park, 2011). It has also been suggested that out-group xenophobia associated with disgust results from disease avoidance, since over evolutionary history different groups had different immunities and carried different pathogens (Curtis, 2011).

Within the more recent adaptationist paradigm, the most direct challenge to the cultural evolution model was presented by Tybur, Lieberman and colleagues based in evolutionary psychology (henceforth referred to as the adaptationist model; Tybur et al., 2009; Tybur et al., 2013). The adaptationist model departs slightly from the mainstream point of view of disgust function by positing that three qualitatively different selection pressures created distinct perceptual and computational processes for three disgust

domains: pathogen disgust, sexual disgust, and moral disgust. This model is in agreement with the cultural evolution model in terms of what sorts of things tend to elicit disgust, and also in the sense that a response to a basic threat of infection was hijacked to address other functional concerns (although the adaptationist model expands this basic infection response beyond the oral route and includes other potential bodily avenues to infection). However, the adaptationist model suggests that what the cultural evolution model calls core disgust, as well as almost all of the domain of animal reminder disgust, can be more parsimoniously explained as pathogen disgust: a response to cues of potential disease. Additionally, the domains exapted beyond the basic infection-relevant domain differ between the two models. Per the cultural evolution model, sex is one of several elicitors of animal reminder disgust, with the same general expressive and physiological response as there is to all other disgust elicitors (in theory). By contrast, the adaptationist model lists sexual disgust as its own specific domain, responding to cues related to maladaptive mate choice, including kinship cues and cues of poor genetic quality. As in the cultural evolution model, sociomoral disgust stands alone, and is purported to motivate the individual to strategically endorse – and socially signal the endorsement of – moral rules that increase his or her fitness, as cued by pathogen and sex disgust responses. The adaptationist model assumes, like the cultural evolution model, that the disgust propensities for pathogen, sex, and moral disgust are essentially independent individual differences.

The adaptationist model has been validated at the psychometric level (Olatunji et al., 2012; Tybur et al., 2009), and recent neuroimaging work supports the distinctiveness of neural activity associated with each of these domains (Schaich Borg et al., 2008). In spite of this empirical support, the adaptationist model has come under fire for several reasons. One criticism of the model involves its treatment of the intersection of disgust and culture. Though the adaptationist model acknowledges the existence of cultural variability in disgust, Rozin and Haidt (2013) have argued that it downplays the effect of culture on disgust by collapsing most of the animal reminder domain into the core disgust domain, thus ignoring the potential psychological distinctions between experiences of animal reminder and core disgust as mediated by cultural forces. Another problem with the model was observed by Olatunji et al. (2012), who found that the items on the Moral Disgust subscale demonstrated a poor relationship to existing theories of moral concepts, and were rated more intensely when the response option was "anger" as opposed to "disgust." Rozin and Haidt (2013) also noted that the moral violations purported to elicit moral disgust under the adaptationist model were primarily associated with harm and fairness violations, which typically elicit anger (but see Chapman et al., 2009).

In addition, the sexual disgust items on the Three Domains of Disgust Scale (TDDS; Tybur et al., 2009), the psychometric instrument that was developed based on this theory, are not particularly relevant to the function of sexual disgust on the

adaptationist model. Because incest-related items violated normality assumptions in the exploratory factor analysis, they were discarded. Consequently, the remaining items do not engage with concepts of incest or poor mate quality (with the exception of one item, where the poor mate quality is simply coded as "someone you don't like") but instead suggest a general disgust with sex. The adaptationist model claims that each different domain of disgust is associated with a computational structure that integrates input across competing selection pressures (e.g., a motivation to copulate alongside a motivation to avoid sexual intimacy with family members). This claim is feasible in the context of the literature on judgment and decision-making. However, the sensitive mechanism for sexual disgust described in the adaptationist model does not manifest in the blunt sexual items on the TDDS, and this discrepancy calls into question the ecological validity of the sexual disgust construct.

An argument might be made that items 2, 8, 14, and 17 on the TDDS (that is, four of the seven items on the sex subscale) do refer to poor mate quality because the potential mates are strangers. Indeed, Buss and Schmitt (1993) suggest that relative unfamiliarity of a potential mate does bear on willingness to copulate. In one of these studies, subjects were instructed to consider a hypothetical scenario in which "conditions were right" to have sexual intercourse with someone they "viewed as desirable," and asked whether they would consent to sexual intercourse after having known the potential partner for anywhere from one hour to five years. Willingness to

engage in sexual intercourse increased as a function of the amount of time the subjects had known the potential partner, but men rated their willingness as higher than women at all time points (except five years, where men and women's willingness ratings converged). Similarly, Clark and Hatfield (1989) found that male subjects were willing to have sex with a stranger between 69% and 75% of the time, whereas female subjects flatly refused. Taken together, these findings suggest that unfamiliarity of a mate interacts with sex such that women are less willing to have sex with strangers. Given that the initial validation study of the TDDS (Tybur et al., 2009) found that women's scores on the sex disgust subscale were significantly higher than men's, it may be that in large part this subscale captures a specific sexual decision-making predisposition (i.e., willingness to mate with a stranger) that is relevant to sexual disgust. This predisposition may or may not fit into the evolutionary framework outlined by Tybur and colleagues. If unwillingness to mate with a stranger is a large part of sexual disgust, it may be because familiarity with the potential mate is necessary to judge mate quality. This is doubtful, given that many of the attributes relevant to short-term mating strategies can be judged relatively quickly (Buss & Schmitt, 1993). A more likely explanation is that disgust at sexual relations with a stranger is tapping into computations related to disease avoidance, because strangers may carry novel pathogens.

1.1.3 An interim summary of the controversies between elicitor-based theories

Despite certain overlapping themes, the two primary theoretical accounts of disgust function appear at first to be ultimately incompatible. Both the cultural evolution and adaptationist models find a way to account for the breadth of disgust elicitors, but they handle it differently: the cultural evolution model clusters disgust elicitors according to theoretical frameworks based on symbols of offensiveness, death, contamination, and divinity, whereas the adaptationist model clusters disgust elicitors according to presumed selection pressures over the course of human evolution. The structures of these clusters provide the basis for hypothesis generation for both of these models, as well as for their associated psychometric measures. These structures appear mutually exclusive for two reasons: (1) the adaptationist model lists sex as an elicitor category unto itself, whereas the cultural evolution model presume that sex belongs under the same superordinate heading as hygiene, death, and body envelope violations; and, (2) the adaptationist model collapses core disgust together with all of animal reminder disgust (except sex), whereas the cultural evolution maintains that there are

cultural reasons to keep these categories separate.

<table>
<tr><th>Cultural evolution model</th><th>Documented elicitors of disgust</th><th>Adaptationist model</th></tr>
<tr><td rowspan="3">Core disgust</td><td>Food</td><td rowspan="6">Pathogen disgust</td></tr>
<tr><td>Body products</td></tr>
<tr><td>Animals</td></tr>
<tr><td>Interpersonal disgust</td><td>Other people</td></tr>
<tr><td rowspan="3">Animal reminder disgust</td><td>Hygiene</td></tr>
<tr><td>Death</td></tr>
<tr><td>Body envelope violations</td></tr>
<tr><td></td><td>Sex</td><td>Sexual disgust</td></tr>
<tr><td>Moral disgust</td><td>Morality</td><td>Moral disgust</td></tr>
</table>

Figure 1: The superordinate domains of disgust, according to the cultural evolution model and the adaptationist model. Adapted from Tybur et al. (2013).

There is some empirical support for both models, but criticisms of both have been voiced as well. Importantly, this partial support for two competing models suggests that neither model fully accounts for disgust, nor for the variability of its set of elicitors; and in attempting to accommodate the elicitor set, each models' empirical utility may have suffered.

While the strong views of the cultural evolution and adaptationist models are clearly incompatible, they have both shown some empirical utility, so it could be that some components of both are valuable and worth combining in pursuit of an explanation for disgust elicitor variability. An account of disgust which supplies an adaptive function (like the adaptationist model) still requires an account of a proximal psychological mechanism whereby the adaptive function is implemented (like the cultural evolution model), and that mechanism is likely to be mediated by symbols and abstract representational associations.

Although the adaptationist model is implemented as an elicitor-based model, Tybur and colleagues stress the contextual nature of disgust (see also Douglas, 1966). For instance, the cognitive architecture which supposedly processes pathogen disgust cues also integrates cues about other internal states, such as hunger (Tybur et al., 2013). One possible expansion on this idea is the interaction of disgust with other affective states, particularly since subdivisions within disgust similar to the canonical elicitor-based ones have been discovered using concurrent affect as the decision boundary. Specifically, Marzillier and Davey (2004) analyzed the emotional experiences concomitant with disgust for a range of elicitors and suggested that disgust may be demarcated into "primary" and "complex" (i.e., sociomoral) disgusts, such that complex disgust tends to co-occur with other emotional states and primary disgust occurs alone.

1.2 Using data-driven methods to evaluate theories

The scientific method is inherently theory-driven. A hypothesis is the operational implementation of an attempt to support generalizations about phenomena in the world. When the phenomenon about which scientists are trying to generalize is complicated, and the factors influencing it obscured, it can be tempting to base theories on factors that are immediately obvious, or to proceed from the disciplinary milieu that is familiar even if it is not appropriate to the phenomenon being studied. For instance, the cultural evolution model of disgust is largely informed by existentialist psychology and some of its attendant paradigms, such as terror management theory (Greenberg et al., 1986; Pyszczynski et al., 1999; Burke et al., 2010). In recent times, terror management theory has been criticized for being implausible (Tritt et al., 2012). However, the claims based in terror management theory about the association between disgust and death are central to the construct of animal reminder disgust, and is the proposed explanation for treating responses to poor hygiene, death, sex, and body envelope violations as a single unified construct, even when the data do not necessarily converge on this interpretation (as when body envelope violations and death loaded onto a single factor during the development of the Disgust Scale; Haidt et al., 1994). The very utility of theory as an interpretive device is related to its greatest weakness: although theory exists to communicate the meaning of information to a subject, the biases held by that subject necessarily inform that interpretation.

When theories conflict, especially theories based in different subdisciplines of psychology, it can be useful to impose some measure of impartiality between the data and the researcher who is trying to evaluate the utility of one model against another (or even a model in isolate). Previous work using data-driven methods such as machine learning classifiers have been able to investigate the validity of theories of affect in ways that are intractable to traditional methods. For example, Kragel and LaBar (2013) used pattern classification to evaluate the relative explanatory strength of a discrete categorical model of emotion against a dimensional account in the peripheral nervous system. Rather than querying the data directly as to whether it supported either the dimensional or categorical accounts, Kragel and LaBar examined the natural distribution of the errors made by the classifier and were able to determine that it produced a signal that was inconsistent with a dimensional account. Doing so allowed for the adjudication between models without the a priori restriction of proving one model correct.

The aim of this dissertation is to discuss ways in which I have used methods that privilege the inherent structure of data over the verification of a priori assumptions. In chapter two, I discuss a factor analysis of individual differences in disgust which introduces a novel element to theories of disgust elicitor organization: the idea that certain categories are more general than others, an issue that impacts the way researchers should generate hypotheses about disgust function and experience. In chapters three and four, I discuss studies which use machine learning to evaluate the

reliability of psychophysiological signals of different disgust responses, and explore the relationship between these results and elicitor-based models of disgust.

2. The structure of disgust experience: Theoretical insights from factor analysis

2.1 Introduction

On the face of it, there is very little that a festering wound has to do with political skullduggery, or that spoiled milk has in common with having sex with one's sister, or that blowing your nose at the table has with murder. Some of these scenarios are morally relevant, and some are not; some of these directly evoke a straightforward threat of infection, and some do not. These scenarios vary in abstraction/concreteness, in the degree of sociality, and also in the richness of the overall affective state they might elicit. Perhaps the one thing these scenarios share is that they all might be labeled as disgusting, and therein lies the conundrum for the study of the psychology of disgust. Historically, affective researchers have tended to emphasize a search for an explanation for the breadth of potential disgust elicitors when attempting to describe a parsimonious conceptual model for disgust, which has proved to be a difficult goal to accomplish. What is the best way to model an emotion which can be elicited by such disparate stimuli? Is disgust one unified construct with a singular neurocognitive substrate that is applied to address multiple concerns, or are there subtypes of disgust with distinct systems for influencing cognition and behavior?

Previous attempts to create such an overarching model (Rozin et al., 1993, 2000, 2008; Tybur et al., 2009; Tybur et al., 2013) exhibit some overlap, but in their strong forms are often mutually exclusive. In other words, there is no consensus framework on

which to base future inquiry about an emotion which has been linked to prejudice and dehumanization (Harris & Fiske, 2006), psychiatric disorders (Olatunji et al., 2017), legal and political decision making (Capestany & Harris, 2014; Nussbaum, 2010), public health (Sherman et al., 2001; Porzig-Drummond et al., 2009; Curtis, 2011), and moral judgment (Schnall et al., 2008; Chapman & Anderson, 2013). It is crucially important to understand an emotion which sits at the nexus of so many aspects of human life.

Here we evaluate two eminent theoretical models of disgust that have been put forward, each with associated psychometric instruments and explanations for the best way to understand the diversity of individual reactions to disgust. The dominant perspective in disgust research is the one proposed by Rozin and colleagues (1993, 2000, 2008), which will for the purposes of this paper be known as the cultural evolution model. This model describes disgust as an evolutionary co-option of distaste, a phylogenetically ancient reaction to bitter tastes and smells that indicate the presence of toxins. By this account, as the human diet strategy shifted to omnivory and the set of potential food sources became larger, the risk of ingesting disease-causing material increased as well, leading to the development of core disgust. Notably, though, the initial formulation of core disgust by the cultural evolution model did not proceed specifically from the principle of disease avoidance. Core disgust was instead defined according to its symbolic mechanism, described by Rozin and colleagues (2008) as the prevention of the ingestion of offensive material, where offensiveness was imparted by

contact with something undesirable. As such, core disgust comprises a response to food, animals (the presence of which may indicate that a food is unsuitable for eating – e.g., maggots, scavengers), and body products (which can contaminate a potential food or water source). Core disgust differs from distaste in that an unpleasant sensory experience is not necessary. As Rozin et al. (1984) point out, even a delicious-smelling soup becomes disgusting once one is informed that the soup was recently stirred with a flyswatter. Hence, Rozin and Fallon (1987) argue that it is the potential to elicit disgust ideationally that distinguishes it from distaste.

Rozin and Haidt (2013) contend that although biological evolution was responsible for the move from distaste to disgust, cultural evolution subsequently acted upon core disgust to give rise to multiple other domains of disgust, in order to perform other symbolic functions. One such domain is animal reminder disgust, which is thought to function to reject reminders of the animal nature of human beings. Such reminders are unpleasant, because the concept of animality is strongly linked with that of mortality (Goldenberg et al., 2001). Animal reminder elicitors therefore said to be disgusting because they remind us that we are animals, and include violations of civilized hygienic practices, violations of the ideal bodily envelope (e.g., mutilation), sex, and death. The cultural evolution model further postulates that core disgust is co-opted to address concerns about the purity of the spiritual self (Haidt et al., 1997), giving rise to moral disgust. Finally, the cultural evolution model suggests a domain-general

construct of interpersonal disgust, which can be engendered by threats of symbolic contamination by another person with misfortune, bad character, evidence of contagious disease, or who is simply unfamiliar (Rozin, Markwith, & McCauley, 1994).

The cultural evolution model has the advantage of being sensitive to the potential contributions of both biological and cultural evolution (Rozin & Haidt, 2013). Simply because disgust or one of its putative subtypes can accomplish a particular evolutionary goal, it may not be due to a biologically innate mechanism, by whatever standard that is defined, but rather due to cultural learning or conditioning over the life history of an individual. However, the cultural evolution model has also attracted criticism. At the conceptual level, the cultural evolution model has been criticized for lacking explanatory parsimony and plausibility, particularly in the context of the biological evolution of disgust (Tybur et al., 2009; Tybur et al., 2013). As Tybur and colleagues point out, there is not much face validity to the claim that any reminder of animality is disgusting: plenty of features shared by both human and non-human animals are not disgusting (note for instance that both humans and non-human animals can drink water and may have legs).

Much of the support for the cultural evolution model comes by way of the psychometric instrument associated with it, the Disgust Scale (Haidt et al., 1994). However, the validity of the DS can be criticized for several reasons. The initial DS was derived from the 221 nominations of disgusting items made by "15 students and 5

secretaries at the University of Pennsylvania," who were instructed to "describe the three most disgusting experiences of their lives, and then to list as many disgusting things as they could think of" (p. 702). It might be said of this approach that items were drawn from a small sample of convenience, and consequently may show poor ecological validity. Another issue with the DS is potential weakness of construct validity, stemming from the way the nominations were converted into a questionnaire. Haidt et al. (1994) reviewed the nominations, subjectively determined the constructs represented by those nominations (they concluded that the items could be labeled as belonging to the categories of food, body products, sexuality, violations of the body envelope such as mutilation or deformity, immoral people, certain animals, dirt/germs, and death), and wrote items which they believed reflected these categories. These items were then submitted to a factor analysis which yielded subscales that matched the categories intuited, for the most part, by Haidt et al. (1994). Interestingly, items representing the putatively separate categories of death and body envelope violation loaded onto the same factor; nevertheless, the authors maintained that although these categories "might better be considered one domain than two…[Haidt et al. (1994)] preferred at this point to retain separate representations of both Death and Envelope Violations," suspecting that future responses "might show more specificity in future research with more culturally or clinically diverse samples" (pp. 707-708). To summarize, the DS was created by soliciting nominations of disgust elicitors first, interpreting their latent factors second,

creating items based on those latent factors third, and lastly subjecting these factors to analysis and verification. This order of events allows for the possibility of theoretical bias entering the model – in other words, the interpretations of the researchers intervene between the collection of data and the verification of the model, and any bias held by the researchers may be entrenched in the items. It is possible that the interpretation of items about death and body envelope violation as two factors rather than one reflects a similar sort of theoretical override of the story told by the data. Conversely, if items had been created to match more directly onto the nominations themselves and then submitted to factor analysis, rather than qualitatively interpreting factors beforehand for subsequent confirmation by factor analysis, there may have been less theoretical bias in the resulting model.

A revised form of the instrument, the Disgust Scale-Revised or DS-R (Olatunji et al., 2007), reinforces the idea that core disgust is separable from animal reminder disgust, as well as from a weaker, domain-general contamination factor (which may map onto interpersonal disgust). The DS-R has demonstrated predictive validity in terms of behavior, physiology, and clinically relevant individual differences (Olatunji et al., 2008). However, it is unclear whether the DS-R should be held up as evidence for the theoretical positions of the cultural evolution model writ large. For one thing, although core disgust is represented in the DS-R with items spanning the three supposed elicitor categories of core disgust (food, animals, and body products), animal reminder disgust

is only represented with items from death and mutilation, which, as mentioned above, quantitatively comprised a single factor during the initial development of the DS but were nevertheless interpreted as separate factors. No items in the animal reminder disgust subscale of the DS-R involve sex, another putative animal reminder elicitor category, since sex items demonstrated a high level of skewness in Olatunji et al.'s investigation of the psychometric properties of the DS (2007); furthermore, items to do with hygiene correlated much more strongly with scores on the domain-general contamination factor (r = .70) than with scores on the animal reminder factor (r = .23). Ultimately, in spite of its predictive validity, the support it offers for the cultural evolution model as a comprehensive, generalizable theory of disgust is limited, since any generalizations about animal reminder disgust pulled from research using the DS-R run the risk of only tapping into the construct of mutilation.

Tybur and colleagues (Tybur et al., 2009; Tybur et al., 2013) have offered a competing framework, referred to herein as the adaptationist model. Proceeding from the assumptions of evolutionary psychology, the adaptationist model proposes that three qualitatively different environmental problems exerted selection pressures to create distinct perceptual and computational processes, behavioral programs, and physiological reactions for three disgust domains: pathogen disgust, sexual disgust, and moral disgust. The adaptationist model suggests that pathogen disgust developed prior to sexual and moral disgust and responds to cues of potential disease vectors, the

elicitors of which span the cultural evolution model's core disgust domain and most of the animal reminder domain. As in the cultural evolution model, the adaptationist model suggests that the other domains of disgust are elaborations upon pathogen disgust. However, the adaptationist model posits the existence of domains of disgust organized around the evolutionary selection pressures related to different types of social interaction. Sexual disgust is meant to respond to cues related to maladaptive mate choice, such as kinship cues. Moral disgust is purported to motivate the strategic condemnation of another person who has committed an act that transgresses sociomoral norms; specifically, moral disgust is thought to be evoked as a sort of social signal, motivating behavior in line with an individual's social fitness strategy (e.g., advertising a cooperative nature by displaying disgust at people who cheat).

Like the cultural evolution model, the adaptationist model is vulnerable to criticism. There is a psychometric instrument associated with the model known as the Three Domains of Disgust Scale (TDDS), which has demonstrated associations with a variety of evolutionarily relevant tasks, such as avoidance of pathogens in mate choice (Jones et al., 2013). However, the content of the TDDS is somewhat afield of what it purports to measure. The sexual disgust items do not have much to do with the function of sexual disgust as described in the adaptationist model theory itself. In particular, items do not entail incest or genetic incompatibility, but instead suggest a general disgust with sex – having sex with a stranger, hearing two other people having sex, etc.

Olatunji et al. (2012) further noted that labeling the choice options for the TDDS's moral disgust subscale with anger instead of disgust produced more intense responses, suggesting perhaps that moral disgust as indexed by the TDDS is closer to anger than disgust.[1] Just as the predictive validity of the DS-R does not necessarily support the theoretical structure of the cultural evolution model, the predictive validity of the TDDS does not necessarily bolster the claims of the adaptationist model. In order to generate a disgust psychometric in a similar way to Haidt et al. (1994), Tybur et al. (2009) asked "a group of 14 individuals (4 undergraduate students, 5 graduate students, and 5 psychology professors) to each list up to 15 things they found disgusting" (p. 107), rendering the TDDS vulnerable to the same sorts of criticisms of low ecological validity which might be levied at the DS and DS-R.

Additionally, Tybur et al. (2009) instructed their nominators that items should "reflect a variety of acts that people might consider 'disgusting' in any way, including issues related to sexuality and morality" (p. 108). The way these instructions are phrased might plausibly have led nominators to consider three factors: sexual disgust, moral disgust, and the prototypical elicitors of disgust, which are generally associated with pathogens (Haidt et al., 1997; Curtis & Biran, 2001). In other words, it is feasible that these instructions inadvertently ensured that nominators provided items related to the

[1] Some researchers suggest that what is called "moral disgust" actually *is* anger, at least some of the time; see Nabi, 2002, and Gutierrez et al., 2011 for accounts of this nature, but see also Rozin et al., 1999 and Hutcherson & Gross, 2011 for conflicting perspectives.

three factors which had been theorized about a priori by the researchers. In doing so, the creators of the TDDS used a method which may hamstring any claim that pathogen disgust, sex disgust, and moral disgust comprehensively span the structure of disgust.

Finally, both of these models claim to speak to the proximate mechanisms of disgust experience and its variability, but they cluster the documented proximate elicitors of disgust in mutually incompatible ways (Figure 1). One potential source of this conflict is the theoretical constraints under which each model was created. Specifically, it is possible that some of the anthropological and psychodynamic assumptions which informed the cultural evolution model lessened its explanatory power, for instance by clustering two potentially distinct categories – sex and body envelope violations – into the same superordinate domain, since they could be described as sharing the same relationship to mortality salience threats. Perhaps the evolutionary psychological assumptions which informed the adaptationist model lessened its explanatory power in much the same way. As Rozin and Haidt (2013) pointed out, there is good reason to think that cultural-evolutionary pressures exert a great deal of influence on an emotion as culturally variable as disgust (Haidt et al., 1997), and as broad a domain as pathogen disgust may in fact elide some meaningful variability in disgust experience (see also Curtis & de Barra, 2018).

In short, it may be the case that the reason the elicitor clustering schemes of the two models are incompatible is that the models were derived from data from samples

with potentially problematic characteristics (size, convenience, and homogeneity), and possibly allowing contamination of researcher bias to influence data in favor of the hypothesized models, sacrificing ecological validity for theoretical consistency. The goal of the present work was to use a data-driven approach to try to avoid these pitfalls, and to assess the extent to which a data-driven model converges on either theory-driven model. In doing so, the evidence from the data-driven model could serve as evidence for some components of existing models, suggest modifications to existing models, and potentially provide some information on which to adjudicate between the models. We derived a data-driven model of disgust from an exploratory factor analysis performed on a set of vignettes based on crowdsourced disgust nominations. If the factors suggested by an exploratory factor analysis could be easily mapped onto pathogens, sex, and immoral behavior, the exploratory factor analysis would support the utility of the adaptationist model. Conversely, if the factors could be mapped onto core disgust, animal reminder disgust, interpersonal disgust, and moral disgust, the exploratory factor analysis would support the cultural evolution model. If a novel structure emerged, the factors which were not present in the theoretically-driven models could suggest modifications to the existing models and indicate the appropriate way to synthesize the existing structures into a more comprehensive, consensus model of disgust. Finally, we employed a confirmatory factor analysis to examine the extent to

which the data-driven model converged on the structures advanced by either the cultural evolution model or the adaptationist model.

