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Psychophysiological Responses to Disgust: Cardiovascular and Facial Muscle Patterns Associated with Different Functional Domains

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PSYCHOPHYSIOLOGICAL RESPONSES TO DISGUST: CARDIOVASCULAR AND FACIAL MUSCLE PATTERNS ASSOCIATED WITH DIFFERENT FUNCTIONAL DOMAINS

By

Robert Oum

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Psychophysiological Responses to Disgust: Cardiovascular and Facial Muscle Patterns Associated with Different Functional Domains

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This study examined the distinguishing physiological characteristics of the disgust reaction across different domains. According to an evolutionary analysis, disgust is a heterogeneous emotion with features that are specific to three distinct domains: pathogens, sex, and morality. Each domain is predicted to take as input information specific to the adaptive problem it evolved to solve and regulate behavior accordingly. The goal of the present study was to investigate whether there are any adaptive physiological differences associated with the disgust response across domains. Participants were asked to imagine acts that elicit pathogen, sexual, and moral disgust. It was hypothesized that there would be both quantitative and qualitative differences in the physiological reactions based on the appropriate functional outputs for the social (moral and sexual) and nonsocial (pathogen) domains. Individual differences in self-report ratings of disgust as well as the role of religiosity in regulating social disgust were also explored. Results showed significant differences in parasympathetic influences on the heart in response to the sexual stimuli but not to the other domains. Also, the self-report ratings showed that females were more sensitive than males to the sexual stimuli but not to pathogens or moral acts. These results lend further support to the dissociation between

the functional domains of disgust. Correlations between levels of religiosity and both subjective ratings of fear towards pathogens and *levator labii* activation when viewing pathogen stimuli were found. This study provides preliminary evidence of dissociations between different domains of disgust and provides a methodological guideline which can help inform future studies of disgust. Implications of the current findings are discussed, as well as limitations of the current methodology and avenues for further exploration.

DEDICATION

This dissertation is dedicated to:

My family, you have provided me with so much throughout my life.

My friends, I am so lucky to have the greatest friends in the world.

And to everyone who has ever taken an extra second to show they care.

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Chapter 1: Introduction

The last two decades have seen a proliferation of research on disgust. Recent studies have identified a number of distinct behavioral, physiological, and neurological patterns associated with the subjective feeling of disgust (Curtis, Aunger, & Rabie, 2004; Moll et al., 2005; Schaich Borg, Lieberman, & Kiehl, 2008; Schnall, Haidt, Clore, & Jordan, 2008; Stark, Walter, Schienle, & Vaitl, 2005; Vrana, 1993; Vrana & Lang, 1990). A wide range of stimuli have been used in these studies as disgust elicitors, ranging from vomit to incest to child abuse. This diversity of stimuli has led many researchers to put forth theoretical models that attribute domain-general functions to disgust (see Miller, 2004). Here, I will use an evolutionary framework to examine the structure of disgust and use a functional analysis to suggest that disgust operates in functionally discrete domains which predict distinct physiological markers.

A history of disgust

Disgust has long been accepted as one of the most basic and primitive emotions. In his seminal work *The Expression of the Emotions in Man and Animals*, Charles Darwin described disgust as "something revolting, primarily in relation to the sense of taste, as actually perceived or vividly imagined" (1872, p. 253). Disgust has since been identified by Paul Ekman as one of the primary emotions, seen across all cultures and associated with a universal facial expression (1993). Similarly, in Robert Plutchik's circumplex model, disgust is classified as one of the primary bipolar emotions (in opposition to acceptance; 1960). Other emotion researchers have focused on identifying and studying the possible functions of disgust, often linking it to the rejection of contaminated or bad-tasting food (Angyal, 1941; Frijda, 1986; Tomkins, 1963). More

recently, they have extended the concept of disgust to include not only the response to foods, but also to stimuli such as child abuse and incestuous relationships (Haidt, McCauley, & Rozin, 1994; Tybur, Lieberman, & Griskevicius, 2009).

The commonality across all of these models is that disgust is defined as an emotion that motivates avoidance of unpleasant stimulation. However, disgust, can be elicited by a great number of varied stimuli. In a recent study, Joshua Tybur and colleagues (2009) found that when college students were asked to list things that disgust them, answers ranged from stepping in dog feces to illegal immigrant workers to having sex with a significantly older person. Recently, researchers have been focusing on differences in the reaction to the various elicitors as a tool in understanding the structure of disgust (Haidt et al., 1994; Olatunji et al., 2005; Schaich Borg et al., 2008; Schnall et al., 2008; Tybur et al., 2009). One approach has generated a model of disgust that suggests there are three adaptive domains: pathogen disgust, sexual disgust, and moral disgust.

Pathogen disgust

Disgust is an aversive emotion that motivates avoidance behavior in response to a number of different stimuli. It is generally agreed that disgust is a primitive emotion with a long evolutionary history and originally served to prevent the oral ingestion of potentially infectious substances (Angyal, 1941; Darwin, 1872/1998; Ekman & Freisen, 1975; Rozin & Fallon, 1987; Tomkins, 1963). Infectious organisms have long been a major part of the evolutionary landscape, and their impact may be seen in innumerous epidemics and extinctions (Diamond, 2005), and perhaps even in the evolution of sexual reproduction itself (Bell, 1982; Bremermann, 1980; Hamilton, 1980; Jaenike, 1978;

Tooby, 1982). These infectious organisms would have represented a strong and recurrent threat to the survival of their hosts, and defenses against these agents would have been favored by natural selection. Clear evidence for such defenses can be seen in the complexity and specificity of the human physiological immune system. Similarly, the emotion of disgust may be thought of as a behavioral immune response, motivating withdrawal from potential sources of infection (Schaller, 2006; Schaller & Duncan, 2007). Several studies have shown that stimuli possessing cues that are more likely to be indicative of pathogen presence elicit greater disgust responses in both laboratory and naturalistic settings (Curtis et al., 2004; Oum, Lieberman, & Aylward, in press).

The function of disgust as a pathogen avoidance mechanism is widely accepted and fairly non-controversial in field. Most taxonomies of disgust have at least one factor or domain that closely parallels pathogens. The predominant model today, espoused by Haidt and colleagues, includes a domain that they call "core disgust," where disgust functions to prevent the body from coming into contact with offensive objects (Haidt, McCauley, & Rozin, 1994; Haidt, Rozin, McCauley, & Imada, 1997; Olatunji et al., 2007; Rozin, Haidt, & McCauley, 2000). Another of their proposed domains, animal reminder disgust, also contains elements of pathogen-related aversions (e.g., poor hygiene, dead bodies).

If disgust was a well-designed behavioral immune system, it would activate cognitive, behavioral, and physiological processes that would withdraw the individual from the elicitor to lessen infection risk. The physiological processes in this particular domain of disgust should exhibit features that are functionally designed to reduce exposure to pathogens. In fact, the stereotypical facial reaction associated with disgust

contains features that are thought to reduce the likelihood of exposure to pathogens: crinkling of the nose and narrowing of eyes (Ekman & Friesen, 1978).

Sexual Disgust

Independent of pathogen-related elicitors, various sexual stimuli have also been linked to disgust (Tomkins, 1963; Tybur et al., 2009; Westermarck, 1881/1921). Choosing appropriate sexual partners is an adaptive problem that is functionally distinct from pathogen avoidance. Selection of sexual partners carries with it a unique set of risks and consequences that are different from those that are associated with pathogen infection. While sexual encounters do entail a risk of infection due to pathogen exposure, they are also associated with other distinct fitness consequences. A poor mating choice can result in lost opportunity costs for better matings, and, in the case of females, an unwanted pregnancy. Thus, choosing a sexual partner requires an assessment of others' mate value according to a number of different criteria.

Of particular interest here, many of the criteria that are associated with low mate value are often linked with disgust reactions within the mating context. These criteria can be both objective and subjective relative to the individual making the judgment. The objective criteria are associated with low mate values across all individuals. Features such as body and facial asymmetry, poor complexion, or obesity, for example, are universally seen as unattractive, presumably because they are indicative of pathogen infection or developmental instability (Manning, Trivers, Singh, & Thornhill, 1999; Moller & Thornhill, 1998, Perrett et al., 1999). The subjective criteria refer to qualities that are relative in terms of genetic compatibility. Mating with close kin may decrease the health and quality of offspring as it increases the probability of homozygous recessive

alleles (Adams & Neel, 1967; Bittles & Neel, 1994). Disgust within the sexual domain is linked with both objective and subjective indicators of low mate value, (Lieberman, Tooby, & Cosmides, 2003). Individuals that display these indicators are likely to be poor mate choices as they will incur costs inherent with less healthy offspring. While day-to-day social interactions with these individuals may not elicit disgust, potential sexual interactions with them may do so, even when pathogen-related disgust is low. Thus, I predict that sexual disgust operates independently of pathogen disgust.

While a pathogen avoidance system would have features designed to lessen infection risk, sexual disgust would have its own unique features designed to motivate avoidance of particular individuals as sexual partners. Identifying a low value mating partner is a distinct problem from avoiding pathogens, requiring its own set of functional inputs. Cues that are indicative of mate value are often irrelevant for the purposes of pathogen avoidance. Whereas some cues such as maternal perinatal association and human leukocyte antigen similarity have been shown to be cues used in kin detection, and therefore sexual avoidance, they would have no bearing on pathogen detection (Lieberman et al., 2003; Lieberman, Tooby, & Cosmides, 2007; Tybur et al., 2009; Wedekind & Furi, 1997; Wedekind, Seebeck, Bettens, & Paepke, 1995). Similarly, while both of these systems may activate the felt emotion of disgust, the appropriate behavioral output motivated by each type of elicitor would differ. While pathogen detection would lead to a more general avoidance reaction (since disease can be communicated through many modes), sexual disgust would lead to avoidance only within the sexual realm. As the function of disgust within the sexual domain requires very specific behavioral

outputs, I predict the physiological systems activated by sexual disgust would be well-designed for sexual avoidance.