2.2 Disgust database development

Disgust elicitor nominations were crowdsourced from Amazon Mechanical Turk (MTurk) using the largest sample, to our knowledge, in the extant literature. Ninety-eight subjects were instructed to provide five non-redundant "objects, actions, experiences, people, or anything else that [were] disgusting." We intended for this wording to avoid giving participants any cues to substantive domains of disgust elicitors (with the possible exception of "people"), but rather provided anchors that were so general as to span nearly all documented elicitors of disgust, and could be used to describe other emotions. 571 disgust nominations were collected (note that Haidt et al., 1994 collected 221, and Tybur et al., 2009 collected 105). The sample was split relatively evenly across gender (56 women, 41 men, 2 genderqueer or other) and was predominantly White (72 White/Caucasian, 8 Black/African, 4 multiracial, 3 Hispanic/Latinx, 2 Native American, 9 Asian and 1 non-answer). The sample was politically left-leaning: on a 1 to 7 scale where 1 was "Extremely liberal," 7 was "Extremely conservative," and 4 was "Moderate," the mean political affiliation score was 3.14 (SD = 1.67), which differed significantly from "Moderate," $t(97) = -5.067$, $p < .001$, with a medium effect size, Cohen's $d = 0.51$. The mean age was 35.61 (SD = 10.16, ranging from 18-65). All participants provided informed consent to participate in

accordance with procedures approved by the Duke University Institutional Review Board.

Although ideally, an ecological sample of disgust nominations would remain unfiltered, it was necessary to do some data cleaning, both in order to ensure that nominators were following instructions and that nominations would be appropriate for conversion to future vignettes. Appropriateness in this case comprised something which might alienate or be unfamiliar to participants in general or a subset of participants, allowing for a sampling which would be broadly applicable for future research and/or would not discourage potential subjects from participating in studies using these vignettes. The total pool of potential disgust nominations was filtered for items which two independent raters agreed were (1) the result of misunderstanding task instructions (e.g., providing nominators about something they found specifically frightening), (2) disgusting by virtue of being about a demographic class and nothing more (we did not want to include items about "women" or "Middle Easterners" being disgusting, for example), (3) so extremely distressing that they ran the risk of resulting in a subject departing the study (e.g., vivid descriptions of bizarre scatological imagery), or (4) too ambiguous to interpret. In addition, items that were too specific (e.g., a person's name) or political issues were flagged so that resulting vignettes would be rewritten in a more general manner (e.g., nominations about "Dishonest Hillary Clinton" were flagged to be interpreted as a dishonest nonspecific politician), so that the vignettes would be more

universal and not yoked to a particular episodic context. Redundant nominations were collapsed, with the signal element of each nomination (i.e., the thing that made them disgusting) in mind; for instance, a nomination about the smell of excrement was treated as something different than the sight of it.

Nominations were converted into vignettes that represented one signal element or a small number of closely related signal elements. Vignettes were constructed to be between 12 and 17 words, and to have a Flesch-Kincaid reading ease level above 30 and a grade level below 12. In addition, vignettes were altered in order to match each other in terms of abstractness/ concreteness: that is, since some nominations were highly specific and grounded whereas others comprised a single word, the vignettes adapted from these nominations were adjusted by the experimenters to be concrete and visualizable to approximately the same degree.

It is important to note the way in which this process differs from the initial development of the Disgust Scale. There is indeed a great deal of overlap in the procedures. However, we argue that our approach was more granular and more atheoretical than Haidt et al.'s. Instead of speculating on the latent constructs underlying the semantic similarity behind nominations and then writing items to reflect those speculations, we attempted as best we could to discern the "signal element" which made a given nomination or set of nominations disgusting (i.e., "inconsiderate behavior," "the smell of feces") and write a vignette to reflect that, rather than attempt to interpret latent

constructs out of these "signal elements" from the beginning. Of course, some interpretive bias is inevitable in this process, but we believe that the approach we took mitigated this risk.

Surprisingly, there was a smaller than expected number of nominations about sex and body envelope violations/mutilation, perhaps due to a reporting bias (e.g., discomfort on the part of the subjects with generating taboo nominations). Given the aim of the present work to adjudicate between the cultural evolution model and the adaptationist model, the lack of these nominations presented a problem for the study goals. Sex is one of the adaptationist model's three factors, and the category of body envelope violations is central to the DS-R. We generated additional items about sex and mutilation so that these crucial elements of each theory would be represented in the adjudication process. Incest vignettes were not included, due to their high likelihood for generating ceiling effects, their absence from the psychometrics associated with the theories to be tested, and their putative theoretical relationship with other non-incest-related sexually disgusting stimuli that could capture the latent construct of sexual disgust (Tybur et al., 2009). It is true that ecological validity was diminished by adding sex and mutilation items novelly generated by the researchers. However, we reasoned that the potential relationship between the theory-derived constructs of sex disgust and mutilation disgust and the latent factors which emerged from the data-driven approach would still be illuminating in terms of evaluating the two theoretical models. We also

wrote 16 neutral vignettes that were semantically related to a pseudorandom subset of nominations but without the element that made the nomination disgusting.

The resulting vignettes were submitted to 297 new raters on MTurk for validation, across three waves. Each vignette was rated at least 20 times. Subjects rated a random subset of 15 vignettes on frequency, comprehensibility, and imaginability, on 5-point Likert scales (in addition to 2 more neutral vignettes at the beginning and end of the survey). Frequency was assessed by asking subjects to rate "how common the thing being described is – in other words, how often [do they] encounter, see, or hear about things like this, either in [their] everyday life or in the media." Frequency judgments were collected to support future work using this stimulus set where a subjective sense of familiarity of a stimulus might confound certain measures (e.g., Somerville & Whalen, 2006; see Clifford, Iyengar, et al., 2015, for a similar approach). Comprehensibility was assessed by asking subjects to rate "how easy it is for [them] to understand what's going on in the scenario." Imaginability was assessed by asking subjects to rate "how easy it was to make a mental image of what was described." Subjects also answered the question of whether or not the vignette was disgusting with a "yes", "maybe", or "no." Vignettes intended to be disgusting but which were rated with "yes" or "maybe" under 50% of the time were rewritten once to potentially be more disgusting, and then discarded if the next round of rating did not achieve the 50% mark. The criterion of 50% of "yes" or "maybe" responses was selected due to the high degree of individual

variability in disgust at different kinds of elicitors (see Olatunji et al., 2007 for a discussion of the multifactorial nature of disgust), as well as in keeping with the proposed nature of disgust as a prototypical category, with some more typical elicitors such as excreta, and more peripheral category members being less universally agreed-upon (Haidt et al., 1997). Notably, in order for a factor to be identified in a factor analysis, there needs to be variability in item ratings: for example, sexual disgust items were excluded from the DS-R due to their extreme skewness (Olatunji et al., 2007).

After these modifications, the final vignette set constituted 120 disgusting items and 16 neutral items (Appendix A). Vignettes were easy to comprehend (M = 1.46, SD = 0.25, where 1 = "Extremely easy" and 5 = "Extremely difficult") and imagine (M = 1.64, SD = 0.32, on the same scale as comprehensibility), and tended to seem as though they happened somewhat rarely on balance (M = 3.68, SD = 0.61, where 1 = "Extremely often" and 5 = "Extremely rarely"). Despite the challenges inherent in vignette development and validation with respect to participant representativeness, researcher bias, and item sampling and vetting, we believe that our process improved upon previous efforts, yielding a vignette database that represented disgust elicitor categories in such a way as to permit a fair adjudication of the two theoretical models that were the focus of the present study.

2.3 Study 1: Exploratory factor analysis

The purpose of Study 1 was to examine the latent structure of the vignette database using an exploratory factor analysis, in order to assess the extent to which the theory-driven models were reflected in the data-driven model.

2.3.1 Methods

2.3.1.1 Participants

Data were collected online from 549 participants via the Amazon Mechanical Turk subject recruitment platform across three waves (N's = 36, 372, and 141). Individual cases were excluded in the following manner. One participant provided nonsensical answers to basic demographic questions at the end of the survey (e.g., stating that the religion practiced in their childhood home was "kentucky"), suggesting a lack of engagement with the task. Two participants selected the same rating 95% of the time or more across all items. Ten participants reported that English was not their first language, and they didn't learn English until after age six. When ratings of disgust vs. neutral items were subjected to a t-test, 29 participants did not show a significant difference between ratings, which could reflect task noncompliance or inability to discriminate emotions, and were subsequently eliminated. Several participants met more than one of these exclusionary criteria, resulting in an eligible sample size of N = 512 for data cleaning. A missing value analysis was conducted on this data sample using SPSS 24. Little's MCAR test was significant, $\chi^2(476) = 585.135$, $p < 0.001$. Four values were missing, each from different items and subjects, suggesting that the data were missing at random. Listwise

deletion of these subjects was therefore appropriate (Tabachnick & Fidell, 2013), leaving a sample size of N = 508 (283 female, M age = 36.24, SD = 9.85). All participants gave informed consent via the online Qualtrics survey portal, in accordance with the Duke University Institutional Review Board, and were given $1.50 in compensation.

2.3.1.2 Procedure

Using online Qualtrics survey software, participants rated items on a 7-point Likert scale, indicating how disgusting they felt the vignette to be. 16 items were neutral in content, included to prevent an overall negative mood induction as well as to identify subjects who did not respond appreciably differently to disgusting and non-disgusting material.

2.3.1.3 Data preprocessing

Variables were assessed for univariate normality (using the R "MVN" package, Korkmaz, Goksuluk, & Zararsiz, 2014) and the presence of outliers. Per the recommendation of Curran, West, and Finch (1996), items were tested for absolute values of skewness greater than 2 or kurtosis greater than 7, and per Tabachnick & Fidell (2013), outliers were identified as values greater than |3.29| standard deviations away from the mean rating of a given variable. Two variables (D081 and D101; skewness = -2.06 and -2.57, respectively) demonstrated an unacceptable skewness, and 10 variables included outliers. Univariate nonnormality as well as the presence of outliers were addressed by transforming variables first with a square root transformation, proceeding to a logarithmic transformation if outliers and nonnormality remained, and finally with an

inverse transformation if a logarithmic transformation failed to achieve normality (Tabachnick & Fidell, 2013). Items with negative skewness were reflected prior to transformation (ibid), yielding items where ratings were effectively reversed; these items are noted in Appendix B, and should be interpreted as having had the scale points as the poles flipped. Following these transformations, none of the variables met criteria for univariate nonnormality, and no univariate outliers remained.

The modified data set was then investigated for multivariate outliers. Forty-four outliers were identified as exceeding the critical chi square value of $\chi^2(122) = 176.014$ for a right-tailed chi-square distribution at a significance level of $\alpha = 0.001$. Mardia's test showed that multivariate normality was not achieved either with or without these outliers (skewness > 354001.699, p's < 0.001; kurtosis > 59.496, p's < 0.001). Rather than eliminate these outliers, factor analysis proceeded using techniques that are robust to violations of multivariate normality.

The data set was then assessed for multicollinearity and singularity. The highest bivariate Pearson's correlation among the variables was r = 0.772. Since the planned analysis was an analysis of structure (i.e., an exploratory analysis of the causal factors underlying the relationship between the variables), variables with high bivariate correlations with other variables were retained. None of the squared multiple correlations computed for each variable were greater than or equal to 0.99, suggesting that there was no multicollinearity or singularity present.

2.3.1.4 Factorability of the dataset

The Kaiser-Meyer-Olkin value, which tests the sampling adequacy across individual variables as well as for the dataset as a whole, was 0.974, which maps to the best possible level of sampling adequacy for the test (Kaiser & Rice, 1974). The minimum value on the diagonal of the anti-image correlation matrix was 0.908, which indicates that the data set was favorable for factor analysis.

2.3.1.5 Determining the number of factors

In an exploratory factor analysis, there is no hypothesis to be tested; therefore, the number of factors is not definite. There are several approaches which are used to approximate the number of factors which will provide the model which best explains the data. One method is to conduct a preliminary principal component analysis and identify the number of eigenvalues which exceed 1, i.e., Kaiser's "little jiffy" method (Kaiser, 1974). This method applied to the present study yielded 16 factors to interpret, which was deemed to be an unreasonable and possibly noisy number of factors. A parallel analysis (Horn, 1965) was conducted in order to suggest the number of factors to retain in the final analysis. Parallel analysis is a technique which compares the size of the eigenvalues in a dataset to the size of the eigenvalues in a simulated dataset of the same dimensions, indicating the size of eigenvalues which could be expected by chance alone in the actual data. The parallel analysis suggested that 7 factors be retained. Another way to determine the number of factors is to visually inspect the scree plot of the data for the "elbow," or the point at which the eigenvalues of principal factors appear to

decrease much less as the number of factors are increased. Visual inspection of the scree plot suggested 7 factors be retained as well. Another way to assess the optimal number of factors in a dataset is to calculate the average of the partial correlations of items and to determine the minimum of these values and use the number of factors in the correlation matrix at that minimum, i.e., Velicer's Minimum Average Partial (Velicer, 1976). An analysis of Velicer's MAP for the present data suggested 8 factors. In accordance with accepted practice for exploratory factor analysis, the analysis was iterated varying the number of factors according to the suggestions of these tests, as well as one number greater or less than each (Costello & Osborne, 2005). Hence the factor analysis was initially run with six, seven, eight, and nine factors, and the output was compared for interpretability. The 7- and 9-factor solutions each generated a factor where no item loaded saliently (greater than |.30|), while the 8-factor solution generated a factor with only 2 salient items. The 6-factor solution had the fewest non-loading items of the analysis iterations (9), the most singly loading items (97), and the fewest items with complex loadings (14). Furthermore, the factor with the fewest salient items (Factor VI) had five singly-loading salient items, which is an acceptable number of items for factor interpretation. For these reasons, the 6-factor solution was chosen for interpretation (Appendix B).

Table 1: Variance explained by each factor, and factor intercorrelations

	Proportion variance explained	I	II	III	IV	V	VI
Factor I	0.30	1.00	0.43	0.48	0.47	0.49	0.31
Factor II	0.17	-	1.00	0.46	0.19	0.21	0.12
Factor III	0.18	-	-	1.00	0.42	0.42	0.29
Factor IV	0.15	-	-	-	1.00	0.35	0.24
Factor V	0.13	-	-	-	-	1.00	0.27
Factor VI	0.07	-	-	-	-	-	1.00

The standard factor extraction method in an exploratory factor analysis is the maximum likelihood estimation method. However, given the multivariate nonnormality of the data set, an analysis with minimum residual factor extraction method was conducted since this method is robust to violations of multivariate distributions. An oblimin rotation was selected in all cases, due to the high intercorrelations between the variables (see also Olatunji et al., 2007). Factor analysis (as well as factorability estimates and initial estimates for the appropriate number of factors to extract) were conducted in the R package "psych" (Revelle, 2018).

2.3.2 Results

Factor I relates primarily to body products. As salient loadings decrease, it begins to include vignettes that map more broadly onto the cultural evolution model construct of core disgust by including items about objectionable food (e.g., moldy leftovers) and small animals associated with decay or disease (e.g., roaches, maggots, flies). Factor I absorbs all of the vignettes about smell (with the exception of D116, a vignette about smelly

unwashed laundry left on the bedroom floor), a factor which has been distinguished from core disgust in previous analyses (Walls & Kleinknecht, 1996).

Factor II consisted of morally loaded items, especially as concerns acts of harm, unfairness, or dishonesty (e.g., beating a dog with a tire iron, scamming elderly people, lying politicians).

Factor III loads items associated with non-normative sexual behavior. As mentioned previously, participants did not tend to generate scenarios relating to sexual disgust, and vignettes were generated by researchers in order to create a stimulus set that could engage with theories of disgust that encompass sexual disgust (Tybur et al., 2013). Variables with lower salient loadings related to sex less directly by including content about inappropriate urination (e.g., in the shower, in public). Notably, an item about a sexual predator exposing himself to children (D101) did not load highly onto Factor III, but rather onto Factor II (moral disgust) as well as Factor I (core/general disgust). Factor III items tended to be either non-harmful (e.g., paraphilia) or less directly harmful (e.g., trying to convince a partner to have sex without a condom).

Factor IV straightforwardly relates to the category of mutilation, referred to in the cultural evolution model as body envelope violations, and includes vignettes that describe surgeries, severe burns, and injuries. Less salient loadings also include vignettes that generally imply the presence of blood (e.g., a deer that has just been shot; oozing sores).

Factor V concerns people demonstrating bad manners. This category spans norms for personal hygiene as well as for appropriate eating behavior: burping, blowing one's

nose at the dinner table, popping a pimple, a child coughing up phlegm to amuse his friends, etc.

Factor VI is the least straightforward to interpret, encompassing vignettes about slimy sensations, insects in motion, and dirty dishes. One possibility is that this factor relates to the tactile experience of disgust.

<table>
<tr><th>Cultural evolution model</th><th>Data-driven model</th><th>Adaptationist model</th></tr>
<tr><td>-</td><td rowspan="2">Factor I (core disgust and aversive smells)</td><td>-</td></tr>
<tr><td>Core disgust</td><td rowspan="4">Pathogen disgust</td></tr>
<tr><td>Interpersonal disgust</td><td rowspan="2">Factor V (bad manners, hygiene, dining etiquette)</td></tr>
<tr><td rowspan="3">Animal reminder disgust</td></tr>
<tr><td>Factor IV (mutilation disgust)</td></tr>
<tr><td>Factor III (sexual disgust)</td><td>Sexual disgust</td></tr>
<tr><td>Moral disgust</td><td>Factor II (moral disgust)</td><td>Moral disgust</td></tr>
<tr><td>-</td><td>Factor VI (aversive tactile sensations)</td><td>-</td></tr>
</table>

Figure 2: Implications of the present findings on the cultural evolution model and adaptationist model's formulations of the superordinate structure of disgust categories.

2.3.3 Discussion

The exploratory factor analysis generated a 6-factor solution that provides a novel, data-driven perspective on the subjective experience of disgust in response to

crowdsourced vignettes. In Figure 2, we compare the outcome of our factor analysis against two prevailing theoretical models of disgust, the cultural evolution model and the adaptationist model. In contrast to our findings, the cultural evolution model predicts a 4-factor solution whereas the adaptationist model predicts a 3-factor solution. An outcome based solely on the basic-level documented elicitor domains would have yielded a solution with more factors. Instead, the factors which appeared in our solution appear to provide partial support for each theory while regrouping some elicitors and subdividing some key theoretical constructs.

In support of the cultural evolution model, our results show that Factor I maps neatly onto core disgust by including all three of its proposed categories: food, body products, and animals. One slight difference between Factor I and core disgust is a greater emphasis on body products. Core disgust as formulated by the cultural evolution model is thought to serve the function of avoiding oral incorporation of offensive objects, so food is more symbolically fundamental to the construct: body products and animals are disgusting in core disgust as they relate to rendering food disgusting (Rozin et al., 2008). The centrality of body products found in our analysis is supported by cross-cultural work by Curtis and Biran (2011), who found that excreta and vomit were nearly universally nominated as disgusting. Factor I does not wholly encompass core disgust, however, since small animals (particularly insects) were also found in Factor VI. An alternative interpretation is that Factor I relates to a general disgust propensity. Disgust has been described as a prototypical category (Haidt et al., 1997), where the prototypical, almost universal core of the category relates to biologically inevitable selection pressures

such as disease avoidance (Curtis & Biran, 2001), but more peripheral instances of the category are variable and dependent on cultural socialization. If that is the case, it is possible that Factor I indexes a general propensity for disgust (similar to the concept of *g* in investigations about individual differences in intelligence; Ogden & Spearman, 1925), since core disgust/disease-relevant stimuli are highly typical of the disgust category. Importantly for the evaluation of the adaptationist model, Factor I appears to represent a fraction of pathogen disgust, which supports the idea that pathogen disgust is not best thought of as one unique construct (see also Curtis & de Barra, 2018).

Factor II straightforwardly represents moral disgust, although in a manner closer to its conception in the adaptationist model rather than the cultural evolution model. The adaptationist model's understanding of moral disgust is as a response to antisocial behavior such as cruelty, whereas the cultural evolution model describes moral disgust as a symbolic degradation of the soul via impure behavior or characteristics. The crowdsourced nominations of disgust with a moral element did not tend to describe impurity (e.g., items from the purity subscale of the Moral Foundations Sacredness scale, such as a human surgically appending a tail to their spine; Graham, Haidt, & Nosek, 2008) but rather acts of harm, unfairness, or dishonesty. This pattern may relate to Gray & Keeney (2015)'s finding that when participants are instructed to generate an "impure" immoral act, they are most likely to suggest harmful acts (for a discussion of the relationship between harm and other kinds of immorality, such as unfairness or dishonesty, see Schein & Gray, 2016; but see Graham et al., 2013 and Parkinson et al., 2011 for a discussion of dissociations between harm and other types of moral violations).

In any case, the moral disgust factor represented in our analysis is better thought of as supporting the adaptationist model than the cultural evolution model, although it could be marshaled as support for both to some extent in that there is a single moral factor.

Factor V related to bad manners across domains such as hygiene and dining. The concept of manners has not been the target of much investigation in the field of disgust psychology, although recent work suggests that manners are frequently relevant to disease avoidance concerns (Curtis, 2017). In addition, manners that engage with disgust tend to be more culturally stable over time than manners related to idiosyncratic cultural norms (Nichols, 2002). This factor might be plausibly thought of as relating to the contamination factor of the cultural evolution model proposed by Olatunji et al. (2012), since it does include failures of hygiene (shaking the clammy hand of a new acquaintance) and potential contact with germs (someone coughing without covering her mouth); however, there appears to be a normatively proscriptive element to this factor (i.e., people behaving in an unmannerly fashion but not immorally) that is not present in the contamination factor.

As predicted by the AM, factors emerged that mapped onto sexual disgust and moral disgust. However, pathogen disgust appears to be diffused across Factor I as well as Factor VI and Factor IV (body envelope violations), and perhaps Factor V (which includes violations of hygiene). One possibility is that pathogen disgust is a more superordinate domain than sexual and moral disgust, and that it comprises multiple subtypes. However, it is necessary to characterize these subtypes to ensure that elicitor categories are not attributed to the pathogen disgust domain when they might be better

considered as constructs at the same level of hierarchical organization as sexual and moral disgust. Similarly, the putative animal reminder domain appeared to be diffused across three other factors: Factor III (sex), Factor IV (mutilation), and Factor V (which includes violations of hygiene), suggesting that animal reminder disgust may exist at a different level of hierarchical organization than core disgust and moral disgust.

In sum, an exploratory factor analysis based on a crowdsourced set of disgust vignettes yielded a novel 6-factor structure. The superordinate domains of pathogen disgust and animal reminder disgust did not pull out as factors of their own, but were rather dispersed across multiple factors. This pattern suggests that the functional organization of both the cultural evolution model and adaptationist model ought to be revised to model pathogen disgust or animal reminder disgust as more general constructs, which include latent constructs at the same level of abstraction as core disgust, sexual disgust, and moral disgust.

2.4 Study 2: Confirmatory factor analysis

The results of Study 1 might prompt disgust researchers to consider two options. One possibility is to interpret the past contributions of each model through a data-driven lens (i.e., the structure associated with the exploratory factor analysis), and scaffold future disgust research on the resulting synthesis. Another option is to compare which of the models perform better. A confirmatory factor analysis was conducted in order to facilitate both of these potential options. It was expected that, in keeping with past research, both of the theoretically-driven models would achieve at least an adequate model fit, but that using information criterion values would allow the direct comparison

of one model fit to another. In addition, if the fit of the data-driven model suggested by the exploratory factor analysis outperformed that of either theoretically-driven model, it further justifies the argument made above that both theoretically-driven models need revision in order to achieve ecological validity.

2.4.1 Methods

2.4.1.1 Participants

Data were collected online from 525 participants via the Qualtrics subject recruitment platform. The same exclusionary criteria were used as for Study 1. Twenty-nine participants provided nonsensical answers to basic demographic questions at the end of the survey; seventeen participants selected the same rating 95% of the time or more across ratings of all items; nineteen participants reported having learned English past the age of six years old; when ratings of disgust vs. neutral items were subjected to a t-test, 100 participants did not show a significant difference between ratings, and were subsequently eliminated. Many participants met more than one of these criteria, resulting in an eligible sample size of N = 407.

A missing value analysis was conducted using SPSS 24. Little's MCAR test was not significant, $\chi^2(282) = 182.839$, $p = 1.000$, suggesting that data were missing completely at random and that listwise deletion of these subjects was acceptable (Tabachnick & Fidell, 2013). Removing these cases left a sample size of N = 404 for initial statistical analysis (224 female, M age = 43.68, SD = 11.49). All participants were compensated in accordance with the Qualtrics recruiting platform's policies, in the form

of gift cards and other monetary incentives in varying amounts, approximately $1.50 on average.

2.4.1.2 Procedure

The task was identical to that used to collect data for Study 1.

2.4.1.4 Data preprocessing

Per the recommendation of Curran, West, and Finch (1996), items were tested for absolute values of skewness greater than 2 or kurtosis greater than 7 using the R "MVN" package (Korkmaz et al., 2014). All items demonstrated acceptable kurtosis, but 3 variables demonstrated unacceptable skewness. In addition, 13 variables demonstrated the presence of univariate outliers. Variables were transformed and reflected according to the same procedure used for Study 1. All the variables achieved univariate normality after this procedure.

Thirty-one multivariate outliers were calculated at the critical chi square value of 143.344; however, Mardia's test for multivariate normality was significant with and without the outliers (skewness > 173905.551, kurtosis > 44.264, ps < 0.001). Multivariate outliers were therefore included in the data set, but a Satorra-Bentler correction was used to rescale measures of model fit, since statistics rescaled in this way are robust to violations of multivariate nonnormality.

Vignettes were included in the dataset if they could be straightforwardly assigned to a factor from Study 1, a superordinate domain from the cultural evolution model (e.g., animal reminder disgust), and a superordinate domain from the adaptationist model (e.g.,

sexual disgust) (see Appendix C). Vignettes that did not fall into these categories or might have spanned more than one superordinate domain (e.g., a vignette where the disgusting element was both sexual and food-related in nature) were excluded, leaving a total of 95 vignettes to be submitted to the confirmatory factor analysis. Confirmatory factor analysis was conducted using the R "lavaan" package (Rosseel, 2012) for four models: the data-driven model suggested by the exploratory factor analysis from Study 1, one suggested by the cultural evolution model, one suggested by the adaptationist model, and one where each vignette was placed into its basic-level elicitor category (i.e., food, body products, animals, hygiene, body envelope violations, sex, and morality).

2.4.2 Results

Table 2: Indices of model fit for the models submitted to confirmatory factor analysis

Model	Number of factors	Robust RMSEA (confidence intervals)	Robust CFI	Robust TLI	SRMR	AIC	Sample-size adjusted BIC
Cultural evolution	3	0.057 (0.055, 0.059)	0.769	0.764	0.067	118531.707	118770.257
Adaptationist	3	0.051 (0.049, 0.053)	0.817	0.813	0.063	117317.717	117556.268
Elicitor categories	7	0.042 (0.040, 0.043)	0.851	0.847	0.062	116501.472	116754.931
Data-driven	6	0.045 (0.044, 0.047)	0.855	0.851	0.063	116403.700	116652.190

All 4 models achieved values of robust root mean squared error of approximation (RMSEA) less than 0.57 (see Table 5), indicating that all models fit the data adequately (model fit is indicated by a value of RMSEA less than 0.60). Additionally, all standard

root mean residual (SRMR) values were less than 0.080 (SRMR < 0.067). Across all models, the robust comparative fit index (CFI) and Tucker-Lewis index TLI values were lower than 0.95 (CFI < 0.855; TLI < 0.851). Although ideally these latter values would exceed 0.95 to indicate a well-fitting model, the convergence of other measures on adequate model fit suggests that the data were not significantly different from the predicted estimation of the data as per the *a priori* models. A chi square test is not advisable to test the adequacy of models on large sample sizes, since increases in sample size tend to increase the potential detection of spurious differences.

While meaningful in terms of evaluating the fit of a model, these measures are not appropriate for comparing the performance of competing models. A chi square difference test was also not appropriate for this application, since the models were not nested (see Table 5). In order to directly compare the models, Akaike's information criterion (AIC) was computed for each model (Table 5). The difference in AIC values between multiple models corresponds to the amount of information (in information theoretic terms, information refers to the decrease in uncertainty) that is lost when going from one model to another; for instance, when comparing two models of the same data, the model with the higher AIC value contains less information relative to the model with the lower AIC value. The model suggested by the exploratory factor analysis had the lowest AIC of the tested models, indicating superior performance relative to the other models. The differences in AIC between the exploratory factor analysis model and the cultural evolution model, adaptationist model, and basic-category model were all greater than 10 (2128.007, 914.017, and 97.772, respectively), implicating virtually no support for the

other models relative to the exploratory factor analysis model (Burnham & Anderson, 2004). In comparing the AIC for the cultural evolution model and adaptationist model, the adaptationist model performed substantially better ($delta_i$ = 1213.989), indicating support of the adaptationist model over the cultural evolution model in the current data set. A similar pattern was obtained when examining the sample-size-adjusted Bayesian Information Criterion (BIC), a value similar to the AIC but which penalizes higher-dimension models to protect against overfitting (Schwarz, 1978). The exploratory factor analysis model had the smallest value of any tested model, suggesting that it performed the best out of all the tested models (see Table 5). All models were separated by a distance greater than 10, suggesting that the adaptationist model fit the data better than the cultural evolution model (Raftery, 1995). Importantly, the convergence of patterns of AIC and BIC values across models not only strengthens the idea that the exploratory factor analysis model exceeds the other two models, it addresses the potential concern that the difference in performance between models is not attributable to the overall number of factors contained within them, since the exploratory factor analysis still exhibited superior performance in spite of the penalties imposed on it by the BIC due to its high number of parameters relative to the other models.

2.4.3 Discussion

A confirmatory factor analysis demonstrated the generalizability of the results from Study 1 to a new sample. In a direct model comparison, the data-driven model from the exploratory factor analysis substantially outperformed the cultural evolution model and the adaptationist model, suggesting that they do not comprehensively describe the

variance in disgust across an ecologically valid sample of disgust elicitors. The exploratory factor analysis model also outperformed a model made up of the basic elicitor categories themselves (e.g., food, body products, etc.), eliminating the possibility that the data-driven model was not favored because it was more basic than the theory-driven models or because it had more parameters. The results of the test of the data-driven model legitimizes its use as a standard by which to judge the two theoretically-driven models – for instance, to suggest refinements to either model if a given domain or factor is missing in the theoretically-driven model but present in the data-driven model. Specifically, the fit of the data-driven model suggests that a comprehensive model of disgust needs to include a factor for sexual disgust distinct from other animal reminder elicitors (cf. Tybur et al., 2009), and a factor for body envelope violations distinct from other animal reminder elicitors and pathogen elicitors (cf. Kupfer, 2018).

Direct adjudication between the adaptationist model and the cultural evolution model via confirmatory factor analysis yielded greater support for the adaptationist model in this sample. Notably, the 7-factor model comprising each basic category of disgust elicitor outperformed the superordinate organization of the theoretically driven models, reinforcing the potential differences in hierarchical abstraction of broader domains like pathogen disgust and animal reminder disgust.

2.5 General discussion

Disgust and its breadth of elicitors have been the subjects of investigation within the philosophy of biology, psychology, and anthropology (Kelly, 2011; Rozin et al., 2008; Curtis & de Barra, 2018). Different characterizations of the proximate mechanisms

of disgust, as well as their relationship to the evolutionary function of disgust, have been put forward (Rozin et al., 2008; Tybur et al., 2013), largely focusing on the symbolic nature of disgust experience (e.g., reminders of death) and cognitive mechanisms which selectively bias behavior and information processing (e.g., deciding to eat something a little gross due to being very hungry). These two prominent accounts of disgust disagree, in large part due to the theoretical backgrounds in which they were conceived. The present studies investigated the variability of disgust experience using factor analytic techniques on a new database of disgust vignettes, and in so doing was able to adjudicate how well these two theoretically-derived models were corroborated by a data-driven investigation.

On balance, the adaptationist model fared better than the cultural evolution model. The adaptationist model fit the data better than the cultural evolution model in the confirmatory factor analysis (Study 2), though not as well as the data-driven model. However, the results of the preceding studies do not represent an unqualified endorsement of the adaptationist model at the expense of the cultural evolution model. There are several findings that suggest that neither model is wholly comprehensive, and some that may be interpreted as supporting the cultural evolution model over the adaptationist model. Neither theory achieved a perfect match to the data-driven model in terms of mapping factors to domains (Study 1), and since the data-driven model outperformed both existing theoretical models (Study 2), it may be considered as a legitimate potential standard by which to judge the existing theory-derived models.

Historically, putative domains of disgust (e.g., pathogen disgust, core disgust) have been differentiated based on which ecological stimuli elicit them. Several corollaries emerge from this paradigm: first, that a given domain will selectively apply to the disgust elicitors that it is supposed to (and not others), and second, that a given domain should not be subdivided further. These corollaries can be operationalized into two predictions that should be supported if the models being tested can be validly applied to the study of variability in the subjective experience of disgust. First, no factor should include items from multiple domains of disgust – e.g., in order for the cultural evolution model to be supported, there ought to be no factor which responds to food as well as envelope violations, since those elicitors come from different domains (core disgust and animal reminder disgust respectively). Second, one domain should correspond to one single factor – e.g., in order to support the adaptationist model, there should be one single factor which responds to pathogen disgust, rather than multiple factors for different subtypes of pathogen disgust.

In general, the first corollary appears to have been supported in both models. The data-driven model did not generate factors that spanned multiple domains of the cultural evolution model or adaptationist model, with several small exceptions. Factor V seems to pull from hygiene norms as well as norms about proper etiquette surrounding food and body products, which can be seen as representing elicitors from the core, animal reminder, and perhaps interpersonal domains of the cultural evolution model. However, this might reflect some natural functional overlap of these domains. Rozin et al. (2008) point out that animal reminder disgust has a "civilizing" effect on eating and grooming

behavior, both of which are closely related to food and body products. Furthermore, interpersonal disgust is thought to be elicited by individuals with moral taint and disease among other things, suggesting that it is a construct orthogonal to core and animal reminder disgusts.

The second corollary fails in some domains and is supported in others. The data-driven model did not just generate factors corresponding to pathogen disgust, sexual disgust, and moral disgust; neither did it generate factors corresponding to core disgust, animal reminder disgust, interpersonal disgust, and moral disgust. Instead, it is clear that sexual disgust must be a factor unto itself (unlike in the cultural evolution model), as well as body envelope violations/mutilation (unlike either model). Convergent evidence on this latter point was recently demonstrated by Kupfer (2018), who showed that items about painful injuries loaded into a factor apart from pathogen, sexual, and moral disgust and concluded that it may not be appropriate to include body envelope violations under the heading of pathogen disgust in spite of their potential association with infection risk. Additionally, pathogen disgust was diffused across several different factors in Study 1, rather than arriving at one in and of itself. Curtis and de Barra (2018) investigated the variability within pathogen disgust specifically by factor analyzing disgust response to a set of potential disease vectors, and concluded that factors were driven by the different behavioral strategies used to avoid disease vectors in any given instance. Notably, core disgust emerged almost exactly as formulated by cultural evolution model as the first factor – that is, by including body products, inappropriate food, and animals. From the perspective of the AM, all the elicitors which fall in the core disgust domain should

essentially be united under the header of pathogen disgust, but the present findings, along with Curtis & de Barra's (2018), suggest that there is some heterogeneity within pathogen disgust that is not captured in the AM, and that perhaps some of that heterogeneity is better explained by the construct of core disgust.

Taken together, the evidence summarized above indicates that the one major refinement to be levied at the extant disgust models is to reevaluate the relative hierarchical placement of a given disgust domain. Figure 1 demonstrates the hierarchical organization of both models – to wit, there is a basic level of elicitor categories (food; hygiene; etc.), and then a superordinate level of disgust domain (pathogen; core; etc.). In certain cases, a basic level category is the same as a superordinate domain (as in the case of moral disgust). However, the results of Study 1 suggest that important information about variability in disgust experience may be lost if domains are treated as belonging to the same hierarchical level when they really do not. This mistake may be easy to make proceeding from theoretical assumptions rather than a data-driven perspective, since it is difficult to judge the relative similarity of proposed disgust domains a priori. For instance, while pathogen disgust might be thought of as a singular adaptation in response to a specific evolutionary selection pressure, the disease avoidance mechanism seems to be multiply realized in its psychological implementation (see Tinbergen, 1963 for a discussion of the distinction between the "ultimate" and "proximate" cause of a behavior). In other words, pathogen avoidance appears to be related to more than one psychological mechanism (cf. Curtis & de Barra, 2018). In a similar fashion, the proposed goal of animal reminder disgust – to avoid reminders of mortality – may be a

more distal psychological goal than the proximate goals of rejecting non-normative sexual behavior or appropriately responding to exposure to violated body envelopes. It is also possible that the function of so-called animal reminder disgust is not to avoid mortality salience reminders, or that the relationship between mortality salience and disgust (Kelley et al., 2015; Cox et al., 2007; Goldenberg et al., 2001) is not confined specifically to the formulation of animal reminder disgust put forth in the cultural evolution model. For instance, perhaps there is a relationship between disgust and other kinds of psychological threats, such as violations of the barrier of the self (Burris & Rempel, 2004) or violations of categories as Mary Douglas (1966) suggested (see Hanna & Sinnott-Armstrong, 2018 for a discussion of the potential relationship between disgust and domain-general threat compensation).

We acknowledge some limitations to our approach. In spite of our efforts, the present study was not purely data-driven: it walked a middle ground between crowdsourced development and fitness for use in research. For instance, it may be the case that some factors of disgust may not show up without prompting, so relying entirely on an uncued instruction to come up with disgust elicitors might leave out important elements of the disgust landscape. We noted that sexual disgust was infrequently nominated compared to more prototypical disgust elicitors such as excrement, in spite of the fact that motivation to avoid maladaptive sexual behavior has been strongly linked with disgust (Lieberman et al., 2007; Schaich Borg et al., 2008). It may be the case that there are other ways to collect ecologically valid nominations of disgust using a method that does not rely on a participant consciously generating and reporting an example and

fitting it to the label of "disgust" – possibly an approach using natural language processing of online social media data would avoid this pitfall. In writing our own sexual disgust items to reflect previous success linking sex to disgust, we attempted to have the best of both worlds by acknowledging some theoretical information in order to interface with existing theoretical models, while mostly relying on crowdsourced information. Similarly, it is possible that the reason moral disgust tended to be more harm- and fairness-based rather than purity-based (i.e., better fit the adaptationist model's idea of moral disgust than the cultural evolution model's idea) is reflective of the fact that non-harm-based purity violations which are extreme enough to elicit disgust do not readily occur to participants. Gray and Keeney (2015) noted that when they asked participants to generate examples of moral impurity, most of the nominations tracked harm and cruelty, and did not bear much resemblance to the bizarre exemplars put forth in previous work on the purity-based moral disgust, such as surgically adding a tail to one's spine. Finally, even though the research design was crafted to avoid certain practices which might have allowed researchers' interpretive bias to leak in, it was virtually impossible to completely avoid that, particularly since vignettes had to be adapted from nominations in order to avoid redundancy or inappropriate content. Consequently, holding up the data-driven model as a totally atheoretical model may not be appropriate. However, the data-driven model was still relatively impartial with respect to the existing theoretical models, and therefore can be thought of as being an appropriate benchmark for evaluating those models.

We have identified several potential implications of the present work for existing theories. In the first place, it may be worthwhile to revise extant psychometrics of disgust. The existing instruments attached to these theories do exhibit predictive validity (Olatunji et al. 2008; Tybur et al., 2009), but if the constructs mapping to those subscales require refinement, then doing so may increase the sensitivity of these measures. Additionally, by expanding a psychometric assessment to appropriately encompass all of the types of disgust identified in a data-driven analysis, relationships between individual differences in disgust and other factors such as psychiatric disease may be identified (Olatunji et al., 2017).

Secondly, the conceptual utility of these theories may need to be reevaluated. It seems likely that these theories represent complementary approaches to understanding the multiple aspects of disgust as a psychological trait (Tinbergen, 1963). Disgust is likely grounded in biological evolution, and the distinctiveness of the adaptationist model's sexual disgust domain may speak to the disparate selection pressures which may have influenced the multifactorial nature of disgust. However, proceeding in a confirmatory way from adaptationist theorizing may leave room for eliding certain sources of variability under the same evolutionary explanation (e.g., injury disgust; Kupfer, 2018). The psychological mechanisms anticipated by an evolutionary account may not map onto the psychological mechanisms observed from a more empirical, symbol-based account, such as is offered by the cultural evolution model.

It is our position that theories from these levels of analysis should interact and inform each other. A wholly adaptationist account, which, for instance, identifies

pathogens as a single selection pressure mapping onto one subconstruct within disgust, may fail to identify proximally-implemented behaviors and individual differences corresponding to that construct (Curtis & de Barra, 2018). A wholly symbolic psychological account may suggest the existence of functional domains which lack parsimony or leave out important sources of variability driven by evolutionary concerns. By using data-driven methods, it may be possible to select the ecologically valid contributions of each theory, so that the field of disgust research may proceed in as rich and nuanced a way as possible.

3. Psychophysiological distinctiveness of responses to mutilation: Implications for theories of disgust

3.1 Introduction

Disgust is pervasive throughout the human experience. It has been shown to intersect with psychiatric dysfunction (Phillips et al., 1998), decision-making (Kelley et al., 2015), and social and moral judgment (Capestany & Harris, 2014; Chapman & Anderson, 2013), among many other domains. In spite of its relevance, disgust has puzzled researchers for many years due to its apparent multifactorial nature. Often, people report having a reliable level of disgust in response to a certain cluster of semantically similar things (different kinds of body products, for instance), an individual difference which can vary distinctly from disgust at other clusters of elicitors (e.g., immoral character traits). Furthermore, differences have been found across the neurophysiological processing (Schaich Borg et al., 2008; de Jong et al., 2009; Shenhav & Mendes, 2014) of different clusters of things which elicit disgust. These findings have led some scientists to treat disgust as a multifactorial construct (e.g., Olatunji et al., 2007, Olatunji et al., 2008), with distinct effects on cognition and behavior associated with the specific subtype of disgust.

This contention raises the question of how best to think about these different putative subtypes of disgust. If different kinds of disgust uniquely predict important outcomes, it is crucial to have a strong understanding as to whether or not those putative subtypes of disgust are actually distinct. In other words, making valid

predictions is dependent on using predictor constructs which map well onto reality. Unfortunately, there is a lack of consensus as to how best to model the differences between types of disgust. Two prominent models which have been advanced to explain the subdivisions within disgust have offered conflicting views (see Figure 1). The older and more influential model, referred to herein as the cultural evolution model, was put forth by Rozin and colleagues (1993, 2000, 2008) and conceptualizes of disgust as having several different domains which respond to a specific set of elicitors and which have unique functions. Core disgust is thought to be the most ancient form of disgust, and serves the function of protecting an individual from ingesting offensive substances, such as food which has been contaminated with body products. Other domains of disgust are thought to have emerged from core disgust via the process of cultural evolution. Animal reminder disgust is thought to function to protect an individual from anything which reminds them of their animal nature (i.e., attributes of human behavior or anatomy which are shared between human and nonhuman animals), because contemplating animality is linked to uncomfortable contemplations of mortality (Goldenberg et al., 2001). Examples of animal reminder disgust include sex and violations of the body envelope (most commonly, mutilation). Moral disgust is thought to function to protect an individual against degradation of the symbolic soul, and is activated by perception of morally wrong behavior or character, particularly (but not solely) violations of the moral foundation of "purity" (Graham et al., 2013) such as engaging in taboo acts. A newer

model, referred to here as the adaptationist model, was offered by Tybur, Lieberman and colleagues (Tybur et al., 2009; Tybur et al., 2013). It subdivides disgust according to assumptions about the selection pressures which shaped various instantiations of disgust over human evolution. Per the adaptationist model, there are three domains of disgust: pathogen disgust, which serves the adaptive function of discouraging contact with pathogens; sexual disgust, which discourages sexual behavior which leads to the decreased genetic fitness of offspring (e.g., incest); and moral disgust, which promotes behavior that conforms with social norms and in-group cohesion/out-group exclusion.

Both of these models make claims about the evolutionary and proximate mechanisms of these domains, but the two models are not mutually compatible (Figure 1). One notable example of this is mutilation disgust: a response labeled as "disgusted" to things like violations of the body envelope, gore, injuries, surgeries, etc. The cultural evolution model suggests that disgust mutilation falls under the purview of the animal reminder domain. As such, the cultural evolution model believes that disgust at mutilation is the same construct that responds to disgust at sex (another animal reminder elicitor), but is distinct from core disgust (e.g., disgust at body products) and moral disgust. The adaptationist model, by contrast, does not believe mutilation to be the same construct as disgust at sex, because mutilation belongs to the domain of pathogen disgust (i.e., the same response as disgust at body products), which is separate from the domain of sexual disgust. The disagreement in the basic science of disgust over

mutilation may be of particular importance with respect to psychiatric and socially important applications. For instance, mutilation disgust shows predictive validity for blood-injury-injection phobia (e.g., Sawchuk et al., 2000), as well as political affiliation (e.g., Ahn et al., 2014). In order to investigate interventions for psychiatric disease related to mutilation disgust, or to learn more about political decision-making, it would be helpful to know if it is effectively the same thing as the disgust response for other sorts of domains.

One way to investigate the potential differences across disgust responses is to look at differential physiology. Emotions are often described as being probabilistically associated with certain peripheral physiological patterns (Kreibig, 2010; but see Lindquist et al., 2013). In fact, differences in physiological responses to mutilation and to non-mutilation disgust (generally operationalized as core disgust) have been shown numerous times (Shenhav & Mendes, 2014; de Jong et al., 2011; Harrison et al., 2010), although not consistently (van Overveld et al., 2009).

Notably, most formulations of the cultural evolution model do not actually suggest a physiological difference across domains; in general, the disgust response is said to be "conserved" across domains (Rozin & Haidt, 2013). However, empirical investigations of the difference in responses to mutilation as opposed to other kinds of disgust have invoked the labels of the cultural evolution model in the past, and one of the original authors of the cultural evolution model co-authored a paper which

suggested suggest specific physiological correlates for animal reminder disgust distinct from core and contamination/interpersonal disgust (Olatunji, Haidt, et al., 2008). Additionally, as noted above, the cultural evolution model has been invoked in previous investigations of disgust physiology, regardless of whether or not it makes that claim itself, and as a result it is important to validate whether labels like core disgust and animal reminder disgust are suitable for such ends. The authors of the adaptationist model have also been cautious about making claims as to the physiological distinctiveness of these domains (Tybur et al., 2013), suggesting more generally that a distinct computational structure and suite of behaviors is associated with each disgust domain. However, it is similarly important to ascertain whether or not the adaptationist model is appropriate to use in describing variability in the psychophysiology of disgust.

Previous research has employed pattern classification techniques to assess the reliability of the multivariate physiological patterns associated with different emotions, and to compare the explanatory power of competing models of emotion representation as pertains to physiology. Kragel and LaBar (2013) trained a pattern classifying algorithm on the physiological responses associated with several discrete emotions (e.g., contentment, surprise, fear, anger, etc.), and were able to show that not only was it possible for the algorithm to predict above chance the emotion being elicited in a participant in a new instance. Furthermore, by examining instances where the classifier made an error, the researchers were able to make inferences about whether emotional

experience is better modeled as a set of discrete categories (i.e., basic emotions theory; Ekman 1992) or two orthogonal dimensions of valence and arousal (Barrett, 2006). To illustrate an example, a dimensional account of emotion might suggest that a classifier might be likely to misclassify an observation of fear as an observation of anger, because fear and anger are both typically negatively valenced, high arousal states, and less likely to misclassify fear as contentment (a typically positive, low-arousal state). If the physiological representation of emotion was indeed something which reflected the two axes of valence and arousal, then the classifier could be expected to make errors that respected these axes. However, if classifier errors were random -- for instance, if a misclassification of fear as anger was just as likely as a misclassification of fear as contentment -- it might be more consistent with a categorical account of emotion, which predicts unique physiological representations for each discrete emotion, rather than for the two general emotional axes of valence and arousal.

The goal of the current study is to a similar approach to compare the power of the cultural evolution model and adaptationist model when it comes to explaining differences in disgust physiology. The present study used a support vector machine learning algorithm to investigate whether discriminant, reliable signals in peripheral physiology could be learned for the responses to a select set of disgust elicitor categories: mutilation, sex, body products, and immorality. The cultural evolution model and adaptationist model make contrasting predictions about the disgust domains into which

these categories fall, and by examining the errors made by the classifying algorithm, it might be possible to evaluate the utility of these two models. For instance, if animal reminder disgust has an associated psychophysiological pattern, a classifier which is trained on the patterns associated with mutilation disgust and sexual disgust may tend to mutually misclassify these observations, since they are both animal reminder disgust; furthermore, these misclassifications of mutilation and sex will be more likely than a misclassification of mutilation as body products, since mutilation is animal reminder disgust and the response to body products is core disgust.

3.2 Methods

3.2.1 Participants

Participants were N = 34 volunteers (24 female, mean age = 26.44 years old, SD = 7.95) who reported no psychiatric or neurological illness or use of psychoactive medication, and who gave written informed consent. The study was approved by the Institutional Review Board of Duke University. Participants were compensated $15 per hour for their time.

3.2.2 Stimuli

Stimuli consisted of 14-17 word vignettes meant to evoke disgust in one of four ways, as well as neutral vignettes (see Appendix C). Some vignettes were drawn from a stimulus set of vignettes meant to evoke disgust (Hanna et al., in preparation), some

were drawn from a set of vignettes meant to assess moral judgment (Clifford, Iyengar, et al., 2015), and some were novel to the present study.

The four conditions were selected to cut across the domains of the cultural evolution model and the adaptationist model in such a way that the classification schemes of both models could be compared (see Figure 1): mutilation, sex, body products, and immorality. The cultural evolution model assigns stimuli related to mutilation or body envelope violations to the domain of animal reminder disgust, whereas the adaptationist model positions it as part of the domain of pathogen disgust; for ease of reference in evoking both of these labeling schemes, the mutilation condition was coded in this study as ARPATH for analysis purposes. As with mutilation, the cultural evolution model views sex as a kind of animal reminder disgust; however, the adaptationist model views sex as a unique disgust domain, so the sex condition was coded as ARSEX for analysis. Whereas the adaptationist model views body products as evoking pathogen disgust, the cultural evolution model sees them as belonging to the domain of core disgust, so body products were coded as COREPATH for analysis. Finally, both the cultural evolution model and adaptationist model suggest that moral disgust is a domain unto itself, and stimuli meant to inspire moral disgust were coded as MORAL for analysis.

3.2.3 Procedure

Subjects were instructed to read vignettes and vividly imagine that they were actually witnessing the event being described. In order to decrease potential mindwandering, subjects were informed that there would be a memory task following the physiological recording block, and instructed to do their best to pay attention. Additionally, subjects were told to press a button when they had finished reading each vignette, and to continue visualizing the image even after they had pressed the button.