Moral Disgust

Finally, the third domain predicted for disgust is the moral domain, which would address another unique set of selection pressures distinct from both pathogen avoidance and selection of mating partners. Separate from pathogen- and sex-related disgust, many social transgressions have been found to elicit disgust. Numerous studies have shown that certain acts within the moral sphere, such as spousal abuse or infanticide, elicit a felt sense of disgust (Haidt et al., 1994; Haidt et al., 1997; Jones & Fitness, 2008; Nabi, 2002; Tybur et al., 2009). In highly social populations, engaging in these types of behaviors imposes costs on other individuals in the social network. Being associated with these actions, and with those who engage in these actions, can lead to significant reputational damage since cooperation and cohesion is important in networked societies where individuals are extremely interdependent. In an apropos analogy, Curtis and Biran (2001) consider social trangressors to be "social parasites" and liken them to the physical parasites discussed earlier. Thus, avoidance of these behaviors would have constituted a significant selection pressure in highly social societies.

Whether the emotion that is elicited by witnessing acts such as physical abuse, cheating, or homicide is actually disgust has been a subject of recent debate. Some argue that rather than eliciting "true" disgust, the label of disgust is rhetorically applied to a felt sense of anger (Bloom, 2004; Nabi, 2002). Converging lines of research, however, seem to indicate that these moral stimuli are processed through some of the same cognitive and neurophysiological pathways as pathogen-related disgust stimuli. In a recent study,

Schnall and colleagues (2008) elicited pathogen disgust using a fart spray and found that moral judgments become harsher as a function of the intensity of the smell, indicating an implicit link between the two. Similarly, two recent neurological studies have shown that both pathogen-related and morality-related stimuli activate the neural regions that are commonly associated with disgust, such as the basal ganglia, amygdala, and thalamus (Moll et al., 2005; Schaich Borg et al., 2008). These findings support the notion that the emotion of disgust is actually elicited by moral transgressions, rather than just being a rhetorical label.

Since the risk of being associated with moral transgressions is distinct from the risks of pathogen infection, different design features would be associated with a moral disgust system. A separate set of cues would be used to judge the morality of social transgressions, which would trigger behavioral outputs separate from pathogen or sexual disgust. Again, as moral disgust requires specific adaptive behaviors, the underlying physiology should reflect this functional design.

Previous support for the functional analysis

Recent self-report studies lend support to the idea that the three domains above are distinct and dissociable. In a series of four studies, Joshua Tybur and colleagues (2009) used self-report measures and factor-analytic methods to partition disgust sensitivity into the functional domains as described above. Furthermore, they used their findings to develop a new measure of disgust sensitivity, the Three Domain Disgust Scale, which takes into account the functional domains in which disgust operates. This study, however, only assesses the subjective experience of disgust, and not the underlying biology.

Neurobiology of disgust

Since the subjective experience of emotions has historically been the focal point of the discussion of emotions, less is known about the biology of the disgust. Recently, however, the biology of disgust has been increasingly studied using the latest neurological techniques available (Ekman, Levenson, & Friesen, 1983; Rohrmann et al., 2004; Stark et al., 2005; Vrana, 1993). Neuroscientists have made great strides in understanding how disgust, as well as other emotions, is represented in the brain. By studying populations with disgust impairments, clinical neuroscientists have started to identify specific brain regions that are associated with the disgust reaction. Parkinson's patients have shown impairments stemming from the basal ganglia-insula system (Carlsson & Carlsson, 1990; Obeso et al., 2000). Patients with obsessive-compulsive disorder have shown impairments in the caudate nucleus and insula (Mataix-Cols et al., 2004; Robinson et al., 1995; Scarone et al., 1992; Shapira et al., 1993). The subjective feeling of disgust has also been correlated with increased activity in the basal ganglia and thalamus in healthy populations (Moll et al., 2005; Schaich Borg et al., 2008).

A recent study using functional magnetic resonance imaging (fMRI) to examine disgust found dissociations that fit well with the functional domains discussed above. Schaich Borg and colleagues (2008) showed that while imagining pathogen, sexual, and moral disgust all activated common neural regions associated with disgust, there were also distinct brain regions that were dissociable between these domains when stimuli pertained to siblings. Similarly, Moll and colleagues (2005) have used fMRI methods to find that pathogen-related disgust ("pure disgust") and moral indignation activate mostly overlapping neural regions, but with key differences in the frontal and temporal lobes.

Converging evidence also comes from dissociations in sensitivities in pathogen and sexual disgust in individuals with specific brain lesions (Calder et al., 2001). The primary goal of this study is to explore whether the physiological correlates of disgust vary according to the functional domains of the elicitors.

Psychophysiology of disgust

The behaviors associated with disgust are ultimately caused by the neurological changes by way of the physiological response. While understanding the neurobiology of disgust sheds light on the brain processes underlying behavioral responses, it is a few steps detached from the behavioral component of the disgust response. Analysis of the physiological response gives a more proximate account of how the disgust response influences the action of biological processes.

To date, very few studies have specifically examined the psychophysiology of disgust reactions. Most of the previous physiological work that has touched on disgust groups it together with the other negative emotions, namely, fear and anger. A number of studies showed that negatively-valenced stimuli, including those believed to elicit disgust, lead to a greater startle response when compared to positively-valenced or neutral stimuli, as indexed by a greater magnitude and shorter latency of the eyeblink (Grillon, Ameli, Woods, Merikangas, & Davis, 1991; Vrana, Spence, & Lang, 1988).

Only more recently, a handful of studies have examined the startle reflex specifically in response to disgusting stimuli, but the conclusions drawn have largely been indistinguishable from other emotions. Vrana (1994), for example, showed greater startle reflexes when participants were imagining disgusting scenarios than when imagining neutral scenarios, but no differences were found when disgust was compared

to anger-inducing scenarios. Similar results have been found with disgusting pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001; Stanley & Knight, 2004; Yartz & Hawk, 2002) and noxious odors (Ehrlichman, Brown, Zhu, & Warrenburg, 1995; Kaviani, Wilson, Checkley, Kumari, & Gray, 1998; Miltner, Matjak, Braun, Diekmann, & Brody, 1994). While all of these studies have shown robust physiological correlates of disgust, they have been unsuccessful in distinguishing it from other negative emotions.

Negative emotions have also been indexed by EMG activity at the *corrugator supercilii* and *levator labii* muscle regions of the face. The *corrugator* muscle lies above the eye and tightens the eyebrows. Like the startle reflex, *corrugator* activity shows increased activity when viewing disgusting pictures and when imagining disgust scenarios, but again, this activity cannot be differentiated from anger or most of the other negative emotions (Bradley et al., 2001; Hamm, Cuthbert, Globisch, & Vaitl, 1997). One study, however, showed that *corrugator* activity was greater when viewing disgust-inducing pictures compared to fear-inducing pictures (Yartz & Hawk, 2005).

The *levator labii superioris* is a muscle that extends from the orbits of the eyes to the upper lips beside nose. *Levator* contraction crinkles the nose, elevating the upper lip and closing the nostrils. In contrast to the *corrugator,* the *levator* muscle has shown to be specifically sensitive to disgust (Scheinle, Star, & Vaitl, 2001; Vrana, 1994; Yartz & Hawk, 2002). When asked to imagine disgusting scenarios, participants exhibited greater *levator* activity when compared to not only the joyful scenarios, but also to anger-inducing scenarios (Vrana, 1994). This study was the first to show a specific pattern of EMG activity in response to disgust that is distinct from other negative emotions, and

subsequent studies have replicated this dissociation using disgusting pictures (Schienle et al., 2001; Stark, Walter, Scheinle, & Vaitl, 2005).

Disgusting stimuli have also been shown to decrease heart rate, but again, this response has not been differentiated from other negative emotions (Levenson et al., 1990; Stark et al., 2005). Other cardiovascular studies specifically examining disgust have been scarce and inconclusive. To my knowledge, only two studies have specifically investigated cardiovascular correlates of disgust, and both found that disgust had no effect on blood pressure (Rohrman & Hopp, 2008; Schienle et al., 2001). Rohrman and Hopp (2008) did find differences in participants' heart rate variability (HRV), pre-ejection period to left ventricular ejection time ratio (PEP/LVET), stroke volume (SV), and peripheral resistance when viewing disgust-inducing films as compared to neutral films. Even these differences, however, were not always consistent across their disgust films, all of which were pathogen-related. To my knowledge, no studies to date have examined domain-specific physiological correlates of disgust. The main purpose of this study is to explore how physiological patterns compare between the different disgust domains.

The impact of religiosity on disgust reactions

Although each domain of disgust is proposed to have been shaped over human evolutionary history, the reaction itself may be influenced by modern cultural factors in some or all of the domains. That is, culture may interact with the innate response to calibrate the reaction to the local environment. For pathogen-related disgust, regular exposure to certain stimuli without adverse consequences may render the stimulus safe, even if it has the stereotypical cues to pathogen presence. The social domains may also

have different cultural factors that calibrate the disgust response. One cultural factor that has a particularly large role in maintaining social order in modern society is religion. Many, if not most, of the world's religions derive some sort of morality from their central ideas, which may be used in conjunction with social disgust to govern aspects of social behavior. One may then expect that the social disgust reaction would be affected by religion. A secondary purpose of this study is to examine how religiosity may affect both the subjective feeling of disgust towards the social stimuli, but also the physiological response associated with it.

The current study

According to the functional analysis presented above, disgust is predicted to motivate different behavioral actions when examined across the domains of pathogens, sex, and morality. Research participants were presented with stimuli that have previously been shown to evoke disgust in each of the domains. Physiological recordings were then taken from these participants and analyzed to ascertain whether the physiological correlates of disgust vary according to the domain of the stimuli. Subjective self-report ratings of the stimuli were also assessed. As self-reports of emotions are essentially semantic evaluations of the subjective experience, there may be a mismatch between the subjective report of disgust and physiological markers of the disgust reaction. Finally, individual differences that are expected to predict differences in disgust sensitivity both across and between domains, such as religiosity and sex, were explored via self-report questionnaires.

Predictions

Since the different domains of disgust require different behavioral actions, situations from each domain will have distinct task demands to prepare the body for the behavior appropriate to the specific situation. Therefore, I predict that, when all measures are taken into account together, the physiological pattern of activation of each domain of disgust will fit the behavioral output required by each. Despite the differences in adaptive function that were discussed earlier, predicting the physiological functioning entails a different level of analysis, and I expect that the sexual and moral domains would work in much the same way physiologically. The appropriate behavioral response in each case is a withdrawal from other people, so both domains can be seen as social avoidance mechanisms. While the adaptive function differs, the behavioral output for moral and sexual disgust would be the same, and both are expected to be distinct from pathogen disgust, which does not involve the avoidance of social interactants. So for the current study, the reactions associated with moral and sexual disgust, the social disgusts, will be combined and contrasted with pathogen, or non-social disgust. This study uses a number of different measures to delineate the differences of physiological functioning between the socially-relevant (moral and sexual) and nonsocially-relevant (pathogen) domains of disgust described above.