Subjects presented with two blocks of each condition in a pseudorandom order unique to each subject. Run orders always began with an additional neutral block to serve as habituation to the task, which was excluded from analysis. Blocks consisted of vignettes presented for 10 seconds each (with an intertrial interval between 1 and 2 seconds), for 140 seconds total. Following each block, subjects were presented with simple arithmetic problems (addition, subtraction, multiplication, and division of single-digit integers) for 100 seconds. This interblock period both served as a washout for previous stimuli and also to allow for sufficient time to collect indices of bradygastria from the previous block (see Harrison et al., 2010 and Shenhav & Mendes, 2014 for similar approaches).

Following the physiological data collection session, subjects were instructed to freely recall as many vignettes as they could, in keeping with the memory task that was used to retain attention during the disgust vignette task (data not presented here). Next,

subjects saw the vignettes they had seen during the task and were asked to rate them on a scale of 1 to 7, where 1 = Not at all disgusting and 7 = Extremely disgusting. Finally, subjects completed three disgust-related psychometrics (data not presented here) and were compensated.

3.3 Planned statistical analyses

3.3.1 Manipulation check

A repeated measures analysis of variance was conducted to investigate the effect of condition on how disgusting the vignettes were rated by subjects after the physiological recording session. One subject chose to stop participating due to time constraints before completing the ratings, leaving a total sample of N = 33 with complete behavioral data.

3.3.2 Classifier performance

Classifier performance was assessed both as a function of the four individual disgust conditions and for the model as a whole. Three performance metrics were calculated on each iteration of the random subsampling procedure: a precision score, a recall score, and an F1 score. Precision is the proportion of true positives out of the total number of positive labels. Recall is the proportion of true positives out of the total number of correctly labeled observations (i.e., false negatives + true positives). The F1 score is the harmonic mean of precision and recall, synthesizing both measures to assess the utility of a classifier. When assessing the model as a whole, the weighted average of

these metrics across conditions was used, in order to account for the varying number of class labels on each iteration of the subsampling procedure. In order to determine whether or not the performance of the classifier given by these metrics was different from chance, the labels in the training set were randomly permuted, and another cohort of SVMs were trained using the same procedure as for the correctly labeled training set. Since the assumptions of parametric tests are violated in the case of this iterated subsampling approach, nonparametric statistical tests were used to compare performance across classifiers trained on true labels and on permuted labels.

3.3.3 Analysis of error distribution

To assess the potential explanatory power of the two theoretical models, the distribution of error made by the classifier was analyzed. Specifically, three Kruskal-Wallis tests were used to assess the effect of ground truth class membership on the weighted average number of predictions for the "COREPATH" class, the "ARPATH" class, and the "ARSEX" class respectively. Since both the cultural evolution model and the adaptationist model set moral disgust as an entity unto itself, and since neither of the models make explicit predictions about the relative distance of each domain from each other (e.g., pathogen is not described as being "more different" from sexual disgust than from moral disgust), tests of misclassifications of trials as "MORAL" would not serve to adjudicate between the models, and were therefore not performed.

A nonparametric test was selected as before because of the violation of assumptions of independence inherent to the analysis. Actual cases of each class were removed from each corresponding analysis, so that only the three conditions where an assignment was necessarily errors would be compared: for instance, true cases of COREPATH, ARPATH, and MORAL were compared in terms of the weighted average number of times they were predicted to belong to the ARSEX class. The weighted average was used because the random subsampling procedure resulted in slightly different class sizes across iterations. For example, the first of these analyses compared the means of three sets of values: a list of the number of ARPATH trials which were misclassified as COREPATH for each iteration, weighted entrywise to reflect the number of ARPATH trials which were actually present in the cross-validation set on that iteration; a list of the proportion of ARSEX trials which were misclassified as COREPATH for each iteration; and a list of the proportion of MORAL trials which were misclassified as COREPATH for each iteration. The result of this approach is to be able to compare the average number of misclassifications as a given label for the other labels, while controlling for the number of trials in a given conditions present in the test set.

3.3.4 Psychophysiological data collection and feature extraction

Psychophysiological signals were digitized using a BIOPAC MP150 system (BIOPAC Systems Inc., Goleta, CA). Subjects were instructed to find a comfortable position at the beginning of the recording session and to keep feet, head, torso, and

hands as still as possible, in order to limit potential artifact from body movement. All signals were acquired at a sampling rate of 1000 Hz, save for electrogastrogram, which was acquired at 500 Hz; before analysis signals were downsampled to 100 Hz. Acqknowledge software functions (BIOPAC Systems Inc., Goleta, CA), custom scripts implemented in Python (Python Software Foundation, https://www.python.org) and Matlab (MATLAB 2014a, The Mathworks Inc., Natick, MA), and scripts wrapping existing packages for SciPy (Jones et al., 2001) and Neurokit (Makowski, 2016) were used to process the data. Electrodermal activity was recorded from electrodes placed on the hypothenar eminence of the non-dominant palm, and amplified with the GSR 100C module (BIOPAC Systems Inc., Goleta, CA). Data were run through a low pass filter at 1 Hz to remove spurious noise. Tonic changes in skin conductance level were extracted by averaging over the EDA signal for the period of interest. Phasic changes in skin conductance level (skin conductance responses, or SCRs) were detected using a script implemented in Python (Python Software Foundation, https://www.python.org/) which detected rises of at least 2 microsiemens that peaked in between .5 and 5 seconds. The maximum and mean amplitudes of SCRs in the period of interest, as well as the number of SCRs within the period of interest, were all computed. Locations for electrocardiogram and electrogastrogram placement were abraided with NuPrep skin prep gel (Bio-Medical Instruments Inc., Clinton Township, MI). Electrocardiogram data were collected using a lead II configuration with an additional ground to mitigate noise,

and were amplified using an ECG100C module. Electrocardiogram signals were decomposed into heart rate, systole, heart period, respiratory sinus arrhythmia, and heart rate variability (power in the ultra low, very low, low, high, and very high frequency bands). Gastric activity data were collected from electrodes placed along the transpyloric plane and amplified using the EGG 100C module, and decomposed into relative power in the tachygastric, normogastric, and bradygastric power bands. Respiratory activity was recorded using a BIOPAC SS5LB respiratory effort transducer placed at the base of the sternum and amplified with the RSP 100C module (BIOPAC Systems Inc., Goleta, CA). Data were bandpass filtered according to BIOPAC's application note specifications and a pulmonary airflow analysis was conducted, extracting measures of peak inspiratory flow, peak expiratory flow, tidal volume, minute volume, breaths per minute, inspiration time, exhalation time, total breath time, and apnea time. These signals were averaged over the period of interest and z-scored within participant (disgust trials only).

3.4 Results

3.4.1 Manipulation check

A repeated measures ANOVA was conducted on the post-recording ratings of the vignettes found that there was a difference in how disgusting vignettes were perceived to be as a function of the condition the vignettes belonged to. Mauchly's test of sphericity was significant, $\chi 2(9) = 17.721$, $p = .039$, so degrees of freedom and statistics

are reported with Greenhouse-Geisser correction. A main effect of condition was found on disgust ratings, $F(3.297,105.490) = 197.312$, $p < .0005$. Post hoc paired sample t-tests were run on each pairwise comparison, Bonferroni-corrected alpha level = .005. Every comparison of a disgust condition to the neutral condition was significant, $ts > 19.534$, $ps < .0005$. The only pair of disgust conditions which significantly differed were COREPATH and ARPATH, $t = 5.534$, $p < .0005$, such that COREPATH was more disgusting.

3.4.2. Classifier performance

Overall, classifier performance was modestly different than chance, in the expected direction. A Mann-Whitney test was conducted to examine the difference in weighted F1 score across the classifiers trained on true labels versus permuted labels, and found that the weighted F1 score of classifiers trained on true labels outperformed those trained on permuted labels, $z = -4.459$, $p < .0005$, $r = 0.45$. Weighted precision followed the same pattern, $z = -4.313$, $p < .0005$, $r = 0.43$, as did weighted recall, $z = -4.493$, $p < .0005$, $r = 0.45$.

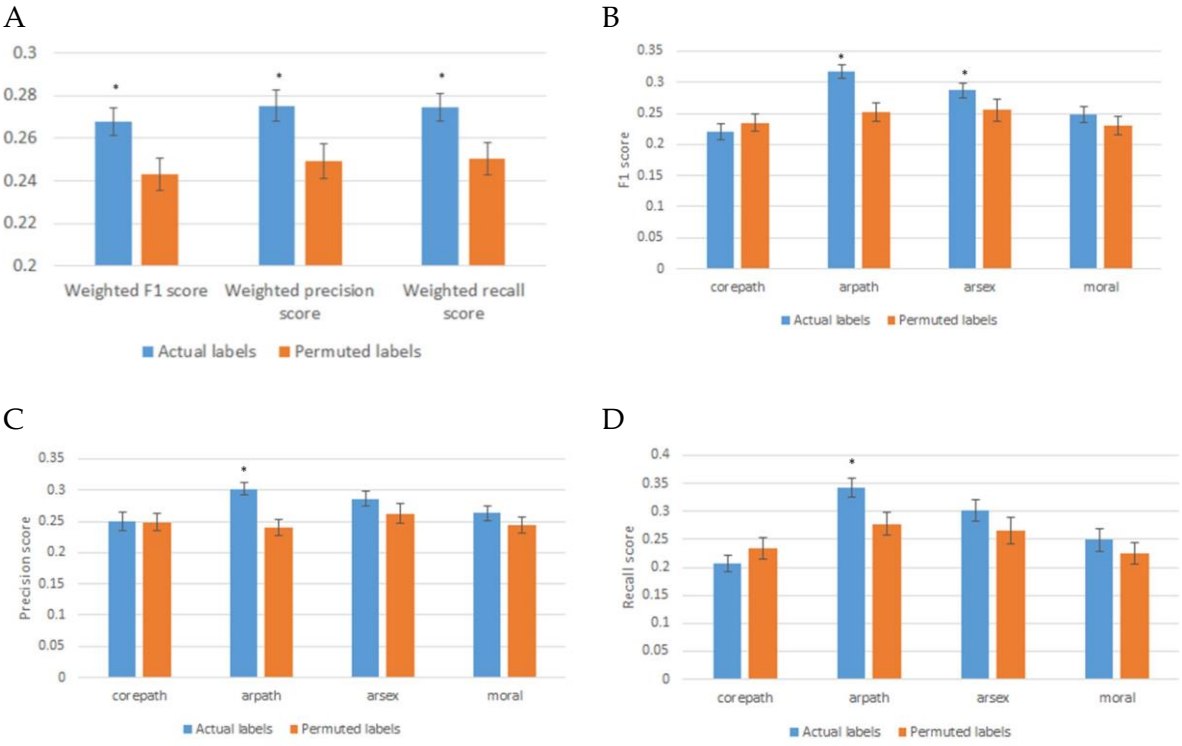

Figure 3: Differences in classifier performance between classifiers trained on true labels and classifiers trained on permuted labels (i.e., a proxy for chance), for the weighted average F1 score, precision, score, and recall score across the model (A), as well as the the F1 score (B), precision score (C), and recall score (D) for each condition. Error bars represent 95% confidence intervals.

Classifier success with respect to individual categories was assessed with Mann-Whitney tests as well. For ARPATH, F1 score, precision, and recall were all greater than chance (i.e., greater than when permuted labels were used), $Zs > |4.7|$, $ps < .0005$. However, no other conditions reached significance on any of the metrics after correction for multiple comparisons (Bonferroni-corrected alpha level for 12 tests = 4.167e-03). A trend in the expected direction could be seen in the difference between F1 scores for

permuted and actual labels for ARSEX, Z = -2.754, p = .006. These results suggest that selective success in classifying ARPATH drove the difference from chance in the model as a whole.

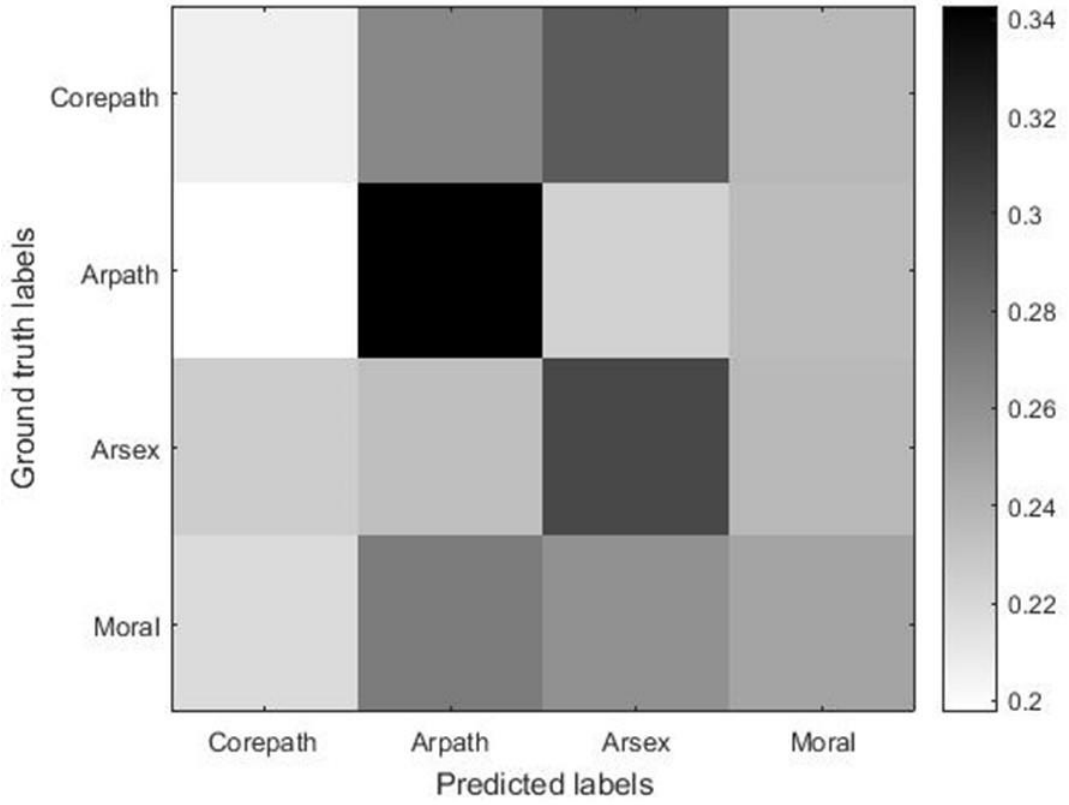

Figure 4: Confusion matrix for overall classifier performance across disgust conditions. The classifiers predicted ARPATH with precision and recall greater than estimation of chance.

3.4.3 Multivariate separation

One reason for the relatively high classifiability of ARPATH was that ARPATH tended to be more separate from other disgust clusters in multivariate space. To test this, the multivariate separation of each disgust trial was computed relative to the general

psychophysiological mean of all disgust trials. A repeated measures ANOVA was conducted to examine the effect of condition on separation from the general mean. A parametric test was appropriate here, since the distance calculations were happening on the complete data set rather than the metrics derived from the subsampling procedure. A repeated measures ANOVA was selected in order to account for the potential individual differences in disgust for different conditions (Olatunji et al., 2007; Tybur et al., 2009). Mauchly's test of sphericity did not indicate a violation of the assumption of sphericity, $\chi 2(5) = 8.803$, $p = .117$. There was a significant effect of condition on distance from the general disgust centroid, $F(3,99) = 3.021$, $p = .033$ (see Figure 5). Paired sample t-tests on pairwise comparisons between conditions showed only a significant difference between ARPATH from COREPATH, $t(33) = 3.266$, $p = .003$, such that COREPATH was on average closer to the center of the feature space than ARPATH was.

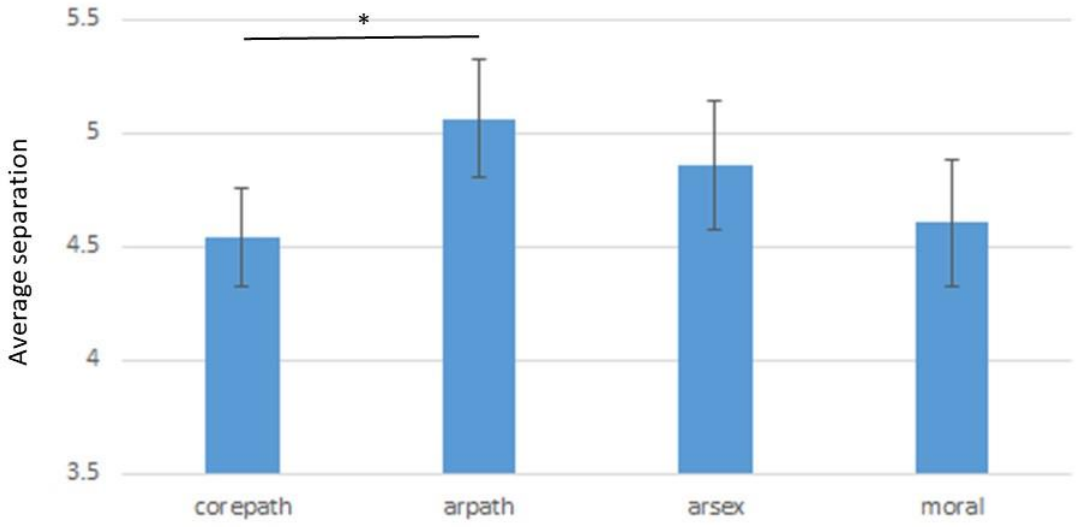

Figure 5: Average Euclidean distance of trials in each condition from the general centroid for psychophysiological measures taken during disgust conditions. Error bars represent 95% confidence intervals.

3.4.4 Analysis of error distribution

Figure 6 summarizes the implications of the error analysis with respect to the corollary predictions of the two theoretical models. Kruskal-Wallis tests were used to difference in weighted average of misclassifications for a particular kind of label across the other labels. The effect of ground truth class membership on weighted average of erroneous predictions each classifier made for "COREPATH" did not reach statistical significance, $\chi 2(2) = 1.554$, $p = .460$. The overall effect of ground truth class membership on the weighted average of erroneous predictions for "ARPATH" was found to be significant across classes, $\chi 2(2) = 13.161$, $p = .001$. Consistent with the adaptationist model, and in direct contrast with the cultural evolution model, on average there were more misclassifications of COREPATH as ARPATH per subsample than ARSEX as

ARPATH, z = -2.792, p = .005. However, in contrast to the adaptationist model, misclassifications of COREPATH as ARPATH were no different from misclassifications of MORAL as ARPATH, z = -0.616, p = .538. Inconsistent with the cultural evolution model, ARSEX was confused for ARPATH significantly fewer times than MORAL was, z = -3.397, p = .001. Finally, there was a significant effect of ground truth class membership on the average number of erroneous predictions for ARSEX, $\chi 2(2) = 16.295$, $p < .0005$. The contrast of ARPATH vs. COREPATH was significant, z = -4.055, $p < .0005$ but it was in the opposite direction than would be expected by the adaptationist model: the average rate of misclassification for ARPATH for ARSEX was lower than the average rate of misclassification of COREPATH for ARSEX (see Figure 6). With multiple comparison correction, MORAL and ARPATH were no different in how likely they were to be misclassified as ARSEX, z = -1.872, p = .061, nor were MORAL and COREPATH, z = -2.116, p = .034.

Label erroneously applied by classifier	Prediction of cultural evolution model	Prediction of adaptationist model	Outcome	Adjudication
COREPATH	*Null* COREPATH solely constitutes the domain of *core disgust* among the conditions, so there will be no difference in the distribution of errors	*ARPATH > [ARSEX, MORAL]* ARPATH and COREPATH together constitute the *pathogen disgust* domain, therefore more true ARPATH trials than ARSEX or MORAL will be misclassified as COREPATH	No difference across groups	Null information for cultural evolution model Fails to support adaptationist model
ARPATH	*ARSEX > [COREPATH, MORAL]* ARPATH and ARSEX together constitute the *animal reminder disgust* domain, therefore a more true ARSEX trials than COREPATH or MORAL will be misclassified as ARPATH	*COREPATH > [ARPATH, MORAL]* ARPATH and COREPATH together constitute the *pathogen disgust* domain, therefore more true COREPATH trials than ÅRSEX or MORAL will be misclassified as ARPATH	COREPATH > ARSEX No difference between COREPATH and MORAL MORAL > ARSEX	Contradicts cultural evolution model Mixed support for adaptationist model
ARSEX	*ARPATH > [COREPATH, MORAL]* ARPATH and ARSEX together constitute the *animal reminder* disgust domain, therefore more true ARPATH trials than COREPATH or MORAL will be misclassified as ARSEX	*Null* ARSEX solely constitutes the domain of *sexual disgust* among the conditions, so there will be no difference in the distribution of errors	COREPATH > ARPATH No difference between COREPATH and MORAL No difference between ARPATH and MORAL	Fails to support cultural evolution model Contradicts adaptationist model

Figure 6: Implications of the error analysis with respect to the predictions of the cultural evolution and adaptationist models.

3.5 Discussion

In the present study, a cohort of support vector machine learning classifiers were trained on the psychophysiological responses of subjects to four different kinds of disgust elicitors: body products (COREPATH), mutilation (ARPATH), nonnormative sex (ARSEX), and immorality (MORAL). These conditions spanned the domain schemes suggested by two eminent models of disgust, the cultural evolution model (Rozin et al., 2008) and the adaptationist model (Tybur et al., 2013), in such a way that they could be used to directly compare these models (see Figure 1). For instance, mutilation – coded in the present study as "ARPATH" – would be assigned to the domain of animal reminder disgust by the cultural evolution model together with the condition of ARSEX but would be assigned to the domain of pathogen disgust (together with COREPATH) by the adaptationist model.

On the whole, performance in discriminating between different psychophysiological states across these conditions was usually no different than chance. However, the classifiers were more likely than chance to succeed at classifying ARPATH, both in terms of sensitivity and specificity. (A trend also emerged for ARSEX, but only for the f1 score.) This specialization of the classifier in learning the multivariate pattern for ARPATH did not appear to be due to the increased disgustingness of ARPATH trials relative to other conditions: according to the retrospective ratings of

disgust given by participants after the physiological recording session, ARPATH was significantly less disgusting than COREPATH, and no different from MORAL and ARSEX. In summary, the physiological response pattern for ARPATH was simply easier for a classifier to learn - indeed, the only category which could be learned among the present stimuli.

One interpretation of this finding is that being exposed to an ARPATH stimulus elicits a more robust, predictable signal in the peripheral nervous system than being exposed to a COREPATH, ARSEX, or MORAL stimulus, at least via the modality of reading vignettes. It is possible that exposure to an ARPATH stimulus elicits an increase in sympathetic arousal or other kind of peripheral physiological orienting response. Sarlo and colleagues (2005) noted that cortical activity in response to pictures of mutilation exceeded activity in response to fear-eliciting and core-disgust-eliciting stimuli, particularly in right posterior regions of the scalp, and suggested a relationship between mutilation and increased attention. The heightened salience of mutilation disgust might correspond to a specific functional physiological state, which could account for differences in the physiological pattern of mutilation disgust and core disgust (Harrison et al., 2010; Shenhav & Mendes, 2014).

Perhaps the most important implication of the present work is the idea of mutilation as separate from the superordinate domains to which it is assigned by the

cultural evolution and adaptationist models. The present work suggests that animal reminder disgust is not a cohesive unit, at least at the level of peripheral physiology. If that corollary of the cultural evolution model were borne out, the algorithm would have tended to confuse ARSEX with ARPATH, since sex is one of the canonical elicitors of animal reminder disgust. However, this was not the case, at least relative to other conditions (Figure 6) – ARSEX was less likely to be confused for ARPATH than COREPATH was. It is notable that the study by Olatunji, Haidt and colleagues (2008) which found distinct physiological correlates for animal reminder disgust used the Disgust Scale-Revised as their measure, wherein all of the animal reminder items refer to either body envelope violations or death. Furthermore, body envelope violations and death loaded as one factor in the initial development of the Disgust Scale (Haidt et al., 1994), suggesting that the animal reminder subscale on the DS-R only samples one construct comprising mutilation/death. Any argument that the DS-R supports the distinctiveness of the animal reminder domain must contend with the fact that the other elicitors -- sex (as measured here) and hygiene (not specifically measured here) -- are not directly measured, so an account of sex as separate from mutilation cannot be eliminated.

Analysis of the error distribution suggests modifying the adaptationist model. Complete support for the adaptationist model would have comprised higher rates of

misclassification COREPATH for ARPATH and vice versa, and would exceed the rates of misclassification of ARSEX and MORAL for COREPATH and ARPATH – in other words, different kinds of pathogen disgust would be more likely to be confused for each other than other. However, there was an absence of evidence of this relationship. Among erroneous predictions of COREPATH by the classifiers, ARPATH trials were no more likely to be misclassified as COREPATH than ARSEX or MORAL trials were, and the pattern of mean rate of confusions of conditions for COREPATH trended in the opposite direction than would have been predicted by the adaptationist model. However, the pattern in the opposite direction partly held: that is, misclassifications of COREPATH as ARPATH exceeded misclassifications of ARSEX as ARPATH, although COREPATH was no more likely to be misclassified as ARPATH than MORAL was.

The present study concords with other recent work that suggests pathogen disgust is not best thought of as a unitary construct, particular as concerns the violations of the body envelope. In a factor analysis of responses to different kinds of stimuli related to various transmission routes of infectious disease, Curtis and de Barra (2018) discovered a factor related to avoidance of lesions such as wounds or boils, separate from other factors that fall under the construct of pathogen disgust according to the adaptationist model (such as spoiled food and poor hygiene). Additionally, Kupfer (2018) found that psychometric properties of the Three Domains of Disgust Scale (the

psychometric instrument associated with the adaptationist model) improved when the structure to be confirmed included a painful injury factor, which included items related to mutilation that was likely to be bloody as well as mutilation that did not involve a break in the skin (such as an obviously twisted ankle). Kupfer's interpretation of this finding is that disgust related to mutilations in this way was better thought of as an aversive empathic response to the pain in the victim, rather than disgust per se. It is possible that the distinct physiological patterning of mutilation disgust found in the present study was really an affective response to simulated pain, or a physiological pattern related to compassion, or perhaps a mixed emotional state (c.f. Kreibig et al., 2013).