Since the socially-relevant disgust stimuli may motivate more active behaviors for social avoidance, more sympathetic activation is predicted for the moral and sexual stimuli than for the pathogen stimuli. Conversely, the nonsocially-relevant stimuli may require a greater down-regulation of the parasympathetic nervous system. Accordingly, I make the following predictions:

H_1: *Pathogen vs. baseline*

Exposure to the pathogen-related stimuli is expected to activate the sympathetic nervous system to mobilize the skeletal muscles for active avoidance of sources of infection. In a complementary manner, the parasympathetic nervous system is expected to be down-regulated as parasympathetic functions (e.g., salvation, digestion, defecation) would be unneeded or perhaps harmful. Therefore, I expect an increase in the markers of sympathetic action (PEP, LVET) during exposure to pathogen-related disgust elicitors and a decrease in the marker of parasympathetic action (RSA).

In regards to the facial muscles, the contraction of the *levator labii* has consistently been identified as part of the stereotypical disgust reaction across cultures. This muscle action is thought to both prevent entry of pathogens into the body and allow the expulsion of infectious agents during exhalation. The *lateral frontalis*, on the other hand, has been more strongly linked with the emotion of anger, and it is thought to serve a social function in signaling anger to others. Thus, I predict that pathogen disgust will increase the activation of the *levator labii* when compared to baseline, while having no effect on the *lateral frontalis* since it does not reduce the likelihood of infection.

H_2: *Social vs. baseline*

Exposure to the social stimuli should also activate the sympathetic nervous system and deactivate the parasympathetic nervous system. Similar to the pathogen stimuli, the social stimuli are expected to lead to a mobilization response to allow active avoidance of social disgust elicitors. Thus, like the pathogen response, exposure to the social stimuli should increase the markers of sympathetic action and decrease the marker of parasympathetic action.

Unlike the pathogen response, communication of emotions via the facial response should be an important part of the social disgust response. Activation of the *levator labii* could not only prevent ingestion of pathogens, but it could also serve as a signal to others that something objectionable is present. Similarly, the outward expressions of emotions can be a valuable signal of the internal state of the expressor. Thus I expect that the social disgust elicitors will lead to greater activation of both the *levator labii* and *lateral frontalis* when compared to baseline, as part of a social function in conveying internal states to others.

Probing further within the social domain, the moral stimuli are also expected to elicit anger as well as disgust, since both have been identified as moral emotions. As the *lateral frontalis* muscles have been strongly linked to anger, especially high activation of these muscles are expected when viewing the moral stimuli when compared to the sexual stimuli.

H_3: *Pathogen reactivity vs. social reactivity*

Although the responses to pathogen and social stressors are predicted to be in the same direction, the specific behavior required for each should still differ quantitatively according to the functional demands of each domain. Avoidance of social disgust, for example, is expected to require a more active reaction than avoidance of pathogens, where even passive avoidance may suffice when the disgust elicitor is inanimate (i.e., not drinking the spoiled milk as opposed to actively running away from it). Social disgust elicitors, however, will by definition be animate and require an active avoidance reaction. Thus, it is predicted that social disgust elicitors are more likely to require more mobilization, and thus sympathetic reactivity is expected to be greater in response to

social disgust than reactivity in response to pathogen disgust. Conversely, parasympathetic measures are expected to be greater in response to pathogen disgust, since a passive avoidance can be sufficient.

When compared to the pathogen disgust response, the reactivity of the social disgust response is expected to have a stronger expressive component in order to communicate the internal state to others. Thus I expect the social stimuli to lead to a greater relative activation of both facial muscles when compared to the pathogen stimuli.

H_4: *Sex differences*

Although elicitors of disgust have consequences for both sexes, many times the costs appear to be greater for females. The costs of a poor mating, for example, are vastly greater for females as they risk the investment of pregnancy and gestation, as well as greater opportunity costs lost for future matings. Therefore, I expect that females will exhibit greater levels of disgust on both the self-report and physiological measures. The magnitude of these differences, however, is expected to vary between the domains, since each might entail different fitness costs between the sexes. As stated above, females would incur a greater cost for choosing a poor sexual partner, but the cost of a pathogen infection may be more similar for males. I expect, then, that differences in disgust sensitivity would be greater in response to the social stimuli, driven by the sexual domain, than for the pathogen stimuli.

H_5: *Self-report ratings of disgust*

A positive correlation is predicted between self-report ratings of disgust and the magnitude of physiological reactions. That is, participants who give higher self-report

ratings for each domain of disgust are expected to show greater physiological disgust reactions within those domains.

H_6: *Religiosity*

As religion is thought to promote social order, a positive correlation is predicted between levels of religiosity and the self-report ratings of disgust within the social domain. In parallel, a positive correlation is also expected between religiosity and the magnitude of the physiological reactions in the social domain.

Chapter 2: Methods

Participants

All procedures were approved by the Institutional Review Board of the University of Miami. Ninety-eight research participants (70 females, 28 males) were recruited from undergraduate introductory psychology courses at the University of Miami. All students aged 18 or over were eligible to participate. Participants' ages ranged from 18-25 (M = 18.7 ± 1.3). Students were compensated for their participation with course credit.

Experimental procedure

After signing a consent form, participants were asked to wash their hands with mild hand soap, and then physiological recording equipment was attached to each participant as will be outlined below. Once this was completed, participants sat in a recliner approximately 6' from a 42" high definition LCD television. First, a 10-minute relaxation video depicting underwater wildlife scenes was shown. After the viewing the baseline video, participants viewed one of three series of written statements describing acts that have been found to be disgusting in previous studies (Oum & Lieberman, unpublished data; Tybur et al., 2009). Each series of acts contained stimuli pertaining to one of the domains as described above (See Appendix A). Each written act was presented onscreen for six seconds, with no inter-stimulus interval between the acts. After the first set of acts was viewed, participants were shown the same 10-minute relaxation video to return participants to baseline physiology levels. The remaining two sets of acts were then presented, with relaxation videos again following each. The order of the series of stimuli was counter-balanced, and the order of the acts within each set was randomized for each participant. Once the stimulus presentation was complete, the physiological

recording equipment was detached from the participants, and they were given a pen-and-paper questionnaire asking for subjective ratings of the stimuli, demographic information, and measures of religiosity.

Stimuli

Items from the Three Domain Disgust Scale (TDDS; Tybur et al., 2009) were used as written stimuli for presentation. In their initial validation, the individual items had been selected for their moderation and variability. A high internal consistency was found for each of the subscales (pathogen disgust = 0.84; sexual disgust = 0.87; moral disgust = 0.84; Tybur et al., 2009). Internal consistency for each of the subscales remained high for the current participants (pathogen disgust = 0.83; sexual disgust = 0.86; moral disgust = 0.94). For the current study, five items were added to each domain which have been shown to elicit more extreme reactions (Oum and Lieberman, unpublished data; see Appendix A for the full set of stimuli). While most previous research in the area has used pictorial stimuli, written stimuli allowed for a more consistent comparison of the disgust manipulation between the different domains. Since the nature of the cues to each of the domains differs, some of the cues, particularly in the moral domain, would have been difficult to represent pictorially.

Measures

Physiological readings were recorded continuously and digitized using a BioNex mainframe and amplifier system and BioLab 2.2 software (Mindware Technologies, Gahanna, OH). A sampling rate of 1000 Hz was used, according to established protocols (Sherwood et al., 1990).

Cardiac measures. Cardiac impedance was recorded using the standard tetrapolar impedance configuration first proposed by Qu, Zhang, Webster, and Tompkins (1986), with the current (I) electrodes along the spine on the back and the voltage (V) electrodes on the top and bottom of the breastbone (Figure 1). Cardiac impedance indices are typically considered measures of sympathetic nervous system activity in the heart, particularly the pre-ejection period (PEP) and left-ventricular ejection time (LVET; Figure 2). The PEP corresponds to the time between electrochemical systole and aortic opening and is used as an index of β-adrenergic influences on the myocardial contractility. The LVET corresponds to the length of time the aortic valve remains open during a cardiac cycle (Figure 2).

Participants' electrocardiographs (ECG) were recorded using two disposable Ag-AgCl electrodes affixed to the right clavicle and the lowermost left rib (Figure 1). The ECG was used to gather information on the QRS complex (see Figure 2), including the location and amplitude of each point in the complex. From the QRS complex, several heart rate variability (HRV) indices were extracted; specifically for this study, changes in respiratory sinus arrhythmia (RSA) were examined. Heart rate variability occurring in the high-frequency respiration band is under vagal control and therefore indicative of parasympathetic nervous system activity (Berntson, et al., 1997).

Respiration rates were obtained from an extrapolation of the impedance waveform. Heart rate variability occurring in synchronicity with respiration in the high frequency band between 0.14 and 0.4 Hz was used as an index of vagal activation. If respiration dropped below this high frequency range, data was excluded from analyses. The beat-to-beat interval series from the ECG waveform was converted into a time series

with a resolution of 4 Hz. A spectral analysis using the Welch method ascertained the power spectral density, which was then log-transformed for an index of RSA. These analyses were done using Mindware Heart Rate Variability software version 2.51 (Mindware Technologies, Gahanna, OH).

Facial electromyography. Facial electromyographs (EMG) were obtained according to established protocols set forth in Fridlund and Cacioppo (1986). Before electrode placement, the participants' skin was abraded at the electrode attachment sites using LemonPrep (Mavidon Medical Products, Lake Worth, FL) until resistance was measured at less than 10 KΩ according to the Checktrode 1089 electrode tester (UFI, Morro Bay, CA). After the abrasion, electrodes were placed over the *levator labii superioris* and *lateral frontalis* according to Figure 3. Three participants indicated that the skin abrasion became too uncomfortable before the appropriate resistance was reached. In these cases the EMG data was still recorded but not used in the analyses.

Dermal measures. Skin conductance (SC) was measured using two disposable Ag-AgCl electrodes affixed to the palm of the non-dominant hand. Prior to affixing the electrodes, participants were asked to wash their hands with a mild bar soap to ensure a clean signal without over-drying the skin. Skin conductance is a measure of electrical resistance in the skin, which is influenced by activity of the eccrine glands. Eccrine activity and, by extension, SC has been shown to be indicative of emotional arousal. Both tonic skin conductance levels (SCL) and skin conductance responses (SCR) were examined in the current study.