The present study should be considered with some limitations in mind. One explanation the lack of classifiability for most of the conditions is that simply being instructed to imagine scenarios was not a powerful enough manipulation to elicit disgust, or that viewing vignettes serially caused participant fatigue. However, a unique multivariate physiological signature for disgust relative to other emotions has in some cases been difficult to find (e.g. Christie & Friedman, 2004). It is possible that although there is a somewhat reliable signature for mutilation disgust, there is a less reliable or more heterogeneous signal for other types of disgust. One promising direction for future work comparing theories of disgust should incorporate longer experimental trials, in

order to have a better chance at capturing variations in the bradygastric frequency band. Previous work that has found differences in gastric power that can distinguish core disgust from mutilation disgust, and it is possible that by extending the sampling time, researchers will be able to detect a more robust core disgust multivariate pattern relate to other types of disgust beyond mutilation.

Additionally, there is a possibility that ARPATH was in fact more disgusting in some sense than other conditions. Subjective ratings of disgust were sampled retrospectively, rather than concurrent with psychophysiological recording, therefore it may be that the disgust reported in response to the ARPATH stimuli was different than the experience the participant had during the initial presentation. However, it is an open question how that would affect retrospective ratings in a way that was specific to ARPATH, rather than causing some habituation in disgust across all conditions.

It does bear noting that the multivariate separation of the ARPATH cluster was significantly higher than for the COREPATH cluster. One interpretation of this result is that COREPATH tended to be a more central, typical representation of disgust, and ARPATH was consistently less typical. Haidt et al. (1997) have suggested that core disgust is the prototypical disgust domain, whereas other sorts of disgust (including mutilation disgust) are more peripheral to the disgust category and may elicit less disgust overall. This position is consistent with the present results.

One question which might be raised following from this finding is whether mutilation disgust is "really" disgust. However, it is epistemically ambiguous to ask such a question in absence of any particular utilitarian goal. As in many attempts at creating useful typologies of multiplex constructs across psychology and neuroscience, there are some elements shared between mutilation disgust and other kinds of disgust, and some elements which differ. If the goal is to use subjective ratings of disgust to predict blood-injury-injection phobia, enough evidence can be marshaled from clinical psychological research on individual differences in disgust to support the inclusion of mutilation in a disgust typology. If a researcher has a goal of generating theories about the effect of disgust on attention, it is worth bearing in mind the difference in arousal and attention that mutilation disgust may have in a way that other kinds of disgust may not (Sarlo et al., 2005; see Schaich Borg et al., 2008 for similar evidence about sexual disgust). Empirical evidence cannot include or exclude mutilation disgust from the disgust canon categorically; it can only characterize ways in which responses to mutilation (such as physiological patterns) differ from or overlap with responses to other things which might be labeled "disgust."

The evidence in the present study supports the idea that physiological response patterns to mutilation stimuli are more easily learned by a support vector machine learning algorithm than certain other kinds of disgust elicitors, and that mutilation

disgust is in some senses a unique physiological phenomenon apart from core disgust, sexual disgust, and moral disgust. Theoretical models of disgust which lump mutilation disgust in with animal reminder elicitors such as hygiene and sex, or with pathogen elicitors such as body products, ought to account for the lack of confusability of responses to these sorts of stimuli with mutilation stimuli, at least at the level of peripheral physiology. In accordance with other recent work (Kupfer, 2018; Curtis & de Barra, 2018), we suggest that any comprehensive theory of disgust which includes mutilation must specify its distinctiveness apart from other superordinate categories, or must exclude mutilation from the typology. Alternatively, and ideally, theories of disgust should be oriented towards the specific scientific questions and levels of analysis they are geared to answer, rather than suggesting one unified theory of disgust that accounts for physiological variability, psychiatric utility, and evolutionary modeling. Although mutilation may indeed have some association with an unconscious motivation to avoid mortality (Rozin et al., 2008), it need not follow that individual differences in mutilation disgust will track with individual differences in response to sexual disgust; and although mutilation disgust may indeed accomplish an evolutionarily adaptive goal that converges with disgust at other sorts of pathogen vectors, it need not follow that the proximate implementation of these two kinds of pathogen disgust in the neurocognitive architecture are the same.

4. Mixed signals: Disgust psychophysiology as an interaction of category membership with complex affective states

4.1 Introduction

Affective scientists often hold that emotions are associated with distinct autonomic signatures (Stephens et al., 2010; Kreibig, 2010; but see Lindquist et al., 2013). In the case of the emotion disgust, however, there has been inconsistency in establishing such a signature. Although some physiological correlates of disgust have been proposed, such as parasympathetic activation, findings are inconsistent (Rohrmann & Hopp, 2008; van Overveld et al., 2009; de Jong et al., 2011; but see Vossbeck-Elsebusch et al., 2012), and a discriminable, reliable psychophysiological signal indicative of disgust relative to other emotions is often elusive (e.g., Christie & Friedman, 2004). Part of the reason for this elusiveness is that disgust is probably a multifactorial construct (Olatunji et al., 2007; Rozin et al., 2008; Tybur et al., 2013) with a complex affective profile. In order to understand the multiplex representation of disgust in the peripheral nervous system, it may be necessary to account for variability within a given type of disgust. In the present study, we investigate the utility of accounting for variation in concurrent emotional states in understanding the way disgust may be parsed into physiological subtypes.

Historically, researchers have attempted to understand disgust and its associated physiology by delving into what stimuli can elicit disgust. For some emotion constructs, this approach can be fruitful. As an example, the canonical antecedents of the emotion fear tend to share in common that they represent relatively immediate physical or sometimes psychological threats (Ekman, 1992). From this premise, it is easy to form a plausible theory about the function of fear, and subsequently to use that theory to make sense of the physiological changes concurrent with fear, such as sympathetic arousal (Cannon, 1915) – all of which are consistent with the function of avoiding a proximate threat. Using this approach to make sense of disgust and its physiological correlates is less straightforward, because the unifying function(s) of the canonical antecedents of disgust are not as easily seen. Although it is commonly held that disgust is elicited by things which are likely pathogen vectors, such as body products and sexual contact (Curtis, 2011), the label "disgust" is also cross-culturally invoked to describe stimuli beyond pathogen vectors, like moral character (see Haidt et al., 1997). Some theorists suggest that disgust responses to non-pathogen stimuli are still a kind of redirected pathogen response. For instance, Curtis suggested that moral disgust is a reaction to parasites of a social rather than microbial nature (2011), and Thornhill & Fincher explained outgroup social disgust as promoting the avoidance of outgroup members who may have encountered unfamiliar pathogens and therefore may act as disease

vectors (2014). However, for some documented elicitors of disgust, the case for a pathogen avoidance function is particularly thin. Perhaps the clearest such example is incest, which elicits a strong disgust reaction (Schaich Borg et al., 2008) and is almost universally taboo. Although sexual activity always represents a risk of contact with pathogens (and is perhaps therefore disgusting in its own right, even outside of incest; see Tybur et al., 2009), incest is more disgusting than sex in general. This is the case even in spite of the fact that the microbial profile of incestuous sexual partners is likely to be very similar, due to a higher likelihood of historical contact and shared environment. The case of incest, in part, has prompted some adaptationist theorists to suggest that there are different subtypes of disgust with distinct functions (Tybur et al., 2013) -- for instance, a sexual domain of disgust, with a function to discourage maladaptive mate choice distinct from the role that pathogen disgust plays in sexual behavior (Jones et al., 2013). Given the physiological impact that disgust can have on sexual behavior (de Jong et al., 2009), and given the putative specialized nature of sexual as opposed to pathogen disgust, it is plausible to hypothesize that there is some distinctiveness to the sexual disgust response which may not have been accounted for in previous investigations of disgust physiology.

Other attempts have been made to subdivide disgust based on putative functions assigned to clusters of elicitors, with direct implications for models of disgust

physiology. Olatunji, Haidt, and colleagues (2008) found distinctive physiological correlates for the disgust subtypes found in a highly influential model proposed by Rozin, Haidt, and colleagues (1993, 2000, 2008). Core disgust is a construct described as engendering an avoidance response to substances which would render potential food items offensive with contact (e.g., body products), and individual sensitivity to core disgust elicitors was related to levator labii muscle tension during experience of a core disgust stimulus (note that activity in levator labii is thought to be correlated with disgust; Vrana, 1993). Individual differences in animal reminder disgust, a putative response to elicitors of disgust that may remind people of their mortality (such as injuries or mutilation), was found to relate to the association between heart rate and viewing an animal reminder-related stimulus. The labels of core disgust and animal reminder disgust, or similar operationalizations, have been applied to previous investigations of disgust physiology, with conflicting evidence: van Overveld and colleagues (2009) found no physiological differences between these two domains, although de Jong et al. (2009), and Harrison et al. (2010) found differences in physiological responding. In sum, although the evidence is mixed, there is some support for the idea that the psychophysiological response may vary based on the semantic category of the disgust stimulus.

The general tendency in disgust research has been to explain differences in disgust physiology, and indeed in the disgust response as a whole, based on the category membership of the stimulus which elicited disgust. However, there is some evidence to suggest that category membership information like this does not wholly explain the differences in disgust physiology. One example was found in the same study which identified physiological correlates of core and animal reminder disgust. Olatunji and colleagues (2008) found that heart rate during the experience of a film clip of someone vomiting was related to individual differences in a construct called contamination disgust, which is thought to be a response that promotes a domain-general avoidance of potential contaminants (particularly through the interpersonal route). Additionally, Ottaviani and colleagues (2013) found physiological differences between responses to disgust stimuli belonging to a sexual-moral category and more basic physical disgust, but this finding was modulated by individual differences in obsessive-compulsive tendencies, such that subjects who were higher in that trait showed more similar physiology between the two conditions than subjects who were lower. Interestingly, when asked to describe their subjective responses to the two disgust inductions, participants in Ottaviani et al.'s study used affect labels related to contempt and anger for the moral disgust stimulus, but not for the physical disgust stimulus, suggesting that one of the reasons for the differing physiology could be that

another negative emotional state was happening either instead of, or in concert with, the disgust state. There is in fact a substantial body of evidence that disgust covaries with other emotions in predictable ways. For example, so-called moral disgust has been described as a mixture of anger and disgust (Ottaviani et al., 2013), an instantiation of anger instead of disgust (Nabi, 2002), or perhaps anger labeled as disgust for certain moral violations but actual disgust for others (Gutierrez et al., 2012). Marzillier and Davey (2004) used cluster analysis on ratings of anger, contempt, disgust, joy, fear, and sadness to subdivide disgust into a "simple" category of elicitors (basic disease-causing stimuli), for which the primary affective response was only disgust, and a "complex" category of elicitors (more sociomoral stimuli), for which the affective profile was complex and involved heightened ratings of other negative emotions besides disgust. Germane to the current investigation, evidence for the effect of mixed emotional states involving disgust on physiology has been found by Kreibig et al. (2013), who used film clips to elicit pure disgust with the elicitor category of mutilation, pure amusement, and a mixed state of amused disgust also semantically related to mutilation (i.e., painful injuries portrayed in a comedic light). Importantly, even though the elicitor category was held constant, the physiological state of amused disgust was not only discriminable from the state of pure disgust, but was interpreted as a distinct emergent physiological state in and of itself.

These findings raise a question about the nature of the relationship between the complex emotional profile of a disgust experience, the semantic category to which the disgust-eliciting stimulus belongs, and an individual's psychophysiological response. It is possible that one of the reasons it has been so difficult to achieve consistency in findings about disgust physiology is that not only are there different subtypes of disgust, but these subtypes have been defined according to the stimuli which are thought to elicit them, and the semantic category to which the stimuli belong. Perhaps the differences are not only by the category membership of the disgust-eliciting stimulus, but by the affective profile which tends to accompany that stimulus. For instance, perhaps moral disgust differs from physical disgust not by solely dint of the fact that there is some intrinsically different response across the neuraxis to stimuli belonging to the category of "moral violations," but also because stimuli which belong to the category of "moral violations" also tend to elicit anger or compassion, and the physiological correlates of anger or compassion interact with the physiology of disgust. In other words, if what has been termed "moral disgust" is actually a broader category of mixed emotional states with varying degrees of disgust and anger and compassion, then perhaps accounting for this emotional variability will increase the power to detect boundaries in disgust.

In the present study, we employed a machine learning approach to investigate the reliability of a multivariate signal for distinct disgust elicitor categories, and its relationship to other concurrently experienced emotions. Separate supervised pattern classifiers were trained to predict elicitor categories using psychophysiological responses, subjective ratings of concurrent emotional states, and the psychophysiology and subjective data together. We hypothesized that adding features about concurrent emotions to the psychophysiological features would improve the performance of the classifier, suggesting that some of the noise in the literature of disgust psychophysiology might be due to the complexity and variability of the affective profiles within a disgust elicitor category.

4.2 Methods

4.2.1 Participants

Participants were recruited from the Durham, NC community and compensated $23 for their time. All subjects reported having no history of psychiatric or neurological disorder and not being on a psychoactive medication. Data from a total of 33 subjects were collected. One subject's run was interrupted with a fire alarm, such that fewer than half of the blocks in the run order were collected. As a result, this subject was excluded from analysis, leaving a total sample size of N = 32 (16 female), M age = 27.31, SD = 6.04, 15 White, 12 Asian, 3 Black, 2 Hispanic/Latinx. One subject's final run was interrupted

with a power surge, such that data was not recorded from all channels for the final two blocks; however, since only one of those blocks was a disgust block, and since there were data for 9 of the 11 blocks, this subject was left in the final sample. Subjects gave written informed consent, and the study was approved by the Institutional Review Board of Duke University.

4.2.2 Materials and procedure

Stimuli consisted of short vignettes corresponding to four different categories of disgust elicitors: body products, nonnormative sexual behavior, mutilation, and immorality (see Appendix C). These conditions were selected because they broadly sample across canonical elicitors of disgust, thereby having the greatest chance of interfacing with existing theories of disgust as a multifactorial construct (see Rozin et al., 2008; Tybur et al., 2013).

Following each block, subjects rated how well each of five emotion words (angry, sad, happy, afraid, or disgusted, presented in a randomized order for each trial) described their experience on a 1-to-9 Likert scale, where 1 indicated that a word did not at all describe how they felt and a 9 indicated that a word perfectly described how they felt. Subjects were encouraged to use the full range of the scale rather than "getting stuck on" the endpoints and midpoint of the scale, and were told to "go with [their] gut."

4.2.3 Psychophysiological recording and preprocessing

Psychophysiological signals were digitized using a BIOPAC MP150 system (BIOPAC Systems Inc., Goleta, CA). Subjects were instructed to find a comfortable position at the beginning of the recording session and to keep feet, head, torso, and hands as still as possible, in order to limit potential artifact from body movement. All signals were acquired at a sampling rate of 1000 Hz, save for electrogastrogram, which was acquired at 500 Hz; before analysis signals were downsampled to 100 Hz. Acqknowledge software functions (BIOPAC Systems Inc., Goleta, CA), custom scripts implemented in Python (Python Software Foundation, https://www.python.org) and Matlab (MATLAB 2014a, The Mathworks Inc., Natick, MA), and scripts wrapping existing packages for Scipy (Jones et al., 2001), Bioread (Vack, 2016), and Neurokit (Makowski, 2016) were used to process the data. Electrodermal activity was recorded from electrodes placed on the hypothenar eminence of the non-dominant palm, and amplified with the GSR 100C module (BIOPAC Systems Inc., Goleta, CA). Data were run through a low pass filter at 1 Hz to remove spurious noise. Tonic changes in skin conductance level were extracted by averaging over the EDA signal for the period of interest. Phasic changes in skin conductance level (skin conductance responses, or SCRs) were detected using a script implemented in Python (Python Software Foundation, https://www.python.org/) which detected rises of at least 2 microsiemens that peaked in

between .5 and 5 seconds. The maximum and mean amplitudes of SCRs in the period of interest, as well as the number of SCRs within the period of interest, were all computed. Locations for electrocardiogram and electrogastrogram placement were abraided with NuPrep skin prep gel (Bio-Medical Instruments Inc., Clinton Township, MI). Electrocardiogram data were collected using a lead II configuration with an additional ground to mitigate noise, and were amplified using an ECG100C module. Electrocardiogram signals were decomposed into heart rate, systole, heart period, respiratory sinus arrhythmia, and heart rate variability (power in the ultra low, very low, low, high, and very high frequency bands). Gastric activity data were collected from electrodes placed along the transpyloric plane and amplified using the EGG 100C module, and decomposed into relative power in the tachygastric, normogastric, and bradygastric power bands. Respiratory activity was recorded using a BIOPAC SS5LB respiratory effort transducer placed at the base of the sternum and amplified with the RSP 100C module (BIOPAC Systems Inc., Goleta, CA). Data were bandpass filtered according to BIOPAC's application note specifications and a pulmonary airflow analysis was conducted, extracting measures of peak inspiratory flow, peak expiratory flow, tidal volume, minute volume, breaths per minute, inspiration time, exhalation time, total breath time, and apnea time. These signals were averaged over the period of interest and z-scored within participant (disgust trials only).

4.2.4 Planned statistical analyses

In order to investigate the reliability of the signal associated with each condition, an ensemble of support vector machine learning algorithms was trained on the psychophysiological and/or emotion rating data, and the algorithm's performance in classifying new data was assessed. A one-versus-one approached was used, meaning that a subset of trials (the training data) was used to estimate the pairwise decision boundaries between elicitor categories across the predictor variables (i.e., the boundary between the multivariate physiological pattern for body products and the pattern for sex, or the boundary between the multivariate emotional patterns for immorality and for mutilation, etc.). The algorithm was then fed the remainder of the trials (the testing data), and predicted them as belonging to one of two conditions, based on where they were in the feature space relative to each of those pairwise decision boundaries. The ultimate classification for each datum was the condition that was predicted most often across all of the pairwise decision boundaries.

For each version of the analysis, the algorithms were trained on 100 pseudorandom 50-50 train-test subsamples of the data, for linear as well as radial basis function kernels. For every variation on the input feature set (i.e., emotions only, physiology only, emotions and physiology together), the radial basis function kernel outperformed the linear kernel, so only results from the radial basis function kernel are

reported for the sake of concision (see also Kragel & LaBar, 2013, for a similar result in a similar paradigm). For each iteration, classifiers were also trained with the same feature data and train-test split, but with randomly permuted labels, in order to produce a series of "chance" classifier performance values to which the correctly trained classifiers could be compared in order to tell whether their performance departed from chance. Hyperparameters were automatically tuned on each of the 100 iterations using GridsearchCV implemented in Python's sklearn package. Three performance metrics were computed: the precision score (or the proportion of true positives within a given predicted label), the recall score (or the proportion of true positives within a given ground truth label), and the F1 score, which conceptually synthesizes precision and recall as the harmonic mean of the two values. Wilcoxon signed-rank tests were used to compare the difference in performance between classifiers trained on correctly labeled training sets and those trained on permuted labels. Wilcoxon tests were used to mitigate the possible effect of the violation of assumptions that came about due to the repeated subsampling procedure, such as a violation of independence (see also Kragel & LaBar, 2013). All data were z-scored within the disgust (that is, non-neutral) trials of each subject before analysis.

4.3 Results

4.3.1 Manipulation check

A repeated measures ANOVA was conducted in order to test whether the disgust conditions elicited more disgust than a neutral control condition. Mauchly's test showed that the assumption of sphericity had not been violated, $\chi 2(9) = 6.986$, $p = .639$. There was an effect of condition on ratings of disgust, $F(4,124) = 83.565$, $p < .0005$. Paired sample t-tests were conducted in order to probe the pairwise differences in disgust across conditions. In every comparison between a disgust condition and the neutral control condition, the disgust condition was rated as more disgusting, $t(31) < -11.320$, $ps < .0005$. No pairwise comparison between disgust conditions reached significance with multiple comparison correction (Bonferroni corrected alpha level = .005) except for the comparison between immorality disgust and body products disgust, $t(31) = 3.263$, $p = .003$, such that the mean disgust rating for body products ($M = 7.08$, $SE = 0.33$) was higher than for immorality disgust (M immorality $= 5.75$, $SE = .37$). Such a pattern corresponds to the idea that disgust is a prototypical category, where body products represent a highly typical exemplar of disgust and social or immorality disgust tends to be more variable (see Haidt et al., 1997).

Table 3: Descriptive statistics for post-block emotion ratings. Parenthetical values represent standard deviation.

Emotion	Body products	Mutilation	Sex	Immorality	All disgust conditions
Anger	4.30 (2.58)	2.70 (2.11)	4.00 (2.40)	6.72 (2.16)	4.41 (2.72)
Disgust	7.17 (2.03)	6.56 (2.03)	6.40 (2.36)	5.67 (2.34)	6.46 (2.24)
Fear	2.03 (1.76)	3.67 (2.42)	2.76 (2.58)	2.52 (2.20)	2.75 (2.32)
Happiness	2.87 (2.08)	2.78 (2.11)	3.21 (2.10)	2.56 (2.02)	2.86 (2.08)
Sadness	3.03 (2.24)	4.24 (2.20)	3.49 (2.55)	5.16 (2.42)	3.97 (2.48)

4.3.2 Classification analysis using psychophysiological data

The classifiers trained on the psychophysiological data performed better than chance in terms of the model as a whole; see Table 4 for summary statistics. The weighted average F1 score for classifiers trained on accurate labels exceeded chance, $z = -6.26$, $p < .0005$, with a medium effect size of $r = 0.63$. The same pattern was found for the weighted average of precision scores, $z = -5.91$, $p < .0005$, with a medium effect size of $r = 0.59$. There was a small effect found on the weighted average of recall scores, $z = -4.04$, $p < .0005$, $r = 0.40$.

Given the possibility that the physiological patterns for certain specific elicitor categories were more easily learned than others, the classifier performance for each specific elicitor category was compared to chance as well. The mutilation and immorality categories were never predicted at any level higher than chance on any performance metric, $p > .03$. There were small significant effects for the categories for

body products and sex on both F1 scores and precision scores, zs < -1.33, ps < .0005, rs > 0.35. There was no difference in recall across any of the elicitor categories, p > .160, despite the fact that the model demonstrated a small effect in the recall score when taken as a whole.

4.3.3 Classification using emotion data

The classification procedure was repeated again, using only emotion ratings to predict the classes. There were large effects for each performance metric computed for difference in the weighted average across conditions from the weighted average performance for permuted labels, zs < -8.64, ps < .0005, rs > 0.86. When assessing each specific elicitor category in isolate, there was always a large effect size found for the difference of F1 scores and precision from chance, ps < .0005. For recall, the difference from chance had a medium effect size, r < 0.73, for every stimulus category except for immorality, for which the difference from chance had a large effect size, r = 0.86.

4.3.4 Classification with psychophysiological and emotion data together

Finally, the classification procedure was repeated with both physiological features and emotion rating features together predicting the specific elicitor categories. As in the emotion-only classifier, the model as a whole exceeded chance on the weighted average for each performance metric, with large effects: zs < -8.68, ps < .0005, rs = 0.87. The classifier trained on physiological and emotion rating data was successful at the

level of each category as well, across every performance metric. Effect sizes were large, $rs > 0.86$, for every comparison except for three medium effect sizes: the difference from chance in precision for sex, $z = -7.68$, $p < .0005$, $r = 0.77$; the difference from chance in recall for mutilation, $z = -5.01$, $p < .0005$, $r = 0.50$; and the difference from chance in recall for body products, $z = -5.75$, $p < .0005$, $r = 0.57$.