Self-report measures. Participants were also asked to give subjective ratings of the stimuli. Participants were given pen and paper surveys with all stimuli that were just

presented with listed in a random order. On 7-point Likert scales (anchored at 0 and 6) participants rated the strength of their reactions to each of the stimuli along four separate dimensions: disgust, anger, fear, and appeal (see Appendix E).

Participants were also asked to complete three different measures of religiosity. The Religious Concept Survey (RCS; Gorsuch, 1968) asked participants to rate a set of adjectives on how well they apply to God. Adjectives were rated on 3-point scales as (1) "The word does not describe 'God,'" (2) "The word describes 'God,'" or (3) "The word describes 'God' particularly well." The original RCS contains 91 items which include five subscales, but only the 13 items corresponding to the Wrathfulness subscale (e.g., Damning, Punishing, Wrathful) and the 12 items corresponding to the Kindliness subscale (e.g., Forgiving, Gracious, Merciful; see Appendix B) were used for this study. These subscales have shown moderate to high reliabilities in previous studies (0.83-0.95; Fairchild et al., 1993; Gorsuch, 1968; Sundin, Ladd, & Spilka, 1995) and remained high in the current study (Wrathfulness: 0.84; Kindliness: 0.94).

The Religious Fundamentalism Scale (RFS; Altemeyer & Hunsberger, 1992) measures how fundamental the religious beliefs of participants are. Representative items include "God will punish most severely those who abandon his true religion" and "Whenever science and sacred scripture conflict, science must be wrong," (see Appendix C). The RFS consists of 20 items rated on a 9-point Likert scale, anchored at -4 ("very strongly disagree") and +4 ("very strongly agree"), with half the items being reverse-scored. Previous studies have shown a high internal consistency for the RFS (0.93-0.95; Altemeyer & Hunsberger, 1992; Hunsberger, 1996), and it remained high in the current study (Cronbach's $\alpha = 0.91$).

The Religious Commitment Inventory-10 (RCI-10; Worthington et al., 2003) is a 10-item refinement of the previous versions of the RCI (McCullough & Worthington, 1995; McCullough, Worthington, Maxie, & Rachal, 1997; Morrow, Worthington, & McCullough, 1993) and measures how steadfast participants are in their religious beliefs and practices. Representative items include "I often read books and magazines about my faith," and "I spend time trying to grow in understanding of my faith." Items are rated on a 5-point Likert scale, anchored at 1 ("not true at all") and 5 ("totally true of me"), and are divided into two subscales of Intrapersonal Religious Commitment and Interpersonal Religious Commitment (See Appendix D). Studies on the RCI-10 have shown high reliabilities for the full measure, Intrapersonal subscale, and Interpersonal subscale (0.87, 0.86, and 0.83, respectively; Worthington et al., 2003), and their reliabilities remained high in the current study (RCI-10 = 0.92; Intrapersonal subscale = 0.85; Interpersonal subscale = 0.90).

Data analysis

Physiological data. Physiological data were cleaned using visual inspection in Heart Rate Variability, Cardiac Impedance, Electrodermal Activity, and Electromyography software from Mindware Technologies (Gahanna, OH). All data were statistically analyzed using SAS version 6.1 (SAS Institute, Cary, NC).

Physiological measures (RSA, PEP, LVET, SCL, SCR, *levator* mean activation, *frontalis* mean activation) were averaged for the duration of each stimulus condition and during the last 72 seconds of the baseline video for each participant. For the social disgust domain, the sexual and moral measures were averaged together. The distribution of the scores was examined using *proc univariate* to identify possible outliers ($M \pm 2SD$). After

outliers were identified and excluded, the ratios of each physiological measure were entered into repeated-measures analyses of variance (ANOVAs), controlling for participants' sex, within *proc glm* to compare between domains. When required, post-hoc Tukey HSD comparisons were conducted for any significant dependent variables, and effect sizes were calculated (Cohen, 1988).

To examine of participants' physiological reactions to each of the individual stimuli within a series, the number of skin conductance responses (SCRs) to each stimulus were analyzed using single-sample univariate tests in *proc ttest*. No other physiological reactions are sufficiently rapid to allow testing at the level of the individual stimulus.

Subjective ratings of stimuli. The subjective ratings replicated previous studies finding that the stimuli fall into three domains of disgust elicitors (Tybur et al., 2009), and these domains also extended further to include the additional five items added to each domain. As already noted, the internal consistency of each of the subscales was found to be high for the current study. For each participant, overall TDDS scores and domain-subscale scores were calculated and standardized.

Religiosity measures. Since reliability coefficients were high for all scales (Cronbach's $\alpha = 0.84 – 0.94$), item scores were summated to create a composite variable for each scale and subscale. These religiosity scores were then correlated with both the self-report ratings and physiological measures, controlling for the effects of participants' sex.

Chapter 3: Results

Reactivity to pathogen disgust elicitors

The presentation of the pathogen-related disgust stimuli led to no significant difference in the parasympathetic heart measure (RSA) from baseline levels ($F(1, 92) = 0.11$, $p = 0.74$) . The pathogen-related statements also had no significant effect on either of the sympathetic heart measures (PEP: $F(1,78) = 0.87$, $p = 0.35$; LVET: $F(1,78) = 0.45$, $p = 0.50$) or sympathetic dermal measures (SCL: $F(1, 39) = 2.38$, $p = 0.13$; SCR: $F(1, 39) = 0.93$, $p = 0.34$) when compared to baseline levels. Thus, contrary to our predictions, the pathogen-related disgust stimuli yielded no significant effects on the functioning of the autonomic nervous system. Additionally, the pathogen-related stimuli led to no significant differences in the muscle activation of either the *levator labii* ($F(1,79) = 0.17$, $p = 0.68$) or *lateral frontalis* ($F(1,79) = 0.86$, $p = 0.36$) as compared to baseline. When sensitivities to sexual and moral disgust were controlled for, no additional effects of physiological reactivity to the pathogen stimuli remained.

Reactivity to social disgust elicitors

As predicted, the presentation of the socially-related disgust stimuli led to a significant decrease in the parasympathetic heart measure, RSA, as compared to baseline levels ($F(1, 92) = 12.38$, $p = 0.0007$; Table 1). None of the sympathetic measures, however, showed any differences between the social conditions and baseline (PEP: $F(1,78) = 0.88$, $p = 0.35$; LVET: $F(1,78) = 0.23$, $p = 0.63$; SCL: $F(1, 39) = 0.71$, $p = 0.41$; SCR: $F(1, 39) = 0.07$, $p = 0.79$). Also, no significant reactivity was found in the activation of the *levator labii* ($F(1,79) = 1.49$, $p = 0.23$) or *lateral frontalis* ($F(1,79) = 2.32$, $p = 0.13$) facial muscles when participants viewed the socially-related disgust

stimuli. After controlling for sensitivity to pathogen disgust, the decrease in RSA remained significant ($F(1, 92) = 7.36$, $p = 0.008$), but no additional effects were found. To get a more fine-grained view of the effects of social disgust, the sexual and moral reactions were analyzed separately. When compared to baseline, a significant lowering of RSA was seen during presentation of the sexual stimuli ($F(1, 92) = 5.90$, $p = 0.017$) but not during the moral stimuli. No other independent effects of sexual or moral disgust were found on the physiological measures.

Differences between pathogen and social disgust elicitors

Repeated-measures ANOVAs indicated that the social stimuli had a greater influence on the functioning of the parasympathetic nervous system than the pathogen stimuli. RSA levels were significantly lower during presentation of the social stimuli as compared to the pathogen-related stimuli ($F(1, 92) = 5.66$, $p = 0.02$). No significant differences in reactivity were shown in either of the sympathetic heart measures (PEP: ($F(1, 78) = 0.24$, $p = 0.62$; LVET: ($F(1, 78) = 0.01$, $p = 0.94$)) , sympathetic dermal measures (SCL: ($F(1, 39) = 2.38$, $p = 0.13$; SCR: ($F(1, 39) = 0.93$, $p = 0.34$), or in facial muscle activity (*levator labii*: ($F(1,78) = 0.02$, $p = 0.88$; *lateral frontalis*: ($F(1,78) = 2.32$, $p = 0.13$).

Sex differences in the disgust response

As predicted, analyses indicated that females showed greater sensitivity to disgust in the self-report measures in both the social domain ($t_{94} = 2.36$, $p = 0.01$) and for the overall sensitivity measure ($t_{94} = 3.69$, $p = 0.02$), but no difference was found for the pathogen domain ($t_{94} = 1.25$, $p = 0.22$; Figure 1). Contrary to hypotheses, no sex

differences were found in any of the physiological disgust reactivities after controlling for the differences in disgust sensitivity.

Impact of disgust sensitivity on physiological responses

Examining the subjective disgust ratings, analyses indicated that individual differences in sensitivity to pathogen disgust as measured by the TDDS predicted RSA ($\beta = 5.57$, $p < 0.0001$) and *levator labii* ($\beta = 2.52$, $p = 0.01$) activity during presentation of the pathogen stimuli. Pathogen disgust sensitivity had no effects on any sympathetic activity measures or on *lateral frontalis* activity in response to any of the domains. Individual differences in sensitivity to either of the social domains did not predict any of the physiological outcome measures in response to any of the domains of elicitors, nor did any individual differences in sexual or moral disgust sensitivity when each were analyzed independently.

After conducting a median split and examining only the most disgust sensitive participants ($N = 45$), increased parasympathetic nervous functioning was seen when viewing the sexually-related stimuli ($\beta = 6.10$, $p = 0.02$). The most disgust sensitive participants showed no other significant physiological differences from baseline. After isolating only the participants who reported being the most disgusted by the sexual stimuli ($N = 45$), an additional effect on activation of the *levator labii* ($\beta = 4.91$, $p = 0.03$) and *lateral frontalis* ($\beta = 6.53$, $p = 0.01$; Table 2) muscles and were seen, as well as the parasympathetic nervous system ($\beta = 8.16$, $p = 0.006$). When examining the participants that reported being most sensitive to the moral stimuli ($N = 43$), a non-significant trend was seen on parasympathetic functioning when viewing the morally-related disgust

stimuli ($\beta = 3.95$, $p = 0.052$). The participants who reported being most disgusted by the pathogen stimuli ($N = 39$) showed no significant physiological differences from baseline.