Table 4: Summary statistics and classification performance metrics for each iteration of the classification procedure

Input feature set: Physiological data only

Stimulus category	Performance metric	Mean performance for true labels	Mean performance for permuted labels (estimate of chance)	z	p	r	Effect size
Body products	F1	0.22 (0.13)	0.16 (0.15)	-3.95	< .0005 *	0.39	Small
	Precision	0.22 (0.12)	0.15 (0.14)	-4.04	< .0005 *	0.40	Small
	Recall	0.30 (0.26)	0.28 (0.35)	-1.33	.184	0.13	-
Mutilation	F1	0.20 (0.13)	0.17 (0.16)	-2.01	.045	0.20	-
	Precision	0.19 (0.13)	0.15 (0.14)	-2.17	.030	0.22	-
	Recall	0.28 (0.26)	0.28 (0.34)	-0.57	.568	0.06	-
Sex	F1	0.23 (0.14)	0.17 (0.15)	-3.49	< .0005 *	0.35	Small
	Precision	0.25 (0.15)	0.16 (0.16)	-4.04	< .0005 *	0.40	Small
	Recall	0.32 (0.29)	0.29 (0.36)	-1.40	.160	0.14	-
Immorality	F1	0.13 (0.11)	0.12 (0.14)	-1.04	.298	0.10	-
	Precision	0.18 (0.19)	0.14 (0.18)	-1.71	.088	0.17	-
	Recall	0.15 (0.18)	0.17 (0.27)	-0.17	.867	0.02	-
Weighted overall score	F1	0.19 (0.07)	0.15 (0.08)	-6.26	< .0005 *	0.63	Medium
	Precision	0.21 (0.10)	0.15 (0.11)	-5.91	< .0005 *	0.59	Medium
	Recall	0.24 (0.03)	0.23 (0.03)	-4.04	< .0005 *	0.40	Small

Input feature set: Emotion rating data only

Stimulus category	Performance metric	Mean performance for true labels	Mean performance for permuted labels (estimate of chance)	z	p	r	Effect size
Body products	F1	0.56 (0.06)	0.19 (0.16)	-8.68	< .0005 *	0.87	Large
	Precision	0.57 (0.09)	0.18 (0.16)	-8.52	< .0005 *	0.85	Large
	Recall	0.58 (0.12)	0.30 (0.34)	-6.90	< .0005 *	0.69	Medium
Mutilation	F1	0.63 (0.05)	0.20 (0.14)	-8.68	< .0005 *	0.87	Large
	Precision	0.68 (0.09)	0.21 (0.17)	-8.52	< .0005 *	0.85	Large
	Recall	0.61 (0.08)	0.32 (0.33)	-6.67	< .0005 *	0.67	Medium
Sex	F1	0.44 (0.08)	0.14 (0.13)	-8.65	< .0005 *	0.86	Large
	Precision	0.45 (0.07)	0.19 (0.17)	-8.34	< .0005 *	0.83	Large
	Recall	0.45 (0.13)	0.18 (0.24)	-7.31	< .0005 *	0.73	Medium
Immorality	F1	0.78 (0.05)	0.14 (0.15)	-8.68	< .0005 *	0.87	Large
	Precision	0.77 (0.08)	0.18 (0.21)	-8.64	< .0005 *	0.86	Large
	Recall	0.81 (0.09)	0.19 (0.27)	-8.55	< .0005 *	0.86	Large
Weighted overall score	F1	0.60 (0.04)	0.16 (0.08)	-8.68	< .0005 *	0.87	Large
	Precision	0.62 (0.04)	0.19 (0.12)	-8.68	< .0005 *	0.87	Large
	Recall	0.61 (0.04)	0.23 (0.05)	-8.69	< .0005 *	0.87	Large

Input feature set: Emotion and physiological data

Stimulus category	Performance metric	Mean performance for true labels	Mean performance for permuted labels (estimate of chance)	z	p	r	Effect size
Body products	F1	0.46 (0.07)	0.18 (0.15)	-8.65	< .0005 *	0.86	Large
	Precision	0.48 (0.10)	0.16 (0.13)	-8.63	< .0005 *	0.86	Large
	Recall	0.48 (0.12)	0.28 (0.32)	-5.75	< .0005 *	0.57	Medium
Mutilation	F1	0.51 (0.07)	0.20 (0.15)	-8.68	< .0005 *	0.87	Large
	Precision	0.52 (0.11)	0.19 (0.14)	-8.68	< .0005 *	0.87	Large
	Recall	0.54 (0.13)	0.33 (0.36)	-5.01	< .0005 *	0.50	Medium
Sex	F1	0.36 (0.10)	0.16 (0.14)	-8.41	< .0005 *	0.84	Large
	Precision	0.38 (0.10)	0.18 (0.17)	-7.68	< .0005 *	0.77	Medium
	Recall	0.39 (0.15)	0.24 (0.31)	-4.93	< .0005 *	0.49	Small
Immorality	F1	0.64 (0.08)	0.11 (0.13)	-8.68	< .0005 *	0.87	Large
	Precision	0.70 (0.10)	0.13 (0.15)	-8.67	< .0005 *	0.87	Large
	Recall	0.61 (0.11)	0.15 (0.23)	-8.39	< .0005 *	0.84	Large
Weighted overall score	F1	0.49 (0.05)	0.16 (0.07)	-8.68	< .0005 *	0.87	Large
	Precision	0.52 (0.05)	0.16 (0.10)	-8.68	< .0005 *	0.87	Large
	Recall	0.49 (0.04)	0.23 (0.03)	-8.69	< .0005 *	0.87	Large

4.4 Discussion

In this study, we attempted to train a machine learning algorithm on the multivariate patterns associated with different subtypes of disgust. By comparing classification success after varying the inputs of the classifier, we were able to make inferences about possible relationships between categories of disgust elicitors and discrete emotions that tend to co-occur with disgust. Surprisingly, training a classifier on emotion data alone resulted in performance of a medium to high effect size across all metrics for all conditions, and there was no real classification performance improvement over the emotion data alone in adding the emotion data to the physiological data.

By delving into the different kinds of performance metrics produced in this study, it is possible to learn something about the nature of the representations in the autonomic nervous system. One notable finding is the high precision but low recall of the psychophysiology-only classifier. The success of the classifier was largely driven by small precision effects in detecting sexual disgust and body products disgust. This suggests that there exist reliable psychophysiological signals for sexual disgust and body products disgust, but that those signals are not common to all instances of sexual or body products disgust. In other words, there is a high variability in sexual/body products disgust psychophysiology, which may comprise a much more variable pattern. While the algorithm detected a typical pattern unique to sexual disgust and a typical

pattern unique to body products disgust, there was enough atypicality across all the observations of sexual disgust and body products disgust that the merely recognizing the most typical pattern did not enable the algorithm to generalize to that many other instances within that category. In machine learning terms, in spite of the fact that there were reliable prototypical patterns of sexual and body products disgust, the distribution of data points in these two classes were dispersed in such a way that the nonlinear boundaries around them were too complicated for the algorithm to comprehensively accommodate.

All of the classes were consistently and powerfully predicted by the multivariate emotion rating feature set. To a certain extent, this classifier success is likely to be an artifact of the modality of self-report and its cuing of semantic information attached to the elicitor categories used in the study. For example, there might be a strong association between cues to morality and the concept of anger (Gutierrez et al., 2012), making it more likely for subjects to rate anger highly following immorality trials. However, this might be considered as a feature instead of a bug: the present results suggest that emotion concepts are reliably linked to subjective representations of different categories of disgust elicitor, to the extent that in tandem these emotion concepts can discriminate one category of disgust from another. This finding builds on the unsupervised classification results of Marzillier and Davey (2004), where disgust variability was

coarsely divided into "primary" and "complex" disgust elicitors. It is now clear that in the context of supervised learning, even a circumscribed set of basic emotions has the power to distinguish at a much finer grain than previously found.

The results of the emotion-only classifier provides some interesting insight into the weak performance of the physiology-only classifier. Since the classifier did not have success with recall in any of the elicitor category classes by themselves, it might be inferred that physiological representations were too varied across observations for a reliable signal to be learned. However, the fact that above-chance precision was achieved for sex and body products disgust suggests that, in spite of the lack of single reliable signal that matched every instance of sexual disgust or body products disgust, there was at least a sexual disgust prototype and a body products disgust prototype that was accessible to the classifier. In summary, the categories of moral disgust and mutilation disgust do not exist as physiological entities in and of themselves: they seem to exist as conceptual entities (see Lindquist et al., 2013), and have some predictable relationship to variability in the subjective experience of other emotions (or some relationship to the concept of these emotions, at any rate). However, the categories of sexual disgust and body products disgust seem to have a consistent representation in the conceptual domain as well as a consistent representation in the physiological domain, and crucially, those representations need not both be held online at once. It is

possible that what a person experiences as sexual disgust or body products disgust may always have a relatively coherent association with concept knowledge and other affective experiences, but that subjective representation of disgust may not always correspond to the same physiological state. Nevertheless, that does not mean there is not a physiological state associated uniquely with body products disgust or sexual disgust: it merely means that that representation does not always occur at the same time as the subjective representation of those disgusts. In other words, the division between categories of disgust is not necessarily consistent across levels of analysis.

It is worth noting that the present results are inconsistent with previous work which has been able to distinguish mutilation disgust from body products disgust or similar types of "core" (Rozin et al., 2008) disgust: Shenhav and Mendes (2014), de Jong et al. (2011) and Harrison et al. (2010) all found psychophysiological differences that distinguished mutilation disgust. There is the possibility of some stochastic coincidence such that the present sample happened to be low in this kind of disgust: several of the subjects during the debriefing mentioned being medical students and therefore not terribly susceptible to disgust at violations of the bodily envelope, so it may be that the characteristics of the sample as having been collected during a time of year when there were a greater degree of medical students seeking to participate in research influenced the results. In light of this, it may be most useful to interpret the present study as a proof

of principle, where the principle in question is: if disgust should be subdivided into categories, based on elicitors or co-occurring affect or any other sort of feature, it is not necessarily the case that that same subdivision scheme will generalize from physiology to concept knowledge, or vice versa.

5. Conclusions

This dissertation reports the outcomes and interpretations of three studies of disgust conducted using data-driven techniques in parallel with theoretical approaches, in an attempt to test existing theoretical paradigms and explore new ones.

In Chapter Two, both exploratory and confirmatory factor analysis was used to evaluate how well the cultural evolution model and adaptationist model of disgust reflected individual variability in the subjective experience of disgust. Both Haidt and colleagues and Tybur and colleagues purported to use data-driven methods to generate their models; however, the small number of people nominating disgust elicitors, as well as the relative homogeneity and convenience of the nominator sample, limited the ecological validity of the subsequent nominations. Furthermore, the way Haidt et al. processed the nominations into factors, and the way Tybur et al. instructed their nominators to come up with elicitors, allowed a greater amount of theoretical bias to leak into the resulting models than is ideal for a model touted to be a comprehensive unified theory of disgust. The approach I took to crowdsourcing nominations and interpreting factors inevitably did not completely avoid researcher bias, but by mitigating some of the study design issues seen in the development of the two theoretical models, I was able to create a model that more closely approximated the natural structure of population variability in disgust, as seen by the fact that the data-

driven model was superior to both theoretical models in the confirmatory factor analysis. The data-driven model was therefore an appropriate benchmark by which to judge both of the theoretical models: that is, points where the theoretical models converged on the data-driven model were evidence in favor of those model components, and gaps in the theoretical models could be indicated by features of the data-driven model not present in the theoretical models. The most notable recommendation of the data-driven results is that the different kinds of disgust domains may vary in how abstract they are. For instance, whereas an a priori conception of disgust per the cultural evolution model might see the animal reminder domain as at the same level of abstraction as core disgust and lead a researcher to generate hypotheses about each at around the same level of abstraction, the data-driven account notes that there may be disgust domains within a more superordinate animal reminder domain – e.g., mutilation and sex within animal reminder.

In Chapters Three and Four, I used machine learning to investigate the reliability of physiological signals corresponding to four different categories of disgust elicitor: body products (which corresponds to core disgust per the cultural evolution model but pathogen disgust per the adaptationist model), mutilation (animal reminder/pathogen), sex (animal reminder/sex), and moral disgust. Across both studies, moral disgust never had a robust physiological signal. Perplexingly, however, the two studies showed

inverse results when it came to the other classes: in Chapter Three, a pattern for mutilation relative to the other classes was discovered, whereas in Chapter Four, a pattern for mutilation was not found but patterns for sex and body products were found. There are several possible reasons for this discrepancy. In the first place, it may simply be that due to the different circumstances of data collection (i.e., time of school year), the population being sampled was different. Certainly there were differences in gender breakdown across the two samples: in Chapter Three, the sample is predominantly female, whereas in Chapter Four the sample was evenly split between male and female participants. Some researchers hold that women are more disgust sensitive than men (Tybur et al., 2009); it may be the case that the imbalance in gender representation bore somewhat on the differences in the results. The other reason that the studies did not replicate each other may have to do with the task instructions. Although the paradigms were essentially the same, there were different instructions given to participants in the different studies. For Chapter Three, although subjects were instructed to vividly imagine the vignette, their effort may have been allocated towards remembering semantic information about the vignettes in order to succeed at the dummy memory task, whereas for Chapter Four, subjects were simply told to pay attention to their emotions while visualizing the vignette. It is possible that the vignettes about mutilation were so intense that paying increased attention to uncomfortable

aversive feelings caused some sort of habituation or emotion regulation in the Chapter Four sample, causing a decrease in physiological reactivity; conversely, in Chapter Three, since their attention was slightly distracted by the memory task, it is possible that the mutilation condition did not exceed the threshold it exceeded in Chapter Four and therefore did not elicit the emotion regulation that decreased the autonomic signals. One takeaway from both of the psychophysiology studies, however, is that there is no consistent domain structure that maps onto either the Rozin or Tybur theory that spans subjective experience and physiological activity. In the first place, an error analysis of the data in Chapter Three did not suggest that representations of so-called pathogen disgust or so-called animal reminder disgust were similar enough to be easily confused for each other. In the second place, whatever representations existed in physiology for a given category of disgust experience, there was not a one-to-one correspondence with the subdivision of disgust concepts at the level of subjective experience. It will be important for disgust researchers in the future to bear in mind that just because there is evidence for the existence of a domain at the level of individual differences in subjective experience, it does not necessarily mean that that domain will be distinct from other domains at the level of peripheral physiology.

Importantly, I do not contend that the results of this dissertation eliminate the use of theory in the study of disgust – not only because it is pragmatically impossible to

do so completely, but because theory is useful. The cultural evolution model introduced some important pieces of information into the basic science of disgust, based on its theoretical underpinnings. For example, the formulation of animal reminder disgust as a response to mortality fear has been called implausible (Tybur et al., 2013), as has the theory on which the function of animal reminder disgust is based (terror management theory; see Tritt et al., 2012). Tybur and colleagues contend that a better model is that things relating to death are disgusting for pathogen-relevant reasons, and that this pathogen detector is implemented in proximal cognitive mechanisms (2013). However, there is a bidirectional link between disgust and death cognition (Cox, 2007) that Tybur et al.'s critique cannot explain. This is not to say that terror management theory or the mortality avoidance function of disgust is correct: it is possible that a model can be conceived which explains the relationship between disgust and death more reliably or more parsimoniously (see Hanna & Sinnott-Armstrong, 2018 for a discussion of the possible role of threat compensation in disgust). Rather, it is to suggest that if one points out fundamental problems with the theory of animal reminder disgust, but cannot produce a model that accounts for the observed instances of animal reminder disgust having predictive validity, then neither of the available theories can be considered totally satisfying.

In the case of a complex construct like disgust, instead of attempting to force an interpretation of data that wholly confirms one theory or the other, I argue that scientists will be better served by momentarily suspending theoretical assumptions in order to take an impartial view of the data, and seeing the ways in which the natural structure of a phenomenon converge with existing theory. The results of this dissertation have shown that integrating data-driven analyses into theoretical pursuits can be a fruitful way to validate existing paradigms, and ensure that the results which emerge from models that converge with the natural structure of data can be trusted to be ecologically valid.

Appendix A. Characteristics of validated vignettes in Chapter 2

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D001	You see a woman picking a piece of pizza off the floor and eating it.	Derived from nomination	84.45	5.21	96.30%	1.41	1.33	3.96
D002	You are changing a baby's diaper and find that it is filled with feces.	Derived from nomination	83.85	5.04	81.82%	1.23	1.14	3.00
D003	You hear the pornographic video that your neighbor is listening to through the wall.	Derived from nomination	59.68	8.41	71.43%	1.79	1.68	4.29
D004	You see a puddle of urine seeping in between the tiles in a public restroom.	Derived from nomination	73.17	6.78	96.00%	1.32	1.20	3.12
D005	You see a teenaged girl spitting her chewing tobacco into an empty glass bottle.	Derived from nomination	59.68	8.41	97.87%	1.83	1.55	4.53
D006	You see a hairy house centipede scurrying quickly over the tiled floor of the kitchen.	Derived from nomination	61.89	8.35	52.00%	1.40	1.32	3.92
D007	You see a young man in a public park drop his pants, squat down, and start pooping.	Derived from nomination	95.03	4.23	100.00%	2.00	1.39	4.68

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D008	You see a plastic container of leftovers in the refrigerator, covered with fuzzy white mold.	Derived from nomination	44.97	10.71	89.66%	1.41	1.34	2.86
D009	You learn that your former classmate left her child in a hot car for an hour.	Derived from nomination	90.13	4.66	93.33%	1.87	1.60	3.70
D010	You look down at the soup you just ordered and see a thin hair floating in it.	Derived from nomination	95.03	4.23	100.00%	1.33	1.24	3.00
D011	You see a smear of dog feces that was tracked inside onto the carpet.	Derived from nomination	83.85	5.04	100.00%	1.27	1.12	4.15
D012	You see a brown streak of excrement on the floor of a public restroom.	Derived from nomination	83.85	5.04	95.00%	1.65	1.50	3.90
D013	You walk into a hotel bathroom and find that the toilet is covered in vomit.	Derived from nomination	73.17	6.78	100.00%	1.76	1.43	4.43
D014	You learn about someone shooting her husband with a gun after a drawn-out argument.	Derived from nomination	59.68	8.41	81.48%	2.04	1.63	3.85

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D015	You see a large brown spider crawling across the bathroom floor towards the window.	Derived from nomination	77.81	5.88	59.09%	1.23	1.27	3.05
D016	You see a woman with a skin disease that made her chin break out in oozing sores.	Derived from nomination	90.05	4.92	95.83%	1.79	1.54	4.21
D017	You feel the person next to you on the sidewalk sneeze, so that droplets hit your face.	Derived from nomination	90.05	4.92	100.00%	1.54	1.38	4.12
D018	You feel a dried booger on a hand rail on an escalator at the mall.	Derived from nomination	84.45	5.21	95.83%	1.67	1.46	4.33
D019	You see an anti-drug ad featuring a bony man missing some of his teeth.	Derived from nomination	71.77	6.73	78.57%	1.50	1.25	2.89
D020	You see a woman smiling broadly with a great deal of yellow plaque on her front teeth.	Derived from nomination	85.07	5.62	90.00%	1.43	1.40	3.10
D021	You feel muddy water sloshing against your pants as you walk through a swamp.	Derived from nomination	83.85	5.04	57.14%	1.75	1.46	4.07

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D022	You see a student claiming he wrote an essay that he secretly copied from his sibling.	Derived from nomination	68.98	7.61	54.05%	1.41	1.41	3.86
D023	You see a sanitation worker heaving a greasy trash bag into the back of a garbage truck.	Derived from nomination	65.17	8.39	70.37%	1.52	1.44	3.00
D024	You smell your neighbor as she walks by, because she almost never wears deodorant.	Derived from nomination	65.73	7.57	96.43%	1.61	1.54	3.68
D025	You accidentally squish a moist earthworm under your bare foot next to a public pool.	Derived from nomination	67.53	7.57	100.00%	1.58	1.38	3.96
D026	You see a little girl pulling at a dark red scab on her knee until it bleeds.	Derived from nomination	90.05	4.92	68.18%	1.64	1.50	3.86
D027	You smell the powerful scent of cat urine coming from a stain on the carpet.	Derived from nomination	78.81	5.99	100.00%	1.82	1.45	3.77
D028	You see a picture online of a piece of bone emerging from a broken leg.	Derived from nomination	78.81	5.99	86.96%	1.65	1.57	3.96

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D029	You see a young woman at the store coughing loudly without covering her mouth.	Derived from nomination	71.77	6.73	95.45%	1.14	1.18	2.68
D030	You watch a television show about parents who force their children to perform in pageants.	Derived from nomination	61.89	8.35	77.27%	1.64	1.50	3.14
D031	You smell the strong, floral perfume of the woman next to you in a movie theater.	Derived from nomination	74.27	6.88	50.00%	1.15	1.05	2.60
D032	You see a pile of yesterday's dishes in the sink, covered in dried tomato sauce.	Derived from nomination	73.17	6.78	52.17%	1.30	1.22	2.52
D033	You smell that your neighbor has just broken wind in the elevator next to you.	Derived from nomination	78.81	5.99	91.30%	1.35	1.26	3.22
D034	You see a child at the playground trying to cough up phlegm to amuse his friends.	Derived from nomination	90.13	4.66	95.83%	1.88	1.75	4.13
D035	You see a student's college application, padded with activities she had never really done.	Derived from nomination	41.55	10.94	60.87%	1.61	1.48	3.74

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D036	You see a little boy picking his nose, looking at the booger, and then eating it.	Derived from nomination	79.56	6.14	96.15%	1.19	1.08	3.42
D037	You feel a warm splat on your shoulder and realize that a bird has pooped on you.	Derived from nomination	95.03	4.23	100.00%	1.19	1.33	3.95
D038	You see an online video of a hunter skinning the body of a deer he just shot.	Derived from nomination	75.12	7.00	50.00%	1.59	1.41	3.77
D039	You put your hand on a counter and find that it leaves your fingers sticky.	Derived from nomination	90.09	4.42	95.45%	1.18	1.14	2.86
D040	You see your friend's new puppy throwing up all over the backseat of her car.	Derived from nomination	84.45	5.21	88.89%	1.44	1.22	3.81
D041	You see a woman with greasy blonde hair that clearly hasn't been washed in days.	Derived from nomination	84.45	5.21	92.00%	1.28	1.12	3.44
D042	You use a brush to scrape the fecal matter off the sides of a toilet bowl.	Derived from nomination	90.13	4.66	96.43%	1.61	1.46	3.04

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D043	You hear your coworker go on and on about how his neighbors are low class.	Derived from nomination	84.45	5.21	80.95%	1.86	1.62	3.33
D044	You shake the hand of a new acquaintance and find her hand to be warm and clammy.	Derived from nomination	90.05	4.92	66.67%	1.38	1.43	2.95
D045	You see that your next-door neighbor has let his cat poop on your front walkway.	Derived from nomination	95.42	3.93	100.00%	1.65	1.39	4.22
D046	You learn that a local politician lied about his intent to fulfill his campaign promises.	Derived from nomination	50.61	9.93	73.08%	1.50	1.35	2.38
D047	You see a friend showing you an infected wound on her elbow that is oozing pus.	Derived from nomination	79.56	6.14	96.67%	1.77	1.60	4.27
D048	You see a cotton swab with a huge amount of yellow, sticky ear wax in the wastebasket.	Derived from nomination	75.12	7.00	80.00%	1.40	1.12	3.52
D049	You see a boy taking a piece of slimy pink gum and sticking it to a lamppost.	Derived from nomination	85.07	5.62	75.00%	1.44	1.39	3.78

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D050	You see a woman dipping her half-eaten chicken wing in a public bowl of barbecue sauce.	Derived from nomination	63.7	8.35	82.61%	1.43	1.35	3.83
D051	You learn that your colleague at work only has sex with women he pays to whip him.	Added by researchers to test theories	90.05	4.92	57.14%	2.32	2.14	4.29
D052	You see a man living off the kindness of his roommates without ever giving anything back.	Derived from nomination	63.7	8.35	66.67%	1.63	1.58	2.79
D053	You see a man in a store slipping a DVD into his coat and leaving without paying.	Derived from nomination	70.14	7.70	73.91%	1.39	1.39	3.43
D054	You smell some rotting chicken that was put in the trash can days ago.	Derived from nomination	89.9	4.20	96.30%	1.70	1.44	3.56
D055	You see a man who hasn't cleaned or trimmed his yellow, half-inch-long fingernails in months.	Derived from nomination	85.07	5.62	95.00%	2.20	1.90	4.10
D056	You see several roaches crawling on your friend's kitchen counter, close to a plate of food.	Derived from nomination	79.56	6.14	100.00%	1.52	1.33	4.29

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D057	You smell an untied garbage bag that was left in an alley on a hot day.	Derived from nomination	90.13	4.66	95.00%	1.20	1.20	3.10
D058	You sit down on a toilet and feel that someone left drops of urine on the seat.	Derived from nomination	90.05	4.92	100.00%	1.35	1.35	2.87
D059	You hear someone throwing up in the stall next to yours in the airport bathroom.	Derived from nomination	84.45	5.21	95.65%	1.52	1.65	4.09
D060	You see a buffet plate at a restaurant piled high with a heap of steamed tentacles.	Derived from nomination	79.56	6.14	54.17%	2.00	1.67	4.25
D061	You see an ad online that is clearly meant to scam elderly people out of their earnings.	Derived from nomination	75.12	7.00	84.62%	1.54	1.31	3.12
D062	You see a documentary where a botfly larva is being removed from beneath somebody's skin.	Derived from nomination	44.97	10.71	100.00%	2.20	1.95	4.30
D063	You smell chicken soup that has been left in the communal refrigerator to spoil.	Derived from nomination	65.73	7.57	100.00%	1.85	1.55	3.90

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D064	You see a man at a dinner table blow his nose and then look at the tissue.	Derived from nomination	90.05	4.92	79.17%	1.33	1.38	3.46
D065	You catch a strong whiff of the breath of the person you are talking to.	Derived from nomination	95.73	3.63	95.65%	1.52	1.35	2.57
D066	You hear the woman sitting next to you at a cafe burp with her mouth open.	Derived from nomination	84.85	5.40	77.27%	1.59	1.36	3.09
D067	You smell the odor of the vomit that you are cleaning up off the floor.	Derived from nomination	90.09	4.42	100.00%	1.60	1.23	4.27
D068	You learn that a person you know can only be sexually aroused by looking at mannequins.	Added by researchers to test theories	63.7	8.35	78.26%	2.65	2.39	4.70
D069	You see a man at the grocery store with a large crusty wart on his hand.	Derived from nomination	95.42	3.93	90.00%	1.80	1.60	4.20
D070	You see a man standing behind a gas station, urinating into a patch of grass.	Derived from nomination	67.53	7.57	77.27%	1.45	1.32	3.73
D071	You hear a woman at a party telling a story that involves a lot of scat humor.	Derived from nomination	75.12	7.00	68.18%	2.09	1.95	3.45

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D072	You see a picture in a medical textbook of a dark red, peeling third-degree burn.	Derived from nomination	67.53	7.57	85.00%	1.75	1.35	4.45
D073	You see little white maggots crawling all over the underside of a decaying log.	Derived from nomination	59.68	8.41	77.78%	1.81	1.52	4.07
D074	You smell the excrement that was left in the public toilet in front of you.	Derived from nomination	84.45	5.21	100.00%	1.45	1.18	3.50
D075	You see a middle school girl making fun of her classmate's acne on social media.	Derived from nomination	67.53	7.57	70.83%	1.96	1.75	3.29
D076	You see someone leaving the restroom without washing their hands after they have pooped.	Derived from nomination	65.73	7.57	100.00%	1.48	1.22	3.04
D077	You learn that someone you know has been using stolen credit card information to buy things online.	Derived from nomination	65.17	8.39	77.78%	1.78	1.63	3.63
D078	You see your neighbor's son punching another kid while his friend films it on a smartphone.	Derived from nomination	79.56	6.14	89.29%	1.54	1.64	3.79

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D079	You learn that a coworker of yours has been cheating on his wife through online dating apps.	Derived from nomination	80.1	6.31	78.26%	1.39	1.30	3.30
D080	You smell that the milk in the glass you are drinking from is spoiled.	Derived from nomination	95.94	3.36	100.00%	1.39	1.18	3.61
D081	You learn that your neighbor has been arrested for beating his dog with a tire iron.	Derived from nomination	74.27	6.88	100.00%	2.56	2.28	4.56
D082	You see a woman leaning close to a mirror to pop a pimple on her chin.	Derived from nomination	84.85	5.40	93.33%	1.33	1.27	3.33
D083	You see a medical video of a surgery being done on a patient's intestines.	Derived from nomination	47.6	10.10	90.00%	2.00	1.60	3.70
D084	You see that the woman next to you on the bus is about to vomit on you.	Derived from nomination	90.05	4.92	96.55%	2.07	1.76	4.34
D085	You see a man across from you at a restaurant laughing with his mouth full.	Derived from nomination	84.45	5.21	82.14%	1.64	1.46	3.04
D086	You see a brownish haze of air pollution hovering over the skyline of a nearby city.	Derived from nomination	58.41	9.09	80.95%	1.33	1.14	2.86

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D087	You hear a young man talking about how he only enjoys having anonymous sex.	Derived from nomination	59.68	8.41	62.07%	1.41	1.31	3.72
D088	You see a friend of yours kneeling down and letting her pet dog lick her mouth.	Derived from nomination	95.42	3.93	66.67%	1.50	1.54	2.75
D089	You see fresh road kill, bloody and squished, lying on the side of the road.	Derived from nomination	95.73	3.63	100.00%	1.42	1.19	2.62
D090	You see a man in a hospital lobby hacking up blood and mucus into a tissue.	Derived from nomination	68.98	7.61	92.31%	1.92	1.73	4.19
D091	You see that your neighbor's septic tank has begun to leak sewage into the grass.	Derived from nomination	78.81	5.99	96.55%	2.00	1.79	4.38
D092	You hear your neighbor's son claiming that he almost always urinates in the shower.	Derived from nomination	65.73	7.57	61.54%	1.46	1.23	3.58
D093	You accidentally step on a patch of cat vomit, and feel that it is still warm.	Derived from nomination	84.85	5.40	96.43%	1.61	1.25	4.04

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D094	You see a snot bubble coming out of the nose of a sick child after he sneezes.	Derived from nomination	85.07	5.62	85.71%	1.38	1.29	2.76
D095	You listen to a person clearing her throat repeatedly after she has been eating.	Derived from nomination	65.73	7.57	81.48%	1.37	1.44	3.07
D096	You see a great deal of hairy gunk that has been pulled out of a sink drain.	Derived from nomination	100	3.53	95.65%	1.39	1.26	3.09
D097	You see a garbage bin with the lid up, with hundreds of flies swarming above it.	Derived from nomination	84.85	5.40	100.00%	1.19	1.19	3.42
D098	You see an empty condom wrapper on the floor of the elevator of a public building.	Added by researchers to test theories	63.7	8.35	72.73%	1.41	1.23	4.36
D099	You see a man at a bar convincing a woman to have sex without a condom.	Added by researchers to test theories	79.56	6.14	77.78%	2.00	1.56	3.89
D100	You hear a woman sitting on a park bench and very quietly having phone sex.	Added by researchers to test theories	73.17	6.78	60.00%	2.08	1.80	4.56

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D101	You read a news story about a man exposing his genitals to children near a public library.	Derived from nomination	55.22	9.78	100.00%	2.33	2.17	4.33
D102	You see a man at the bank looking at something on his smartphone and touching his crotch.	Added by researchers to test theories	90.05	4.92	76.19%	1.57	1.38	4.24
D103	You hear a woman bragging about the extensive number of men she has slept with.	Derived from nomination	73.17	6.78	72.00%	1.44	1.16	3.84
D104	You hear a woman telling her date that she only enjoys anal penetration with dildos.	Added by researchers to test theories	56.25	9.14	61.90%	2.05	1.76	4.48
D105	You watch a nature show about a parasitic wasp that lays its eggs inside a caterpillar.	Added by researchers to test theories	58.41	9.09	64.00%	1.88	1.52	4.24
D106	You see a close-up of a man's injured collarbone that dents visibly into his chest.	Derived from nomination	74.27	6.88	65.52%	2.38	2.00	4.17
D107	You see that your friend has accidentally hammered a nail partway into his thumb.	Added by researchers to test theories	71.77	6.73	72.73%	1.64	1.45	4.41

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D108	You feel sweat on your armpits from commuting in a car during the middle of summer.	Derived from nomination	68.98	7.61	61.29%	1.32	1.32	2.65
D109	You see a woman using gestures to demonstrate to her friend how she masturbates.	Added by researchers to test theories	65.73	7.57	65.22%	1.78	1.52	4.65
D110	You hear the town council voted on a raise for themselves when the homeless shelter needs funds.	Derived from nomination	80.1	6.31	81.82%	1.59	1.41	3.27
D111	You learn that your friend is spreading rumors that you didn't repay a debt you owed him.	Derived from nomination	85.07	5.62	66.67%	1.79	1.50	4.13
D112	You hear the couple sitting behind you in a movie theater making out and moaning during the previews.	Derived from nomination	56.97	9.79	85.71%	1.61	1.25	4.00
D113	You read an erotic message on a dating website from someone who you deeply disliked years ago.	Added by researchers to test theories	60.19	9.09	77.27%	2.09	1.73	4.41

Vignette number	Vignette	Source	Flesch-Kincaid Reading Ease	Flesch-Kincaid Reading Level	% Disgusting or Maybe Disgusting	Imaginability	Comprehensibility	Frequency
D114	You see a winged insect crawling along the edge of the coffee cup you are drinking from.	Derived from nomination	75.12	7.00	80.95%	1.33	1.38	4.10
D115	You see a photograph of an open human chest cavity in a science textbook.	Derived from nomination	59.68	8.41	85.71%	2.19	1.71	4.62
D116	You smell a pile of unwashed laundry on the floor in the corner of a bedroom.	Derived from nomination	84.85	5.40	86.36%	1.36	1.32	2.50
D117	You see a plate of glistening snails in garlic sauce at a fancy restaurant.	Derived from nomination	71.77	6.73	68.18%	2.00	1.68	4.14
D118	You see a large rat that is missing patches of skin running across the sidewalk.	Derived from nomination	78.81	5.99	76.19%	2.00	1.81	4.62
D119	You see a tattooed teenager at the mall who has pierced a hole in her cheek.	Added by researchers to test theories	90.13	4.66	86.36%	2.18	1.64	4.00
D120	You smell the tobacco smoke wafting out of an ashtray overflowing with cigarette butts.	Derived from nomination	53.64	9.26	80.00%	1.56	1.56	2.76

Appendix B: Disgust vignette database with item factor loadings

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D012	You see a brown streak of excrement on the floor of a public restroom.*	**-0.79**	-0.13	0.03	0.00	0.05	0.00	0.34
D013	You walk into a hotel bathroom and find that the toilet is covered in vomit.**	**-0.77**	-0.01	0.02	0.01	0.01	0.08	0.46
D074	You smell the excrement that was left in the public toilet in front of you.*	**-0.77**	-0.01	0.00	-0.07	-0.01	0.00	0.32
D058	You sit down on a toilet and feel that someone left drops of urine on the seat.*	**-0.76**	-0.03	-0.02	0.01	-0.06	0.12	0.39
D004	You see a puddle of urine seeping in between the tiles in a public restroom.	**0.72**	0.04	0.08	0.03	0.03	0.03	0.32
D011	You see a smear of dog feces that was tracked inside onto the carpet.	**0.69**	0.00	0.05	0.09	-0.04	0.09	0.39
D067	You smell the odor of the vomit that you are cleaning up off the floor.*	**-0.68**	-0.06	0.07	-0.05	-0.07	-0.08	0.41
D093	You accidentally step on a patch of cat vomit, and feel that it is still warm.	**0.68**	0.00	-0.01	0.05	0.00	0.07	0.47
D054	You smell some rotting chicken that was put in the trash can days ago.	**0.66**	0.04	0.05	-0.03	0.02	0.19	0.39
D007	You see a young man in a public park drop his pants, squat down, and start pooping.**	**-0.65**	-0.08	-0.15	-0.04	0.10	0.16	0.49

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D017	You feel the person next to you on the sidewalk sneeze, so that droplets hit your face.*	**-0.64**	-0.09	0.05	-0.02	-0.21	0.14	0.43
D080	You smell that the milk in the glass you are drinking from is spoiled.	**0.64**	0.01	0.06	-0.08	-0.04	0.24	0.47
D063	You smell chicken soup that has been left in the communal refrigerator to spoil.	**0.61**	0.09	0.02	-0.04	0.07	0.15	0.45
D018	You feel a dried booger on a hand rail on an escalator at the mall.	**0.61**	0.04	0.03	0.09	0.22	-0.16	0.38
D027	You smell the powerful scent of cat urine coming from a stain on the carpet.	**0.58**	0.09	0.07	-0.02	0.08	0.22	0.36
D091	You see that your neighbor's septic tank has begun to leak sewage into the grass.	**0.57**	0.08	0.09	0.06	-0.05	0.00	0.56
D084	You see that the woman next to you on the bus is about to vomit on you.**	**-0.55**	-0.09	0.05	-0.09	-0.11	0.16	0.58
D056	You see several roaches crawling on your friend's kitchen counter, close to a plate of food.	**0.55**	0.09	0.12	0.11	-0.07	0.00	0.53
D008	You see a plastic container of leftovers in the refrigerator, covered with fuzzy white mold.	**0.54**	0.06	0.10	0.03	-0.03	0.27	0.42
D042	You use a brush to scrape the fecal matter off the sides of a toilet bowl.	**0.53**	-0.07	0.05	0.20	-0.06	0.13	0.55
D010	You look down at the soup you just ordered and see a thin hair floating in it.	**0.52**	0.06	0.06	0.07	0.23	-0.02	0.43
D037	You feel a warm splat on your shoulder and realize that a bird has pooped on you.	**0.51**	0.01	0.09	0.09	-0.01	0.25	0.46

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D076	You see someone leaving the restroom without washing their hands after they have pooped.	**0.51**	0.18	0.11	-0.03	0.15	-0.10	0.47
D057	You smell an untied garbage bag that was left in an alley on a hot day.	**0.48**	0.06	0.07	-0.04	0.08	**0.32**	0.44
D039	You put your hand on a counter and find that it leaves your fingers sticky.	**0.45**	0.14	0.03	-0.06	0.20	0.21	0.47
D065	You catch a strong whiff of the breath of the person you are talking to.	**0.44**	0.04	0.08	-0.07	**0.37**	0.09	0.41
D033	You smell that your neighbor has just broken wind in the elevator next to you.	**0.44**	0.02	0.15	0.03	**0.31**	-0.05	0.43
D045	You see that your next-door neighbor has let his cat poop on your front walkway.	**0.43**	0.12	0.07	0.02	0.17	0.22	0.44
D024	You smell your neighbor as she walks by, because she almost never wears deodorant.	**0.43**	0.04	0.13	0.04	**0.31**	0.03	0.40
D097	You see a garbage bin with the lid up, with hundreds of flies swarming above it.	**0.42**	0.03	0.11	0.15	0.06	0.28	0.42
D073	You see little white maggots crawling all over the underside of a decaying log.	**0.42**	-0.07	0.14	**0.31**	-0.12	0.19	0.49
D059	You hear someone throwing up in the stall next to yours in the airport bathroom.	**0.42**	-0.06	0.06	0.18	0.26	0.02	0.48
D036	You see a little boy picking his nose, looking at the booger, and then eating it.	**0.41**	-0.03	0.16	0.12	**0.31**	-0.13	0.46
D096	You see a great deal of hairy gunk that has been pulled out of a sink drain.	**0.39**	-0.08	0.11	0.11	0.27	0.12	0.47

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D114	You see a winged insect crawling along the edge of the coffee cup you are drinking from.	**0.38**	0.08	0.10	0.17	0.05	0.23	0.49
D055	You see a man who hasn't cleaned or trimmed his yellow, half-inch-long fingernails in months.	**0.38**	0.19	0.09	0.10	0.27	-0.05	0.44
D001	You see a woman picking a piece of pizza off the floor and eating it.	**0.37**	0.06	0.20	0.10	0.18	-0.01	0.51
D025	You accidentally squish a moist earthworm under your bare foot next to a public pool.	**0.36**	-0.07	0.20	0.16	-0.01	0.21	0.57
D118	You see a large rat that is missing patches of skin running across the sidewalk.	**0.33**	0.00	0.16	0.24	0.07	0.13	0.52
D040	You see your friend's new puppy throwing up all over the backseat of her car.	**0.31**	-0.07	0.07	0.18	0.20	0.22	0.54
D050	You see a woman dipping her half-eaten chicken wing in a public bowl of barbecue sauce.	**0.31**	0.18	0.10	-0.10	0.21	-0.06	0.69
D061	You see an ad online that is clearly meant to scam elderly people out of their earnings.	0.06	**0.81**	-0.06	0.06	-0.02	-0.12	0.34
D046	You learn that a local politician lied about his intent to fulfill his campaign promises.	-0.02	**0.76**	-0.02	-0.01	0.06	0.13	0.38
D077	You learn that someone you know has been using stolen credit card information to buy things online.	0.06	**0.76**	0.06	0.04	-0.08	-0.03	0.35
D022	You see a student claiming he wrote an essay that he secretly copied from his sibling.	-0.10	**0.72**	0.05	-0.07	0.09	0.12	0.45
D035	You see a student's college application, padded with activities she had never really done.	-0.11	**0.71**	0.04	-0.07	0.16	0.11	0.46

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D110	You hear the town council voted on a raise for themselves when the homeless shelter needs funds.	0.04	**0.71**	-0.11	-0.01	0.00	-0.07	0.54
D053	You see a man in a store slipping a DVD into his coat and leaving without paying.	-0.11	**0.70**	0.17	0.01	0.14	0.01	0.38
D111	You learn that your friend is spreading rumors that you didn't repay a debt you owed him.	-0.03	**0.70**	-0.01	0.00	0.03	0.05	0.52
D075	You see a middle school girl making fun of her classmate's acne on social media.	0.13	**0.69**	0.05	0.03	-0.05	-0.02	0.39
D052	You see a man living off the kindness of his roommates without ever giving anything back.	0.06	**0.66**	0.00	-0.05	0.09	0.03	0.49
D009	You learn that your former classmate left her child in a hot car for an hour.	0.07	**0.64**	0.05	0.08	-0.03	-0.19	0.50
D030	You watch a television show about parents who force their children to perform in pageants.	-0.04	**0.63**	-0.08	0.02	-0.02	0.11	0.64
D043	You hear your coworker go on and on about how his neighbors are low class.	-0.05	**0.62**	0.04	-0.03	-0.04	0.15	0.59
D081	You learn that your neighbor has been arrested for beating his dog with a tire iron.*	-0.13	**-0.61**	0.06	-0.12	0.13	0.18	0.57
D014	You learn about someone shooting her husband with a gun after a drawn-out argument.	-0.01	**0.58**	0.17	0.18	-0.18	0.03	0.51
D078	You see your neighbor's son punching another kid while his friend films it on a smartphone.	0.10	**0.58**	0.16	0.12	-0.16	-0.14	0.48

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D079	You learn that a coworker of yours has been cheating on his wife through online dating apps.	0.09	**0.55**	0.28	0.00	-0.04	-0.04	0.44
D086	You see a brownish haze of air pollution hovering over the skyline of a nearby city.	0.23	**0.53**	-0.14	-0.01	0.06	0.25	0.51
D101	You read a news story about a man exposing his genitals to children near a public library.**	**-0.32**	**-0.43**	-0.09	-0.02	0.07	0.20	0.57
D104	You hear a woman telling her date that she only enjoys anal penetration with dildos.	-0.09	-0.06	**0.88**	0.06	0.04	-0.05	0.30
D087	You hear a young man talking about how he only enjoys having anonymous sex.	-0.04	-0.01	**0.84**	-0.07	0.04	0.03	0.32
D051	You learn that your colleague at work only has sex with women he pays to whip him.	-0.11	-0.02	**0.83**	0.08	0.02	-0.02	0.34
D109	You see a woman using gestures to demonstrate to her friend how she masturbates.	0.05	-0.01	**0.82**	0.00	-0.01	-0.04	0.32
D003	You hear the pornographic video that your neighbor is listening to through the wall.	0.04	0.00	**0.81**	-0.02	-0.05	0.06	0.32
D103	You hear a woman bragging about the extensive number of men she has slept with.	-0.06	0.06	**0.80**	-0.08	0.07	0.00	0.36
D100	You hear a woman sitting on a park bench and very quietly having phone sex.	0.07	-0.03	**0.80**	-0.02	-0.06	0.02	0.36
D112	You hear the couple sitting behind you in a movie theater making out and moaning during the previews.	0.11	0.11	**0.65**	0.00	-0.07	-0.01	0.45

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D068	You learn that a person you know can only be sexually aroused by looking at mannequins.	0.02	0.11	**0.60**	0.10	0.02	-0.02	0.48
D099	You see a man at a bar convincing a woman to have sex without a condom.	0.09	0.24	**0.58**	-0.03	-0.08	-0.03	0.47
D113	You read an erotic message on a dating website from someone who you deeply disliked years ago.	0.03	0.19	**0.49**	0.03	0.02	0.11	0.54
D102	You see a man at the bank looking at something on his smartphone and touching his crotch.	0.27	0.24	**0.37**	0.05	0.02	-0.06	0.48
D092	You hear your neighbor's son claiming that he almost always urinates in the shower.	0.06	-0.02	**0.35**	0.13	0.23	0.09	0.61
D070	You see a man standing behind a gas station, urinating into a patch of grass.	0.24	0.10	**0.34**	0.10	0.07	0.16	0.48
D098	You see an empty condom wrapper on the floor of the elevator of a public building.	0.20	0.06	**0.34**	-0.01	0.12	0.12	0.61
D115	You see a photograph of an open human chest cavity in a science textbook.	-0.09	-0.03	0.02	**0.83**	-0.01	-0.04	0.38
D083	You see a medical video of a surgery being done on a patient's intestines.	-0.02	-0.03	-0.02	**0.81**	-0.11	0.01	0.42
D028	You see a picture online of a piece of bone emerging from a broken leg.	-0.03	0.08	-0.02	**0.78**	0.01	-0.11	0.43
D072	You see a picture in a medical textbook of a dark red, peeling third-degree burn.	-0.09	0.08	-0.05	**0.78**	0.12	0.04	0.36
D106	You see a close-up of a man's injured collarbone that dents visibly into his chest.	-0.09	0.07	0.07	**0.66**	0.12	0.06	0.46

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D107	You see that your friend has accidentally hammered a nail partway into his thumb.	0.07	0.14	0.03	**0.63**	-0.06	0.02	0.50
D062	You see a documentary where a botfly larva is being removed from beneath somebody's skin.	0.19	0.01	0.06	**0.58**	-0.09	0.00	0.52
D038	You see an online video of a hunter skinning the body of a deer he just shot.	0.08	0.03	0.00	**0.55**	-0.10	0.17	0.61
D047	You see a friend showing you an infected wound on her elbow that is oozing pus.	0.20	0.01	0.04	**0.53**	0.14	-0.01	0.43
D089	You see fresh road kill, bloody and squished, lying on the side of the road.	**0.30**	-0.01	0.13	**0.45**	-0.10	0.20	0.42
D090	You see a man in a hospital lobby hacking up blood and mucus into a tissue.	0.25	0.02	0.03	**0.43**	0.27	-0.09	0.43
D016	You see a woman with a skin disease that made her chin break out in oozing sores.	0.27	-0.05	-0.01	**0.42**	0.26	-0.05	0.48
D026	You see a little girl pulling at a dark red scab on her knee until it bleeds.	0.05	0.00	0.11	**0.41**	**0.39**	0.09	0.38
D105	You watch a nature show about a parasitic wasp that lays its eggs inside a caterpillar.	0.11	0.03	0.06	**0.41**	-0.07	**0.38**	0.52
D019	You see an anti-drug ad featuring a bony man missing some of his teeth.	-0.06	0.09	0.16	**0.35**	0.24	0.21	0.53
D095	You listen to a person clearing her throat repeatedly after she has been eating.	0.00	0.06	0.06	0.12	**0.55**	0.12	0.52
D064	You see a man at a dinner table blow his nose and then look at the tissue.	0.16	0.01	0.24	0.13	**0.52**	-0.08	0.34

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D085	You see a man across from you at a restaurant laughing with his mouth full.	0.06	0.19	0.17	0.02	**0.45**	0.08	0.50
D082	You see a woman leaning close to a mirror to pop a pimple on her chin.	0.07	-0.08	0.11	**0.36**	**0.44**	-0.03	0.46
D066	You hear the woman sitting next to you at a cafe burp with her mouth open.	0.09	0.14	0.20	0.11	**0.44**	0.07	0.42
D041	You see a woman with greasy blonde hair that clearly hasn't been washed in days.	0.14	0.16	0.19	0.01	**0.42**	0.15	0.41
D034	You see a child at the playground trying to cough up phlegm to amuse his friends.	0.17	0.07	0.18	0.13	**0.41**	0.03	0.45
D044	You shake the hand of a new acquaintance and find her hand to be warm and clammy.	0.21	0.07	0.08	0.07	**0.39**	0.14	0.51
D116	You smell a pile of unwashed laundry on the floor in the corner of a bedroom.	0.25	0.07	0.08	-0.03	**0.39**	0.27	0.43
D069	You see a man at the grocery store with a large crusty wart on his hand.	0.25	-0.06	0.01	**0.33**	**0.37**	0.08	0.41
D094	You see a snot bubble coming out of the nose of a sick child after he sneezes.	0.22	-0.09	0.03	0.26	**0.37**	0.07	0.52
D020	You see a woman smiling broadly with a great deal of yellow plaque on her front teeth.	0.26	0.02	0.19	0.07	**0.37**	0.03	0.48
D029	You see a young woman at the store coughing loudly without covering her mouth.	**0.32**	0.23	0.14	-0.04	**0.36**	-0.06	0.42
D048	You see a cotton swab with a huge amount of yellow, sticky ear wax in the wastebasket.	**0.31**	-0.14	0.11	0.24	**0.35**	0.05	0.42

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D049	You see a boy taking a piece of slimy pink gum and sticking it to a lamppost.	0.12	0.18	0.18	-0.05	**0.33**	0.24	0.50
D021	You feel muddy water sloshing against your pants as you walk through a swamp.	0.08	0.07	0.17	0.21	0.05	**0.4**	0.53
D015	You see a large brown spider crawling across the bathroom floor towards the window.	0.16	0.04	0.14	0.15	-0.01	**0.4**	0.6
D032	You see a pile of yesterday's dishes in the sink, covered in dried tomato sauce.	0.03	0.14	0.07	0.08	**0.34**	**0.39**	0.48
D006	You see a hairy house centipede scurrying quickly over the tiled floor of the kitchen.	0.15	0.03	0.08	0.22	-0.04	**0.38**	0.64
D023	You see a sanitation worker heaving a greasy trash bag into the back of a garbage truck.	0	-0.02	0.15	0.22	0.27	**0.35**	0.52
D108	You feel sweat on your armpits from commuting in a car during the middle of summer.	0.14	0.12	0.12	0.07	0.25	**0.32**	0.52
D005	You see a teenaged girl spitting her chewing tobacco into an empty glass bottle.	0.26	0.16	0.07	0.13	0.29	0.06	0.52
D117	You see a plate of glistening snails in garlic sauce at a fancy restaurant.	0.21	0.04	0.13	0.27	0.01	0.14	0.66
D088	You see a friend of yours kneeling down and letting her pet dog lick her mouth.	0.2	0.03	0.15	0.04	0.28	0.06	0.67
D002	You are changing a baby's diaper and find that it is filled with feces.	0.18	-0.13	-0.08	0.29	0.19	0.26	0.64
D120	You smell the tobacco smoke wafting out of an ashtray overflowing with cigarette butts.	0.14	0.21	0.05	0.05	0.19	0.19	0.69

Vignette number	Vignette	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Unique variance
D060	You see a buffet plate at a restaurant piled high with a heap of steamed tentacles.	0.12	-0.03	0.27	0.27	0.03	0.19	0.61
D071	You hear a woman at a party telling a story that involves a lot of scat humor.	0.08	0.14	0.18	0.07	0.17	0.13	0.72
D031	You smell the strong, floral perfume of the woman next to you in a movie theater.	-0.05	0.19	0.05	-0.08	0.21	0.17	0.86
D119	You see a tattooed teenager at the mall who has pierced a hole in her cheek.	-0.12	0.15	0.27	0.24	0.22	0.1	0.63

Salient loadings (greater than |.3|) are shown in boldface. Variables are sorted according to absolute value of loading on the factor on which they maximally load, since negatively loading items were reflected as part of a transformation.

* Item was reflected and square root transformed to address univariate nonnormality; interpret negative loading as positive due to the reflection.