Individual differences in religiosity

As predicted, the RCI-10, as well as each of its subscales, was positively correlated to the subjective ratings of disgust towards the social stimuli (RCI-10: $r = 0.24$, $p = 0.02$, Interpersonal: $r = 0.20$, $p = 0.05$; Intrapersonal: $r = 0.26$, $p = 0.01$). When probing further within the social domain, the correlation of the RCI-10 measures remained significant with the disgust ratings towards the moral stimuli (RCI-10: $r = 0.28$, $p = 0.005$, Interpersonal: $r = 0.26$, $p = 0.009$; Intrapersonal: $r = 0.26$, $p = 0.01$), but none were significantly correlated to the sexual stimuli. Similarly, the RCI-10 and both of its subscales were significantly positively correlated to the subjective anger ratings towards the moral stimuli (RCI-10: $r = 0.27$, $p = 0.007$; Interpersonal: $r = 0.25$, $p = 0.01$; Intrapersonal: $r = 0.25$, $p = 0.01$), but the correlations of the RCI-10 with the ratings towards the sexual stimuli and the social stimuli as a whole were not significant. The subjective fear ratings towards the pathogen stimuli were also positively correlated with the Intrapersonal subscale of the RCI-10 ($r = 0.20$, $p = 0.05$), but no correlation was found with the Interpersonal subscale or the RCI-10 as a whole.

Counter to predictions, the self-report fear ratings towards the social stimuli were negatively correlated with the Wrathful view of God ($r = -0.22$, $p = 0.03$). Exploring deeper within the social domain, these correlations remained significant when examining only the subjective fear ratings of the moral stimuli ($r = -0.24$, $p = 0.02$) but not with the ratings of the sexual stimuli. Further, the overall RCI-10 scores were positively correlated

with the subjective fear ratings of the moral stimuli ($r = 0.20$, $p = 0.05$), but again, there was no correlation with the sexual stimuli.

Chapter 4: Discussion

In this study, I examined whether the physiological reactions associated with the emotion of disgust vary according to functional domains. I found that exposure to the written pathogen stimuli had no discernible effect on the parasympathetic heart measures examined, but the socially-related stimuli decreased the RSA levels compared to baseline. Parasympathetic influences on the heart, therefore, decreased as part of the social disgust response but not as part of the pathogen disgust response. That is, social disgust down-regulated the resting functions of the nervous system, such as salivation, urination, and digestion.

This lends some support to the hypothesis that the parasympathetic functions would be unneeded or even maladaptive when an active reaction is required for avoidance of potentially harmful social situations, although this finding is not conclusive in itself. However, activation of the sympathetic nervous system, which would be expected for stimulating activities, was not found. Interestingly, when the social disgust reaction was further decomposed into moral and sexual disgust, the down-regulation in RSA only remained significant with the sexual response and not the moral. Additionally, these results were magnified when only the most highly disgust-sensitive participants were analyzed. That is, the highly disgust-sensitive participants were particularly reactive to the sexual stimuli. Contrary to hypotheses, no differences in sympathetic nervous system measures or facial muscle activation were seen in any of the disgust conditions when compared to baseline levels.

The decrease in RSA within the high respiration frequency band examined is indicative of a decrease of parasympathetic influence on the heart (Brownley, Hurwitz, &

Schneiderman, 2000). While arrhythmias occurring within the mid- to low-frequencies are influenced by both sympathetic and parasympathetic inputs, the current finding should be interpreted as pure parasympathetic withdrawal without influence of sympathetic arousal. Furthermore, as the range of respiration rate was restricted to the high-frequency band, changes in breathing rate may be ruled out as a possible alternative explanation for the decrease in RSA that was found.

Domain-specificity of disgust

Despite the many null findings, the difference in the RSA levels in response to the sexual stimuli suggests that there might be some difference at the physiological level in the disgust responses between domains. This finding converges with previous work that has dissociated the domains of disgust using self-report and neurological methods (Haidt et al., 1994; Moll et al., 2005; Schaich Borg et al., 2008; Tybur et al., 2009). The sex differences seen in the TDDS further suggest that there are functional differences between the domains of disgust as outlined by Tybur and colleagues (2009). These results also fit well within the evolutionary framework discussed earlier. While most of the literature on disgust suggests that women are universally more sensitive to disgust than men (Haidt et al., 1994), the results here indicate that disgust sensitivity varies with domain. While there was no significant difference in sensitivity to pathogen or moral disgust, there was quite a significant difference in sexual disgust (Cohen's $d = 1.04$). This pattern fits well within the evolutionary framework outlined above, since each domain is likely to have different fitness costs for women and men over human evolutionary history. Women, for instance, would have incurred greater costs associated with a poor

mating decision (Trivers, 1972), whereas exposure to infectious parasites would have represented a more similar selection pressure for both women and men.

Religiosity

As predicted, the RCI-10 was significantly correlated to the self-report ratings of the moral stimuli. As many view religion as a mechanism for maintaining social order, it follows that levels of religiosity would be correlated with reactions to moral transgressions. No effect, however, was found for any of the physiological reactions to the moral stimuli. Thus religiosity may be influencing the conscious reaction to the moral stimuli without affecting the biological response.

A significant positive correlation was also found between Intrapersonal subscale and ratings of fear towards the pathogen stimuli. Although this relationship was not predicted *a priori,* the link between personal commitment to religion and fear of pathogens is interestingly consistent with the most recent research in OCD-related cognitions which have linked compulsive washing behavior with religious beliefs (Greenberg & Witztum, 1994; Olatunji et al., 2005; Raphael, Rani, Bale, & Drummond, 1996; Sica, Novara, & Sanavio, 2002; Tek & Ulug, 2001). For example, Abramowitz and colleagues (2004) found that highly religious Protestants reported more compulsive washing than atheists and agnostics. Current models of OCD actually regard scrupulosity, an incessant guilt regarding religious and moral issues, as one of the categorical forms of the disorder (e.g., Mataix-Cols, Rosario Campos, & Leckman, 2005). Although the correlation between religiosity and aversion to pathogens, taken together with the current clinical literature, suggests a strong link between religious thought and OCD-related cognitions, no causal inferences can be made with the current study.

This correlation also fits with a recent theory on attempting to explain the global distribution of religions. Noting the increased diversity of religions in the tropics, where infectious diseases are more prevalent, Fincher and Thornhill (2010) suggest that religions function, in part, to limit individuals to exposure from parasites. By limiting dispersal and increasing out-group avoidance, a religion can effectively isolate cultures from outside pathogens. Again, no causal inference can be made from the current study, but the correlation between religiosity and aversion to pathogens fits with Fincher and Thornhill's model of the evolution of religion.

Limitations of the current study

It must be noted that many of the hypotheses regarding the physiological responses yielded null results. Inclusion of participants who were under the influence of both over-the-counter and prescription drugs (particularly birth control, allergy medications, and tobacco) make account for the inconsistency of findings as these medications may have had side effects on any number of physiological processes. Exclusion of these participants, however, was not possible as the reduction of power would have been too great to yield any significant results.

It also is possible that the stimuli used did not actually activate disgust and the isolated difference in RSA in response to the sexual stimuli was a result of a Type I error. Although the results of the self-report questionnaire suggest that disgust was activated at the cognitive level, this may be an artifact of experimental demand rather than a true indication that disgust was elicited. Alternatively, disgust may have been effectively elicited, but there are no actual differences across different domains of disgust at the physiological level. However, the discrepancy between the current findings and the

existing literature on physiology of disgust suggest that there may be methodological issues with the current study that need to be addressed with further research. Specifically, the lack of any reactivity to the pathogen stimuli conflicts with the existing literature that has found consistent differences in skin conductance, heart rate, and *levator labii* activity (Ekman et al., 1983; Lang et al., 1993; Schienle et al., 2001; Stark et al., 2005; Vrana, 1993). Most of these previous studies used disgusting pictures or videos as stimuli (Gross & Levenson, 1995; Stark et al., 2005; Vrana, 1993). While the reasons for written stimuli were outlined above, it may be the case that the particular stimuli used did not provide a strong enough manipulation of disgust to provide a visceral internal reaction. Along the same lines, the measures and instruments used may not provide the precision necessary to accurately detect the magnitude of reactions elicited.

Also, the disgusting stimuli may not be equally effective elicitors across all domains. For instance, one might expect that written stimuli could more be more effective in the social domains, which may require higher levels of processing, while being less effective in the pathogen domain, which could require more direct sensory cues. Indeed, as the domains of disgust are proposed to be distinct, it would also suggest that the functional inputs for each domain should also vary in the nature of their presentation. This would then have implications on the type of detection systems utilized in each domain and what cues more effectively activate these detection systems.

Alternatively, any reactivity may have been obscured by the modal difference in baseline and stimulus presentation. Despite the stated purpose of relaxation, the baseline video may have stimulated participants just by virtue of having moving figures, whereas

the static written stimuli may not have had the same effect. This difference in stimulation level may have obscured any actual physiological reactions to the disgusting elicitors.

These methodological issues can be addressed in further studies, as will be discussed below, but the null results could still suggest that there are no differences in physiology between the domains of disgust. That is, the functional requirements for each may be similar enough in degree that the appropriate reactions would not be distinguishable at the physiological level. This conclusion, however, does not necessarily indicate that disgust is a domain-general avoidance system; the domain-specific differences may just exist on the cognitive level.

Future directions

As this is the first study to examine domain-specific patterns of physiological disgust reactivity, it makes a significant contribution to the sparse knowledge of the physiological disgust reaction, but the methodological limitations stated above should be addressed in further studies before definitive conclusions can be drawn. With regard to the stimuli, most of the written acts used were chosen for their moderation and high variability. A future study should use more extreme elicitors, including pictorial and video stimuli, to provide a stronger manipulation of disgust. Since some of the null findings in the current study may be a result of a weak manipulation or imprecise measures, a stronger manipulation would provide a more definitive picture of how well the current psychophysiological methods can be used to investigate disgust responses. Additionally, if written statements are used, neutral acts should be used as the control rather than a relaxation video.

Further, a methodological study examining the interaction between mode of stimulus presentation and the domain could provide more direction on how to more effectively elicit disgust within each domain. As stated above, I would expect that pictures would be more effective in eliciting pathogen-related disgust since direct sensory cues would be more relevant for pathogen detection (Curtis et al., 2004; Oum et al., in press). The sexual and moral domains, however, could be better elicited with the written acts or vignettes, since the detection of those situations would require a higher level of cognitive processing.