** Item was reflected and log root transformed to address univariate nonnormality; interpret negative loading as positive due to the reflection.

Appendix C: Assignments of each vignette to a label per the cultural evolution model, the adaptationist model, and the data-driven model.

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D001	You see a woman picking a piece of pizza off the floor and eating it.	core	pathogen	Factor I
D002	You are changing a baby's diaper and find that it is filled with feces.	core	pathogen	no code
D003	You hear the pornographic video that your neighbor is listening to through the wall.	AR	sex	Factor III
D004	You see a puddle of urine seeping in between the tiles in a public restroom.	core	pathogen	Factor I
D005	You see a teenaged girl spitting her chewing tobacco into an empty glass bottle.	core	pathogen	no code
D006	You see a hairy house centipede scurrying quickly over the tiled floor of the kitchen.	core	pathogen	Factor VI
D007	You see a young man in a public park drop his pants, squat down, and start pooping.	ambiguous	ambiguous	Factor I
D008	You see a plastic container of leftovers in the refrigerator, covered with fuzzy white mold.	core	pathogen	Factor I
D009	You learn that your former classmate left her child in a hot car for an hour.	moral	moral	Factor II
D010	You look down at the soup you just ordered and see a thin hair floating in it.	core	pathogen	Factor I

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D011	You see a smear of dog feces that was tracked inside onto the carpet.	core	pathogen	Factor I
D012	You see a brown streak of excrement on the floor of a public restroom.	core	pathogen	Factor I
D013	You walk into a hotel bathroom and find that the toilet is covered in vomit.	core	pathogen	Factor I
D014	You learn about someone shooting her husband with a gun after a drawn-out argument.	moral	moral	Factor II
D015	You see a large brown spider crawling across the bathroom floor towards the window.	core	pathogen	Factor VI
D016	You see a woman with a skin disease that made her chin break out in oozing sores.	ambiguous	ambiguous	Factor IV
D017	You feel the person next to you on the sidewalk sneeze, so that droplets hit your face.	core	pathogen	Factor I
D018	You feel a dried booger on a hand rail on an escalator at the mall.	core	pathogen	Factor I
D019	You see an anti-drug ad featuring a bony man missing some of his teeth.	AR	pathogen	Factor IV
D020	You see a woman smiling broadly with a great deal of yellow plaque on her front teeth.	AR	pathogen	Factor V
D021	You feel muddy water sloshing against your pants as you walk through a swamp.	no code	no code	Factor VI
D022	You see a student claiming he wrote an essay that he secretly copied from his sibling.	moral	moral	Factor II

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D023	You see a sanitation worker heaving a greasy trash bag into the back of a garbage truck.	no code	no code	Factor VI
D024	You smell your neighbor as she walks by, because she almost never wears deodorant.	AR	pathogen	Factor I
D025	You accidentally squish a moist earthworm under your bare foot next to a public pool.	core	pathogen	Factor I
D026	You see a little girl pulling at a dark red scab on her knee until it bleeds.	AR	pathogen	Factor IV
D027	You smell the powerful scent of cat urine coming from a stain on the carpet.	core	pathogen	Factor I
D028	You see a picture online of a piece of bone emerging from a broken leg.	AR	pathogen	Factor IV
D029	You see a young woman at the store coughing loudly without covering her mouth.	core	pathogen	Factor V
D030	You watch a television show about parents who force their children to perform in pageants.	moral	moral	Factor II
D031	You smell the strong, floral perfume of the woman next to you in a movie theater.	moral	moral	no code
D032	You see a pile of yesterday's dishes in the sink, covered in dried tomato sauce.	core	pathogen	Factor VI
D033	You smell that your neighbor has just broken wind in the elevator next to you.	ambiguous	ambiguous	Factor I
D034	You see a child at the playground trying to cough up phlegm to amuse his friends.	core	pathogen	Factor V

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D035	You see a student's college application, padded with activities she had never really done.	moral	moral	Factor II
D036	You see a little boy picking his nose, looking at the booger, and then eating it.	core	pathogen	Factor I
D037	You feel a warm splat on your shoulder and realize that a bird has pooped on you.	core	pathogen	Factor I
D038	You see an online video of a hunter skinning the body of a deer he just shot.	AR	pathogen	Factor IV
D039	You put your hand on a counter and find that it leaves your fingers sticky.	no code	no code	Factor I
D040	You see your friend's new puppy throwing up all over the backseat of her car.	core	pathogen	Factor I
D041	You see a woman with greasy blonde hair that clearly hasn't been washed in days.	AR	pathogen	Factor V
D042	You use a brush to scrape the fecal matter off the sides of a toilet bowl.	core	pathogen	Factor I
D043	You hear your coworker go on and on about how his neighbors are low class.	moral	moral	Factor II
D044	You shake the hand of a new acquaintance and find her hand to be warm and clammy.	AR	pathogen	Factor V
D045	You see that your next-door neighbor has let his cat poop on your front walkway.	core	pathogen	Factor I
D046	You learn that a local politician lied about his intent to fulfill his campaign promises.	moral	moral	Factor II

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D047	You see a friend showing you an infected wound on her elbow that is oozing pus.	AR	pathogen	Factor IV
D048	You see a cotton swab with a huge amount of yellow, sticky ear wax in the wastebasket.	core	pathogen	Factor V
D049	You see a boy taking a piece of slimy pink gum and sticking it to a lamppost.	no code	no code	Factor V
D050	You see a woman dipping her half-eaten chicken wing in a public bowl of barbecue sauce.	core	pathogen	Factor I
D051	You learn that your colleague at work only has sex with women he pays to whip him.	AR	sex	Factor III
D052	You see a man living off the kindness of his roommates without ever giving anything back.	moral	moral	Factor II
D053	You see a man in a store slipping a DVD into his coat and leaving without paying.	moral	moral	Factor II
D054	You smell some rotting chicken that was put in the trash can days ago.	core	pathogen	Factor I
D055	You see a man who hasn't cleaned or trimmed his yellow, half-inch-long fingernails in months.	AR	pathogen	Factor I
D056	You see several roaches crawling on your friend's kitchen counter, close to a plate of food.	core	pathogen	Factor I
D057	You smell an untied garbage bag that was left in an alley on a hot day.	no code	no code	Factor I
D058	You sit down on a toilet and feel that someone left drops of urine on the seat.	core	pathogen	Factor I

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D059	You hear someone throwing up in the stall next to yours in the airport bathroom.	core	pathogen	Factor I
D060	You see a buffet plate at a restaurant piled high with a heap of steamed tentacles.	core	pathogen	no code
D061	You see an ad online that is clearly meant to scam elderly people out of their earnings.	moral	moral	Factor II
D062	You see a documentary where a botfly larva is being removed from beneath somebody's skin.	AR	pathogen	Factor IV
D063	You smell chicken soup that has been left in the communal refrigerator to spoil.	core	pathogen	Factor I
D064	You see a man at a dinner table blow his nose and then look at the tissue.	core	pathogen	Factor V
D065	You catch a strong whiff of the breath of the person you are talking to.	AR	pathogen	Factor I
D066	You hear the woman sitting next to you at a cafe burp with her mouth open.	no code	no code	Factor V
D067	You smell the odor of the vomit that you are cleaning up off the floor.	core	pathogen	Factor I
D068	You learn that a person you know can only be sexually aroused by looking at mannequins.	AR	sex	Factor III
D069	You see a man at the grocery store with a large crusty wart on his hand.	AR	pathogen	Factor V
D070	You see a man standing behind a gas station, urinating into a patch of grass.	core	pathogen	Factor III

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D071	You hear a woman at a party telling a story that involves a lot of scat humor.	core	pathogen	no code
D072	You see a picture in a medical textbook of a dark red, peeling third-degree burn.	AR	pathogen	Factor IV
D073	You see little white maggots crawling all over the underside of a decaying log.	core	pathogen	Factor I
D074	You smell the excrement that was left in the public toilet in front of you.	core	pathogen	Factor I
D075	You see a middle school girl making fun of her classmate's acne on social media.	moral	moral	Factor II
D076	You see someone leaving the restroom without washing their hands after they have pooped.	AR	pathogen	Factor I
D077	You learn that someone you know has been using stolen credit card information to buy things online.	moral	moral	Factor II
D078	You see your neighbor's son punching another kid while his friend films it on a smartphone.	moral	moral	Factor II
D079	You learn that a coworker of yours has been cheating on his wife through online dating apps.	ambiguous	ambiguous	Factor II
D080	You smell that the milk in the glass you are drinking from is spoiled.	core	pathogen	Factor I
D081	You learn that your neighbor has been arrested for beating his dog with a tire iron.	moral	moral	Factor II
D082	You see a woman leaning close to a mirror to pop a pimple on her chin.	AR	pathogen	Factor V

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D083	You see a medical video of a surgery being done on a patient's intestines.	AR	pathogen	Factor IV
D084	You see that the woman next to you on the bus is about to vomit on you.	core	pathogen	Factor I
D085	You see a man across from you at a restaurant laughing with his mouth full.	no code	no code	Factor V
D086	You see a brownish haze of air pollution hovering over the skyline of a nearby city.	no code	no code	Factor II
D087	You hear a young man talking about how he only enjoys having anonymous sex.	AR	sex	Factor III
D088	You see a friend of yours kneeling down and letting her pet dog lick her mouth.	AR	sex	no code
D089	You see fresh road kill, bloody and squished, lying on the side of the road.	AR	pathogen	Factor IV
D090	You see a man in a hospital lobby hacking up blood and mucus into a tissue.	AR	pathogen	Factor IV
D091	You see that your neighbor's septic tank has begun to leak sewage into the grass.	core	pathogen	Factor I
D092	You hear your neighbor's son claiming that he almost always urinates in the shower.	core	pathogen	Factor III
D093	You accidentally step on a patch of cat vomit, and feel that it is still warm.	core	pathogen	Factor I
D094	You see a snot bubble coming out of the nose of a sick child after he sneezes.	AR	pathogen	Factor V

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D095	You listen to a person clearing her throat repeatedly after she has been eating.	no code	no code	Factor V
D096	You see a great deal of hairy gunk that has been pulled out of a sink drain.	core	pathogen	Factor I
D097	You see a garbage bin with the lid up, with hundreds of flies swarming above it.	no code	no code	Factor I
D098	You see an empty condom wrapper on the floor of the elevator of a public building.	AR	sex	Factor III
D099	You see a man at a bar convincing a woman to have sex without a condom.	ambiguous	ambiguous	Factor III
D100	You hear a woman sitting on a park bench and very quietly having phone sex.	AR	sex	Factor III
D101	You read a news story about a man exposing his genitals to children near a public library.	ambiguous	ambiguous	Factor II
D102	You see a man at the bank looking at something on his smartphone and touching his crotch.	AR	sex	Factor III
D103	You hear a woman bragging about the extensive number of men she has slept with.	AR	sex	Factor III
D104	You hear a woman telling her date that she only enjoys anal penetration with dildos.	AR	sex	Factor III
D105	You watch a nature show about a parasitic wasp that lays its eggs inside a caterpillar.	AR	pathogen	Factor IV
D106	You see a close-up of a man's injured collarbone that dents visibly into his chest.	AR	pathogen	Factor IV

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D107	You see that your friend has accidentally hammered a nail partway into his thumb.	AR	pathogen	Factor IV
D108	You feel sweat on your armpits from commuting in a car during the middle of summer.	core	pathogen	Factor VI
D109	You see a woman using gestures to demonstrate to her friend how she masturbates.	AR	sex	Factor III
D110	You hear the town council voted on a raise for themselves when the homeless shelter needs funds.	moral	moral	Factor II
D111	You learn that your friend is spreading rumors that you didn't repay a debt you owed him.	moral	moral	Factor II
D112	You hear the couple sitting behind you in a movie theater making out and moaning during the previews.	AR	sex	Factor III
D113	You read an erotic message on a dating website from someone who you deeply disliked years ago.	AR	sex	Factor III
D114	You see a winged insect crawling along the edge of the coffee cup you are drinking from.	core	pathogen	Factor I
D115	You see a photograph of an open human chest cavity in a science textbook.	AR	pathogen	Factor IV
D116	You smell a pile of unwashed laundry on the floor in the corner of a bedroom.	AR	pathogen	Factor V
D117	You see a plate of glistening snails in garlic sauce at a fancy restaurant.	AR	pathogen	no code

Vignette number	Vignette text	Cultural evolution label	Adaptationist label	Data-driven label
D118	You see a large rat that is missing patches of skin running across the sidewalk.	core	pathogen	Factor I
D119	You see a tattooed teenager at the mall who has pierced a hole in her cheek.	core	pathogen	no code
D120	You smell the tobacco smoke wafting out of an ashtray overflowing with cigarette butts.	core	pathogen	no code

Appendix D: Vignettes used in Chapter 3 and Chapter 4

Condition name	Vignette
ARPATH/Mutilation	"You watch a training video for dental students about how to perform a root canal."
ARPATH/Mutilation	"You watch as your friend gets her tongue pierced and then inserts the plastic stud."
ARPATH/Mutilation	"You see a patient with a stomach valve open it up and insert a feeding tube."
ARPATH/Mutilation	"You see a close-up of a man's injured collarbone that dents visibly into his chest."
ARPATH/Mutilation	"You see a man in the ER with a hole in his throat for a trachaeotomy [sic] tube."
ARPATH/Mutilation	"You see a picture of a patient who had to have her lower jaw removed."
ARPATH/Mutilation	"You see that your friend has accidentally hammered a nail partway into his thumb."
ARPATH/Mutilation	"You see a documentary about a child who had to have his nose removed."
ARPATH/Mutilation	"You see a movie scene where a character loses his eye, leaving an empty socket."
ARPATH/Mutilation	"You see a tattooed teenager at the mall who has pierced a hole in her cheek."
ARPATH/Mutilation	"Your friend tells you she accidentally ripped her toenail off last week and shows you the toe."
ARPATH/Mutilation	"You see a grayish human hand preserved in a jar in a science classroom."

Condition name	Vignette
ARPATH/Mutilation	"You watch a video of eye surgery and watch the doctor make an incision in someone's cornea."
ARPATH/Mutilation	"You see the mangled face of somebody who has survived a bad car wreck."
ARPATH/Mutilation	"You see a picture in a medical textbook of a dark red, peeling third-degree burn."
ARPATH/Mutilation	"You see a photograph of an open human chest cavity in a science textbook."
ARPATH/Mutilation	"You see a video online of the amputation surgery of a leg with gangrene."
ARPATH/Mutilation	"You come across a picture online of a hand that was partially torn off at the wrist."
ARPATH/Mutilation	"You see someone at the beach who has stuck fish hooks through the skin on his back."
ARPATH/Mutilation	"You see a medical video of a surgery being done on a patient's intestines."
ARPATH/Mutilation	"You see a picture online of a piece of bone emerging from a broken leg."
ARPATH/Mutilation	"Your co-worker leaves early, because she picked at stitches on her forehead and opened the wound."
ARPATH/Mutilation	"You see someone fall, scraping her leg so badly that a flap of skin is hanging off."
ARPATH/Mutilation	"You see a documentary where a botfly larva is being removed from beneath somebody's skin."
ARSEX/Sex	"You hear a woman sitting on a park bench and very quietly having phone sex."
ARSEX/Sex	"You learn that your colleague at work only has sex with women he pays to whip him."

Condition name	Vignette
ARSEX/Sex	"You see a man secretly rubbing his girlfriend's thigh in a crowded public elevator."
ARSEX/Sex	"You hear a woman telling her date that she only enjoys anal penetration with dildos."
ARSEX/Sex	"You hear a young man talking about how he only enjoys having anonymous sex."
ARSEX/Sex	"You see a woman using gestures to demonstrate to her friend how she masturbates."
ARSEX/Sex	"You hear the pornographic video that your neighbor is listening to through the wall."
ARSEX/Sex	"You watch a news story about a man marrying a sex doll and going on a honeymoon."
ARSEX/Sex	"You hear a woman bragging about the extensive number of men she has slept with."
ARSEX/Sex	"You see an empty condom wrapper on the floor of the elevator of a public building."
ARSEX/Sex	"You see a man at the bank looking at something on his smartphone and touching his crotch."
ARSEX/Sex	"You see a man at a bar convincing a woman to have sex without a condom."
ARSEX/Sex	"You read an erotic message on a dating website from someone who you deeply disliked years ago."
ARSEX/Sex	"You hear your neighbor moaning at his girlfriend to let him call her Mommy."
ARSEX/Sex	"You learn that a person you know can only be sexually aroused by looking at mannequins."

Condition name	Vignette
ARSEX/Sex	"You hear the couple sitting behind you in a movie theater making out and moaning during the previews."
ARSEX/Sex	"You see a gray-haired elderly man nibbling on an eighteen-year-old girl's ear at the bar."
ARSEX/Sex	"You see a friend of yours passionately making out with an extremely old man."
ARSEX/Sex	"Your co-worker confides in you that she gets aroused by imagining having sex with her dad."
ARSEX/Sex	"Your friend gets a naked picture over text message from a very old woman."
ARSEX/Sex	"Your friend explains how she's been secretly dating her first cousin for three weeks."
ARSEX/Sex	"You hear about a teenage boy who masturbates to high-school-aged pictures of his mother."
ARSEX/Sex	"Your acquaintance describes how he used to watch his sister masturbate when he was thirteen."
ARSEX/Sex	"You see your acquaintance talking about why it's okay that he enjoys sleeping with his twin sister."
COREPATH/Body products	"You see a smear of dog feces that was tracked inside onto the carpet."
COREPATH/Body products	"You smell the powerful scent of cat urine coming from a stain on a lawn chair."
COREPATH/Body products	"You smell the odor of the vomit that you are cleaning up off the floor."

Condition name	Vignette
COREPATH/Body products	"You are changing a baby's diaper and find that it is filled with feces."
COREPATH/Body products	"You see a cotton swab with a huge amount of yellow, sticky ear wax in the wastebasket."
COREPATH/Body products	"You see your friend's new puppy throwing up all over the backseat of her car."
COREPATH/Body products	"You see a jar full of old, bubbly saliva at a modern art exhibit."
COREPATH/Body products	"You see a crumpled-up tissue in the wastebasket, covered with stringy, wet mucus."
COREPATH/Body products	"You see a brown streak of excrement on the floor of a public restroom."
COREPATH/Body products	"You see a great deal of hairy gunk that has been pulled out of a sink drain."
COREPATH/Body products	"You hear someone throwing up in the stall next to yours in the airport bathroom."
COREPATH/Body products	"You see a stewardess disposing of a used barf bag as you get off an airplane."

Condition name	Vignette
COREPATH/Body products	"You see a puddle of urine seeping in between the tiles in a public restroom."
COREPATH/Body products	"You feel a dried booger on a hand rail on an escalator at the mall."
COREPATH/Body products	"You see a preschool teacher cleaning her student's vomit off her skirt with a paper towel."
COREPATH/Body products	""You see that your neighbor's septic tank has begun to leak sewage into the grass."
COREPATH/Body products	"You use a brush to scrape the fecal matter off the sides of a toilet bowl."
COREPATH/Body products	"You see some diarrhea floating on the water of the toilet in the restaurant bathroom."
COREPATH/Body products	"You accidentally step on a patch of cat vomit, and feel that it is still warm."
COREPATH/Body products	"You see the janitor cleaning up a small patch of yellowish vomit in the bathroom corner."
COREPATH/Body products	"You feel a warm splat on your shoulder and realize that a bird has pooped on you."

Condition name	Vignette
COREPATH/Body products	"You sit down on a toilet and feel that someone left drops of urine on the seat."
COREPATH/Body products	"You smell the excrement that was left in the public toilet in front of you."
COREPATH/Body products	"You walk into a hotel bathroom and find that the toilet is covered in vomit."
MORAL/Moral	"You see a special education teacher mocking her student's speech impediment for her friends."
MORAL/Moral	"You see a student claiming he wrote an essay that he secretly copied from his sibling."
MORAL/Moral	"You see a student's college application, padded with activities she had never really done."
MORAL/Moral	"You hear a woman commenting out loud about how fat another woman looks in her jeans."
MORAL/Moral	"You hear a boy telling a woman that she looks just like her overweight bulldog."
MORAL/Moral	"You see a man living off the kindness of his roommates without ever giving anything back."
MORAL/Moral	"You learn that your friend is spreading rumors that you didn't repay a debt you owed him."
MORAL/Moral	"You see a middle school girl making fun of her classmate's acne on social media."
MORAL/Moral	"You learn that a local politician lied about his intent to fulfill his campaign promises."

Condition name	Vignette
MORAL/Moral	"You see a man in a store slipping a DVD into his coat and leaving without paying."
MORAL/Moral	"You hear a woman calling her young son a sissy when he starts crying after hurting himself."
MORAL/Moral	"You see a zoo trainer jabbing a dolphin to get it to entertain his customers."
MORAL/Moral	"You watch a television show about parents who force their children to perform in pageants."
MORAL/Moral	"You learn that someone you know has been using stolen credit card information to buy things online."
MORAL/Moral	"You hear your coworker go on and on about how his neighbors are low class."
MORAL/Moral	"You see a girl shooting geese repeatedly with a pellet gun out in the woods."
MORAL/Moral	"You see an ad online that is clearly meant to scam elderly people out of their earnings."
MORAL/Moral	"You see a teenage boy chuckling at an amputee he passes by while on the subway."
MORAL/Moral	"You see your neighbor's son punching another kid while his friend films it on a smartphone."
MORAL/Moral	"You overhear a man bullying his wife out of ordering dessert at a restaurant."
MORAL/Moral	"You learn that your former classmate left her child in a hot car for an hour."
MORAL/Moral	"You see a boy setting a series of traps to kill stray cats in his neighborhood."

Condition name	Vignette
MORAL/Moral	"You learn that your neighbor has been arrested for beating his dog with a tire iron."
MORAL/Moral	"You see a judge taking on a criminal case although he is friends with the defendant."
NEUTRAL	"You see a man give a woman her purse back after she forgot it on a bench."
NEUTRAL	"You see a man helping his young daughter tie her shoelace in a park."
NEUTRAL	"You smell the fresh fruit that you have just put on your plate to eat."
NEUTRAL	"You see your relative switch on the turn signal of her car while giving you a ride."
NEUTRAL	"You see a butterfly with black, orange, and blue wings land on the trunk of a tree."
NEUTRAL	"You see a shiny, modern faucet in the bathroom of an upscale hotel."
NEUTRAL	"You see a woman comparing different shampoos in the bath aisle of a grocery store."
NEUTRAL	"You see the obituary of a respected man in town, with a list of his accomplishments."
NEUTRAL	"You feel sand under your feet while you walk on the beach in the summer."
NEUTRAL	"You see a woman open a car door and help her child unbuckle his seatbelt."
NEUTRAL	"You see a deer grazing on a patch of grass next to the highway."
NEUTRAL	"You see a magazine ad for jewelry featuring a bracelet on a hand with smooth skin."

Condition name	Vignette
NEUTRAL	"You see a young doctor in a lab coat working on new medicine for tuberculosis."
NEUTRAL	"You learn that two people you knew in high school are engaged to be married to each other."
NEUTRAL	"You smell baby powder in a nursery where a newborn child is sleeping."
NEUTRAL	"You watch a chef wash her hands thoroughly before beginning to prepare food."
NEUTRAL	"You see a man with neatly styled hair walking into an office building."
NEUTRAL	"You hear your neighbor's daughter squealing with delight over how her newly pierced ears look."
NEUTRAL	"You see a stack of folded shirts that have just been washed and dried."
NEUTRAL	"You feel the sun warm your face very early on a brisk spring morning."
NEUTRAL	"You hear a man happily congratulate his friend for her promotion at work."
NEUTRAL	"You see your neighbor riding his new bicycle to work on a paved trail."
NEUTRAL	"You hear a teacher giving a spelling lesson to a classroom of students."
NEUTRAL	"You see a woman put a piece of paper in a recycling bin as she leaves an event."
NEUTRAL	"You overhear a married couple discussing their plans to have a baby in the future."
NEUTRAL	"You see a college student kindly taking care of her roommate who doesn't feel well."

Condition name	Vignette
NEUTRAL	"You smell the fresh scent of pine at a campground in a nearby state park."
NEUTRAL	"You taste the first spoonful of your favorite soup at a local lunch restaurant."
NEUTRAL	"You feel the fluffy material of your friend's new rug under your bare feet."
NEUTRAL	"You see flowers and grass growing at the edges of a road in the countryside."
NEUTRAL	"You see an elderly woman at the bank politely coughing into a lace handkerchief."
NEUTRAL	"You hear a high school student helping his friend with his homework."
NEUTRAL	"You see the new concrete of a sidewalk that was recently built."
NEUTRAL	"You see your neighbor walking his new puppy on a hiking trail."
NEUTRAL	"You see two people smile and shake hands to greet each other."
NEUTRAL	"You feel a polished stone counter top in a newly built house."

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Biography

Eleanor Hanna graduated from the University of North Carolina at Chapel Hill with a Bachelor of Arts in Psychology and Anthropology in 2010. She entered the Duke University doctoral program in Psychology and Neuroscience through the Cognitive Neuroscience Admitting Program and was advised by Drs. Kevin LaBar and Walter Sinnott-Armstrong. She attained a Master of Arts in Psychology and Neuroscience from Duke University in 2016. Her work has been published in such journals as *Cognition and Emotion* and *Psychological Science.* She was a Biosciences Collaborative for Research Engagement Fellow (2013-2019), received a National Science Foundation Graduate Research Fellowship Honorable Mention in 2015, and was the 2018-2019 Phillip Jackson Baugh Fellow for Ph.D. students in Anthropology, Economics, Psychology, and Sociology.

Publications

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