The current study only included cardiac measures of autonomic nervous system action and neglects other autonomic functions that would be associated with disgust, particularly nausea and vomiting. A more thorough study of the function of disgust should also examine differences in the emetic response across the domains. Nausea and vomiting play protective roles by ridding the body of ingested toxins (Horn, 2008). Pathogen disgust would be expected to be linked to the same underlying neurobiology of these systems due to common functions. A future study should also include gastric measures of autonomic function in addition to the cardiac measures to gain a more complete assessment of the physiology of the pathogen-related disgust. Specifically, I would predict that vagal influences would lead to gastric dysrhytmias and gastric relaxation. Also, thoracic and abdominal pressure would change with the activation of the vomiting reflex (Fukuda, et al., 2003).

Within the clinical psychological realm, the link between religiosity and aversion to pathogens should be further explored. Replication of this study with a clinical or sub-clinical OCD population could elucidate more on the connection between disgust

sensitivity, religious obsessions, and washing compulsions by showing the similarities and differences in physiological patterns associated with disgust. A dissociation or linkage of these factors, along with other dimensions of OCD, could give researchers a better understanding of the etiology and development of OCD symptoms.

Closing Remarks

The functional framework that provides the basis for this study suggests that disgust operates differently in response to distinct classes of disgust elicitors, and the current results are the first to suggest some of these domain-specific patterns could be dissociable on the physiological level, although results are inconsistent and inconclusive. Previous behavioral and neurological findings suggest that disgust is not a homogenous and global aversion mechanism, but rather a heterogeneous response that varies based on the appropriate functional output required by a particular situation. Physiological differences would provide a logical bridge between the behavioral and neurological findings, and while the current results provide some evidence of these differences, the inconsistency of the current results raises the question of at what level these differential responses are seen. Although previous studies have shown dissociations between domains at both the neurological (Moll et al., 2005; Schaich Borg et al., 2008) and behavioral (Haidt et al., 1994; Tybur et al., 2009) levels, this is the first study to examine domain-specific physiological reactions (see Stark et al., 2005), and data provides preliminary, though inconclusive, support for physiological differences between domains.

This study could provide the foundation for building future studies to explore the domain-specific physiology of disgust. Conceptually, the evolutionary analysis used here generates empirically-testable hypotheses about what the functional domains are and how

they might differ in physiological requirements. Also, the procedures employed can also provide a methodological guideline for future studies investigating the differential physiological patterns associated with disgust.

The role of disgust in a number of clinical disorders and everyday social processes is becoming increasingly acknowledged in the literature (Cotrell & Neuberg, 2005; Kurzban & Leary, 2001; Navarrete & Fessler, 2006; Olatunji & Sawchuk, 2005), and a deeper knowledge of the associated physiology can only help our understanding of these disorders and processes. Disgust may play a role not only in OCD, as already discussed, but it may also be implicated in other clinical disorders, including Huntington's and sociopathy. A better understanding of the role that disgust plays in these disorders can shed light on their etiologies and, possibly, treatments. Furthermore, disgust has recently been found to be associated with social exclusion, prejudice, and stigmas. Addressing and potentially creating societal change in regard to such issues will require a clearer comprehension of the structure of disgust, as well as other social emotions.

References

Abramowitz, J. S., Deacon, B. J., Woods, C. M., Tolin, D. F. (2004). Association between Protestant religiosity and obsessive-compulsive symptoms and cognitions. *Depression and Anxiety, 20,* 70-76.

Adams, M. S., & Neel, J. V. (1967). Children of incest. *Pediatrics, 40*, 55–62.

Altemeyer, B., & Hunsberger, B. (1992). Authoritarianism, religious fundamentalism, quest, and prejudice. *The International Journal for the Psychology of Religion, 2,* 113-133.

Angyal, A. (1941). Disgust and related aversions. *Journal of Abnormal and Social Psychology, 36,* 393–412.

Barrett, L. F. (1998). Discrete emotions or dimensions? The role of valence focus and arousal focus. *Cognition and Emotion, 12 (4),* 579-599.

Bell, G. (1982). *The masterpiece of nature.* Croom-Helm, London.

Berntson, G. G., Bigger, J. T. J., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., et al. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34*(6)*,* 623-648.

Bittles, A. H., & Neel, J. V. (1994). The costs of human inbreeding and their implications for variations at the DNA level. *Nature Genetics, 8,* 117–121.

Bloom, P. (2004). *Descartes' baby: How the science of child development explains what makes us human.* New York: Basic Books.

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation. I: Defensive and appetitive reactions in picture processing. *Emotion, 1,* 276-298.

Bremmerman, H. J. (1980). Sex and polymorphism as strategies in host-pathogen interactions. *Journal of Theoretical Biology, 87,* 671-702.

Brownley, K. A., Hurwitz, B. E., & Schneiderman, N. (2000). Cardiovascular psychophysiology. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 224-264). New York: Cambridge University Press.

Calder, A. J., Keane, J., Manes, F., Antoun, N., & Young, A. W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience, 3,* 1077–1078.

Carlsson, M., & Carlsson, A. (1990). Interactions between glutamatergic and monoaminergic systems within the basal ganglia-implications for schizophrenia and Parkinson's disease. *Trends in Neurosciences, 13,* 272-274.

Curtis, V., Aunger, R., & Rabie, T. (2004). Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society of London, Series B, 271,* S131–S133.

Curtis, V., & Biran, A. (2001). Dirt, disgust and disease: Is hygiene in our genes? *Perspectives in Biology and Medicine, 44,* 17-31.

Cohen, J., (1988). *Statistical power analysis for the behavioral sciences (Second edition)*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Cottrell, C. A., & Neuberg, S. L. (2005). Different emotional reaction to different groups: A sociofunctional threat-based approach to "prejudice." *Journal of Personality and Social Psychology, 88,* 770-789.

Darwin, C. (1872/1998). *The expression of emotions in man and animal.* Chicago: University of Chicago Press.

Diamond, J. (2005). *Guns, germs and steel: The fates of human societies.* New York: W. W. Norton and Company, Inc.

Ehrlichman, H., Brown, S., Zhu, J., & Warrenburg, S. (1997). Startle reflex modulation by pleasant and unpleasant odors in a between-subjects design. *Psychophysiology, 32,* 726-729.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48,* 384-392.

Ekman, P., & Friesen, W. V. (1975). *Unmasking the face: A guide to recognizing emotions from facial clues.* Englewood Cliffs, NJ: Prentice Hall.

Fairchild, D., Roth, H., Milmoe, S., Gotthard, C., Fehrman, L., Richards, S., et al., (1993). *God images and prayer behavior: Consonance in the psychology of religion.* Paper presented at the joint convention of the Rocky Mountain and Western Psychological Associations, Phoenix, AZ.

Fincher, C. L., & Thornhill, R. (2010). Assortative sociality, limited dispersal, infectious disease and the genesis of the global pattern of religion diversity. *Proceedings of the Royal Society of London, Series B, 275*, 2587-2594.

Fridlund, A. J., & Cacioppo, J. T., (1986). Guidelines for human electromyographic research. *Psychophysiology, 23 (5),* 567-589.

Fukuda, H., Koga, T., Furukawa, N., Nakamura, E., Hatano, M., Yanagihara, M. The site of the antiemetic action of NK1 receptor antagonists. In: Donnerer, J., ed. *Antiemetic therapy*. New York, NY: Karger; 2003. p. 33-77.

Gorsuch, R. L. (1968). The conceptualization of God as seen in adjective ratings. *Journal for the scientific study of religion, 7,* 56-64.

Grillon, C., Ameli, R., Woods, S. W., Merikangas, K., & Davis, M. (1991). Fear-potentiated startle in humans: Effects of anticipatory anxiety on the acoustic blink reflex. *Psychophysiology, 28,* 588-595.

Greenberg, D., & Witztum, E. (1994). The influence of cultural factors on obsessive compulsive disorder: Religious symptoms in a religious society. *The Israeli Journal of Psychiatry and Related Sciences, 31,* 211-220.

Haidt, J., McCauley, C., & Rozin, P. (1994). Individual differences in sensitivity to disgust: A scale sampling seven domains of disgust elicitors. *Personality and Individual Differences, 16,* 701- 713.

Haidt, J., Rozin, P., McCauley, C., & Imada, S. (1997). Body, psyche, and culture: The relationship of disgust to morality. *Psychology and Developing Societies, 9,* 107–131.

Hamm, A. O., Cuthbert, B., Globisch, J., & Vaitl, D. (1997). Fear and startle reflex: Blink modulation and autonomic response patterns in animal and mutilation fearful subjects. *Psychophysiology, 34,* 97-107.

Hunsberger, B. (1996). Religious fundamentalism, right-wing authoritarianism and hostility towards homosexuals in non-Christian religious groups. *The International Journal for the Psychology of Religion, 6,* 39-49.

Jaenike, J. (1978). A hypothesis to account for the maintenance of sex within populations. *Evolutionary Theory*, *3*, 191-194.

Jones, A., & Fitness, J. (2008). Moral hypervigilance: The influence of disgust sensitivity on the moral domain. *Emotion, 8,* 613–627.

Kaviani, H., Wilson, G. D., Checkley, S. A., Kumari, V., & Gray, J. A., (1998). Modulation of the human acoustic startle reflex by pleasant and unpleasant odors. *Journal of Psychophysiology, 12,* 353-361.

Kubicek, W. G., Karnegis, J. N., Patterson, R. P., Witsoe, D. A., & Mattson, R. H. (1966). Development and evaluation of an impedance cardiac output system. *Aerospace Medicine, 37,* 1208–1212.

Kurzban, R., & Leary, M. R. (2001). Evolutionary origins of stigmatization: The functions of social exclusion. *Psychological Bulletin, 127,* 187-208.

Lane, R. D., Chua, P. M., & Dolan, R. J. (1999). Common effects of emotional valence, arousal and attention on neural activation during visual processing of pictures. *Neuropsychologia, 37,* 989-997.

Lang, P. J. (1994). The varieties of emotional experience: A meditation on James-Lange theory. *Psychological Review*, *101,* 211-221.

Levenson, R.W., Ekman, P., & Friesen, W. V. (1990). Voluntary facial action generates emotion-specific autonomic nervous system activity. *Psychophysiology, 27,* 363-384.

Lieberman, D., Tooby, J., & Cosmides, L. (2003). Does morality have a biological basis? An empirical test of the factors governing moral sentiments regarding incest. *Proceedings of the Royal Society of London, Series B, 270,* 819–826.

Lieberman, D., Tooby, J., & Cosmides, L. (2007). The architecture of human kin detection. *Nature, 445,* 727–731.

Lozano, D., Norman, G., Knox, D., Wood, B. L., Miller, B. D., Emery, C. L., et al. (2007). Where to B in dZ/dt. *Psychophysiology, 44*, 113-119.

Mackinnon, L. T., Chick, T. W., van As, A., & Tomasi, T. B. (1989). Decreased secretory immunoglobulins following intense endurance exercise. *Sports Medicine, Training and Rehabilitation, 1,* 209-218.

Manning, J. T., Trivers, R. L., Singh, D., Thornhill, R. (1999). The mystery of female beauty. *Nature, 399*, 214-215.

Mataix-Cols, D., Rosario-Campos, M. C., Leckman, J. F. (2005). A multidimensional model of obsessive-compulsive disorder. *American Journal of Psychiatry,162,* 228-238.

Mataix-Cols, D., Wooderson, S., Lawrence, N., Brammer, M. J., Speckens, A., Phillips, M. L. (2004). Distinct Neural Correlates of Washing, Checking, and Hoarding Symptom Dimensions in Obsessive-compulsive Disorder. *Archives of General Psychiatry, 61,* 564-576.

McCullough, M. E., & Worthington, E. L., Jr. (1995). College students' perceptions of a psychotherapists' treatment of a religious issue: Partial replication and extension. *Journal of Counseling and Development, 73,* 626–634.

McCullough, M. E., Worthington, E. L., Jr., Maxie, J., & Rachal, K. C. (1997). Gender in the context of supportive and challenging religious counseling interventions. *Journal of Counseling Psychology, 44,* 80–88.

Miller, S. B. (2004). *Disgust: The gatekeeper emotion.* Mahwah, NJ: Analytic Press.

Miltner, W., Matjak, M., Braun, C., Diekmann, H., & Brody, S. (1994). Emotional qualities of odors and their influence on the startle reflex in humans. *Psychophysiology, 31,* 107-110.

Moll, J., de Oliveira-Souza, R., Moll, F. T., Ignacio, F. A., Bratami, I. E., Caparelli-Daquer, E. M., et al. (2005). The moral affiliation of disgust: A functional MRI study. *Cognition and Behavioral Neurology, 18,* 68–78.

Moller, A. P., & Thornhill, R. (1998). Bilateral symmetry and sexual selection: A meta-analysis. *American Naturalist, 151,* 174-192.

Morrow, D., Worthington, E. L., Jr., & McCullough, M. E. (1993). Observers' perceptions of a psychologist's treatment of a religious issue. *Journal of Counseling and Development, 71,* 452–456.

Nabi, R. L. (2002). The theoretical versus the lay meaning of disgust: Implications for emotion research. *Cognition & Emotion, 16,* 695–703.

Navarrette, C. D., & Fessler, D. M. T. (2006). Disease avoidance and ethnocentrism: The effects of disease vulnerability and disgust sensitivity on intergroup attitudes. *Evolution and Human Behavior, 27,* 270-282.

Obeso, J. A., Rodriguez-Oroz, M. C., Rodriguez, M., Lanciego, J. L., Artieda, J., Gonzalo, N., Olanow, C. W. (2000). Pathophysiology of the basal ganglia in Parkinson's disease. *Trends in Neurosciences, 23,* S8-S19.

Olatunji, B. O., & Sawchuk, C. N. (2005). Disgust: Characteristic features, social manifestations, and clinical implications. *Journal of Social and Clinical Psychology, 42*, 932-962.

Olatunji, B. O., Tolin, D. F., Huppert, J. D., Lohr, J. M. (2005). The relation between fearfulness, disgust sensitivity and religious obsessions in a non-clinical sample. *Personality and Individual Differences,38,* 891-902.

Olatunji, B. O., Williams, N. L., Tolin, D. F., Sawchuk, C. N., Abramowitz, J. S., Lohr, J. M., & Elwood, L. (2007). The Disgust Scale: Item analysis, factor structure, and suggestions for refinement. *Psychological Assessment, 19,* 281-297.

Oum, R., Lieberman, D., & Aylward, A. (in press). A feel for disgust: Tactile cues to pathogen presence. *Cognition and Emotion.*

Perrett, D., Burt, D. M., Penton-Voak, I. S., Lee, K. J., Rowland, D. A., Edwards, R. (1999). Symmetry and human facial attractiveness. *Evolution and Human Behavior, 20*, 295-307.

Plutchik, R. (1960). The multifactor-analytic theory if emotion. *The Journal of Psychology, 50,* 153-171.

Qu, M., Zhang, Y., Webster, J. G., & Tompkins, W. J. (1986). Motion artifact from spot and band electrodes during impedance cardiography. *Transactions on Biomedical Engineering, 11,* 1029–1036.

Rainville, P., Bechara, A., Naqvi, N., & Damasio, A. R. (2006). Basic emotions are associated with distinct patterns of cardiovascular reactivity. *International Journal of Psychophysiology, 61*, 5-18.

Raphael, F. J., Rani, S., Bale, R., Drummond, L. M. (1996). Religion, ethnicity, and obsessive-compulsive disorder. *International Journal of Social Psychiatry, 42,* 38-44.

Reisenzein, R. (1994). Pleasure-arousal theory and the intensity of emotions. *Journal of Personality and Social Psychology*, *67*, 525-539.

Robinson, D., Wu, H., Munne, R. A., Ashtari, M., Alvir, J. M. J., Lerner, G., … Bogerts, B. (1995). Reduced caudate nucleus volume in obsessive-compulsive disorder. *Archives of General Psychiatry, 52*, 393-398.

Rohrmann, S., & Hopp, H. (2008). Cardiovascular indicators of disgust. *International Journal of Psychophysiology, 68,* 201-208.

Rozin, P., Haidt, J., & McCauley, C. (2000). Disgust. In M. Lewis & S. M. Haviland-Jones (Eds.), *Handbook of emotions* (2nd ed., pp. 637–653). New York: Guilford Press.

Rozin, P., & Fallon, A. (1987). A perspective on disgust. *Psychological Review, 94,* 23-41.

Russell, J.A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, *39*, 1161-1178.

Scarone, S., Colombo, C., Livian, S., Abbruzzese, M., Ronchi, P., Locatelli, M., … Smeraldi, E. (1992). Increased right caudate nucleus size in obsessive-compulsive disorder: Detection with magnetic resonance imaging. *Psychiatry Research: Neuroimaging, 45,* 115-121.

Schacter, S., & Singer, J. (1962). Cognitive , social, and physiological determinants of emotional states. *Psychological Review*, *69*, 379-399.

Schaich Borg, J., Lieberman, D., & Kiehl, K. A. (2008). Infection, incest, and iniquity: investigating the neural correlates of disgust and morality. *Journal of Cognitive Neuroscience, 20,* 1529–1546.

Schaller, M. (2006). Parasites, behavioral defenses, and the social psychological mechanisms through which cultures are evoked. *Psychological Inquiry, 17,* 96-101.

Schaller, M., & Duncan, L. A. (2007). The behavioral immune system: Its evolution and social psychological implications. In J. P. Forgas, M. G. Haselton, & W. von Hippel (Eds.), *Evolution and the social mind: Evolutionary psychology and social cognition* (pp. 293-307). New York: Psychology Press.

Scheinle, A, Stark, R., & Vaitl, D. (2001). Evaluative conditioning: A possible explanation for the acquisition of disgust responses? *Learning and Motivation, 32,* 65-83.

Schnall, S., Haidt, J., Clore, G. L., & Jordan, A. H. (2008). Disgust as embodied moral judgment. *Personality and Social Psychology Bulletin, 34,* 1096-1109.

Shapira, N. A., Liu, Y., He, A. G., Bradley, M. M., Lessig, M. C., James, G. A., … Goodman, W. K. (2003). Brain activation by disgust-inducing pictures in obsessive-compulsive disorder. *Biological Psychiatry, 54*, 751-756.

Sherwood, A., Allen, M. T., Fahrenberg, J., Kelsey, R. M., Lovallo, W. R., & van Doornen, L. J. P. (1990). Committee report: Methodological guidelines for impedance cardiography. *Psychophysiology*, *27*, 1–23.

Sica, C., Novara, C., & Sanavio, E. (2002). Religiousness and obsessive-compulsive cognitions and symptoms in an Italian population. *Behaviour Research and Therapy, 40,* 813-823.

Stanley, J., Knight, R. G. (2004). Emotional specificity of startle potentiation during the early stages of picture viewing. *Psychophysiology, 41,* 935-940.

Stark, R., Walter, B., Schienle, A., & Vaitl, D. (2005). Psychophysiological correlates of disgust and disgust sensitivity. *Journal of Psychophysiology, 19,* 50-60.

Sundin, H., Ladd, K. L., & Spilka, B. (1995). The relation between God images and perceptions of God's control. Paper presented at the annual convention of the Rocky Mountain Psychological Association, Boulder, CO.

Tek, C., & Ulug, B. (2001). Religiosity and religious obsessions in obsessive-compulsive disorder. *Psychiatry Research, 104*, 99-108.

Tomkins, S. S. (1963). *Affect, imagery, consciousness: Vol. II. The negative affects*. New York: Springer.

Tooby, J. (1982). Pathogens, polymorphisms and the evolution of sex. *Journal of Theoretical Biology, 97,* 557-576.

Tybur, J., Lieberman, D., & Griskevicius, V. (2009). Microbes, mating, and morality: Individual differences in three functional domains of disgust. *Journal of Personality and Social Psychology, 97,* 103-122.

Vrana, S. R. (1993). The psychophysiology of disgust: Differentiating negative emotional contexts with facial EMG. *Psychophysiology*, 30, 279-286.

Vrana, S. R. (1994). Startle reflex response during sensory modality specific disgust, anger, and neutral imagery. *Journal of Psychophysiology, 8,* 211-218.

Vrana, S. R., & Lang, P. J. (1990). Fear imagery and the startle-probe reflex. *Journal of Abnormal Psychology, 99,* 189-197.

Vrana, S., Spence, E. L., & Lang, P. J. (1988). The startle probe response: A new measure of emotion? *Journal of Abnormal Psychology, 59,* 55-68.

Wedekind, C., & Furi S. (1997). Body odour preferences in men and women: Do they aim for specific MHC combinations or simply heterozygosity? *Proceedings of the Royal Society of London B, Biological Sciences*. *264,* 1471–1479.

Wedekind, C., Seebeck, T., Bettens, F., & Paepke., A. (1995). MHC-dependent mate preferences in humans. *Proceedings of the Royal Society of London B, Biological Sciences. 260,* 245–249.

Westermarck, E. A. (1881/1921). *The history of human marriage.* London: Macmillan.

Worthington, E. L., JR., Wade, N. G., Hight, T. L., Ripley, J. S., McCullough, M. E., Berry, J.W., et al. (2003). The Religious Commitment Inventory—10: Development, refinement, and validation of a brief scale for research and counseling. *Journal of Counseling Psychology, 50,* 84–96.

Yartz, A. R., & Hawk, L. W. (2002). Addressing the specificity of affective startle modulation: Fear versus disgust. *Biological Psychology, 59*, 55-68.

Table 1. Physiological responses toward baseline video and pathogen- and social-related disgust statements

	Baseline	Pathogen	Sexual	Moral	Social
Respiratory sinus arrhythmia [msec]	$6.64 \pm 1.16_a$	$6.56 \pm 1.15_a$	$6.28 \pm 1.11_b$	$6.41 \pm 1.17_a$	$6.33 \pm 1.11_b$
Left ventricular ejection time [msec]	260.67 ± 52.23	253.50 ± 52.40	256.67 ± 48.21	259.92 ± 47.53	258.04 ± 40.02
Pre-ejection period [msec]	118.96 ± 16.22	117.10 ± 16.38	117.34 ± 17.04	118.58 ± 14.74	117.73 ± 14.86
Levator labii [μV]	0.016 ± 0.015	0.017 ± 0.015	0.018 ± 0.016	0.017 ± 0.019	0.018 ± 0.017
Lateral frontalis [μV]	0.018 ± 0.008	0.019 ± 0.013	0.020 ± 0.012	0.018 ± 0.012	0.019 ± 0.012

Note: Different subscripts within a response are significantly different

Table 2. Regression coefficients of disgust ratings to physiological reactivities for highly disgust sensitive participants to each domain according to the Three Domain Disgust Scale

	RSA		LVET		PEP		*Levator labii*		*Lateral frontalis*	
	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
Pathogen (*N* = 39)	0.03	0.86	0.00	0.95	1.10	0.30	*2.91*	*0.09*	2.47	0.12
Sexual (*N* = 45)	**8.16**	**0.006**	0.00	0.96	1.41	0.24	**4.91**	**0.03**	**6.53**	**0.01**
Moral (*N* = 43)	*3.95*	*0.052*	1.75	0.19	0.02	0.89	0.02	0.88	2.54	0.12

Note: Significant findings are in **bold**, and non-significant trends are in *italics*.

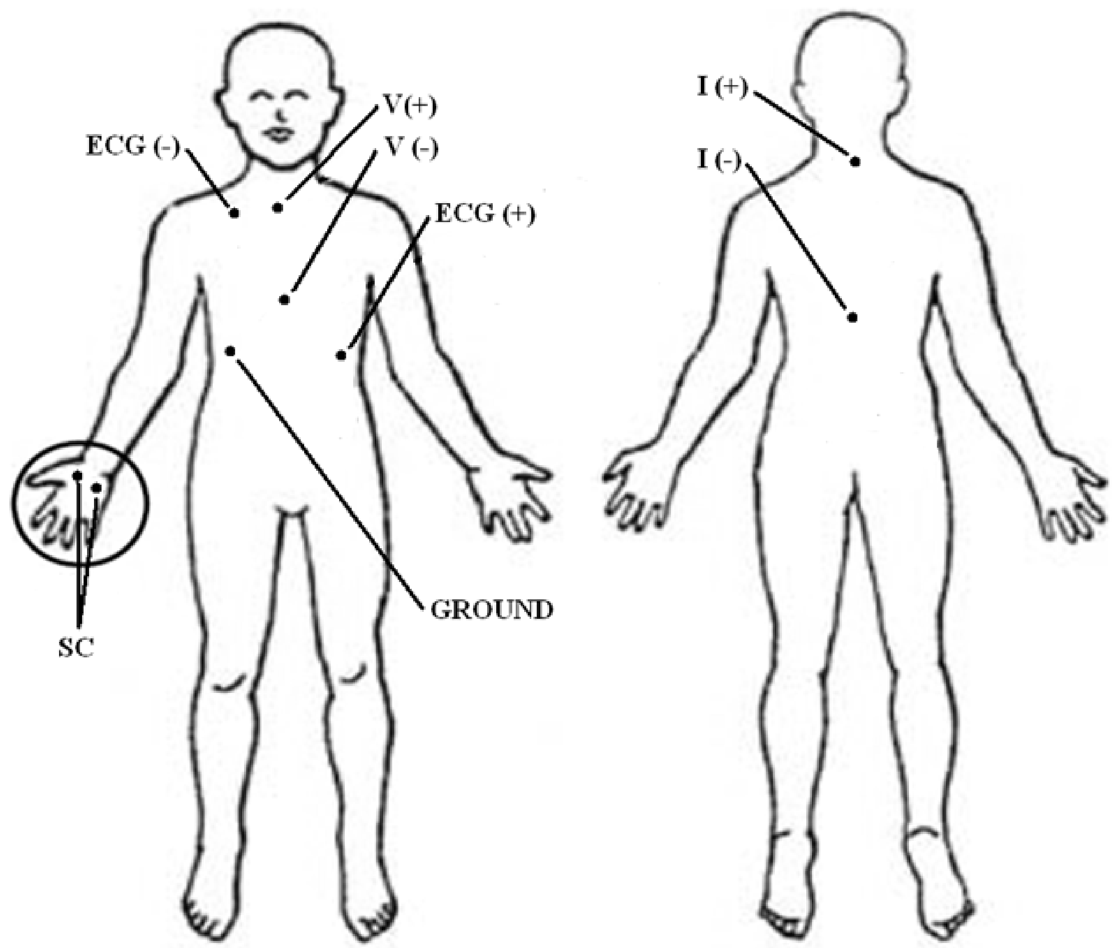

Figure 1. Electrode placements for ECG and impedance cardiography (adapted from Mindware Technologies, Gahanna, OH)

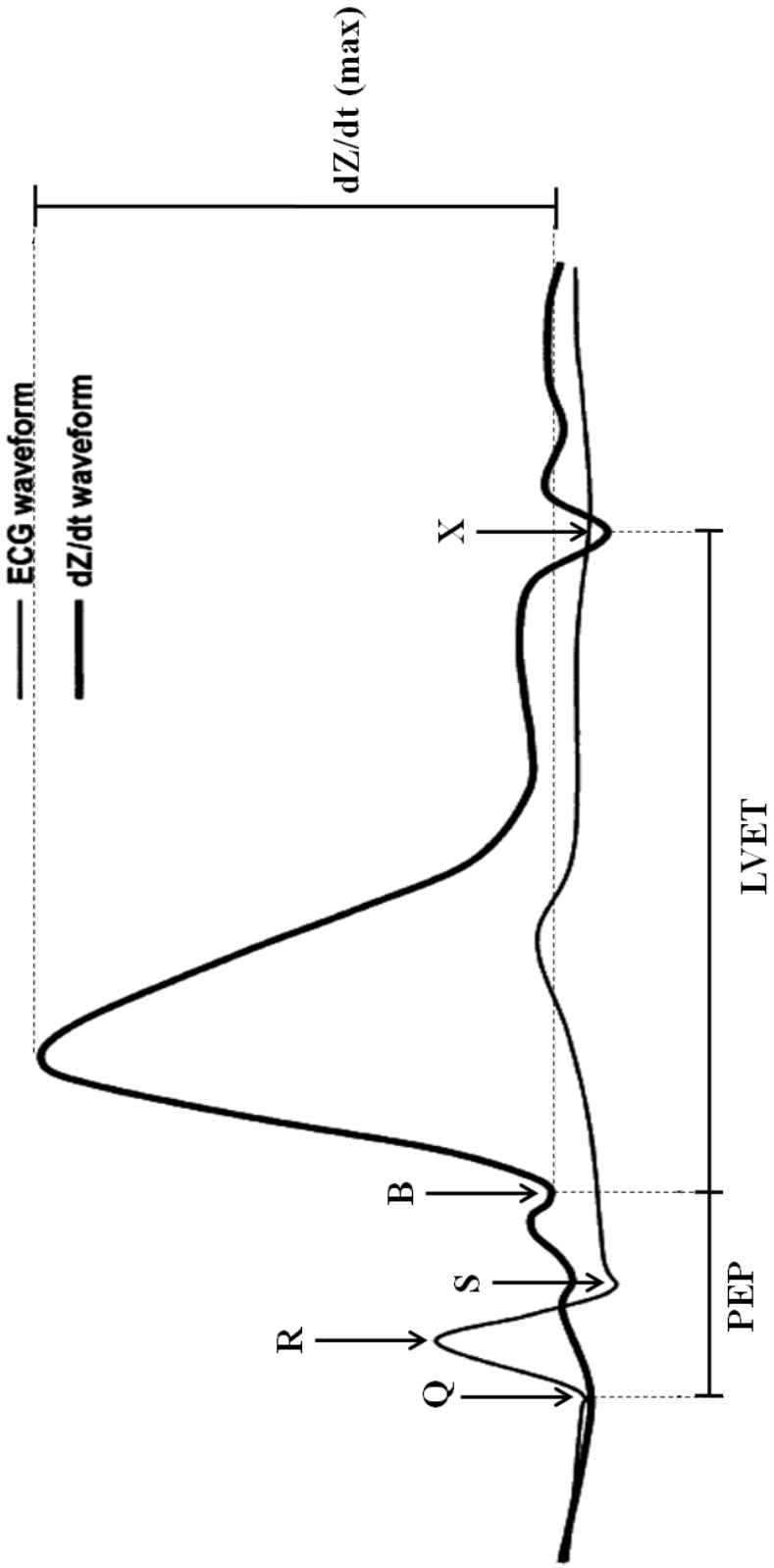

Figure 2. ECG and impedance cardiography waveforms (adapted from Lozano et al., 2007)

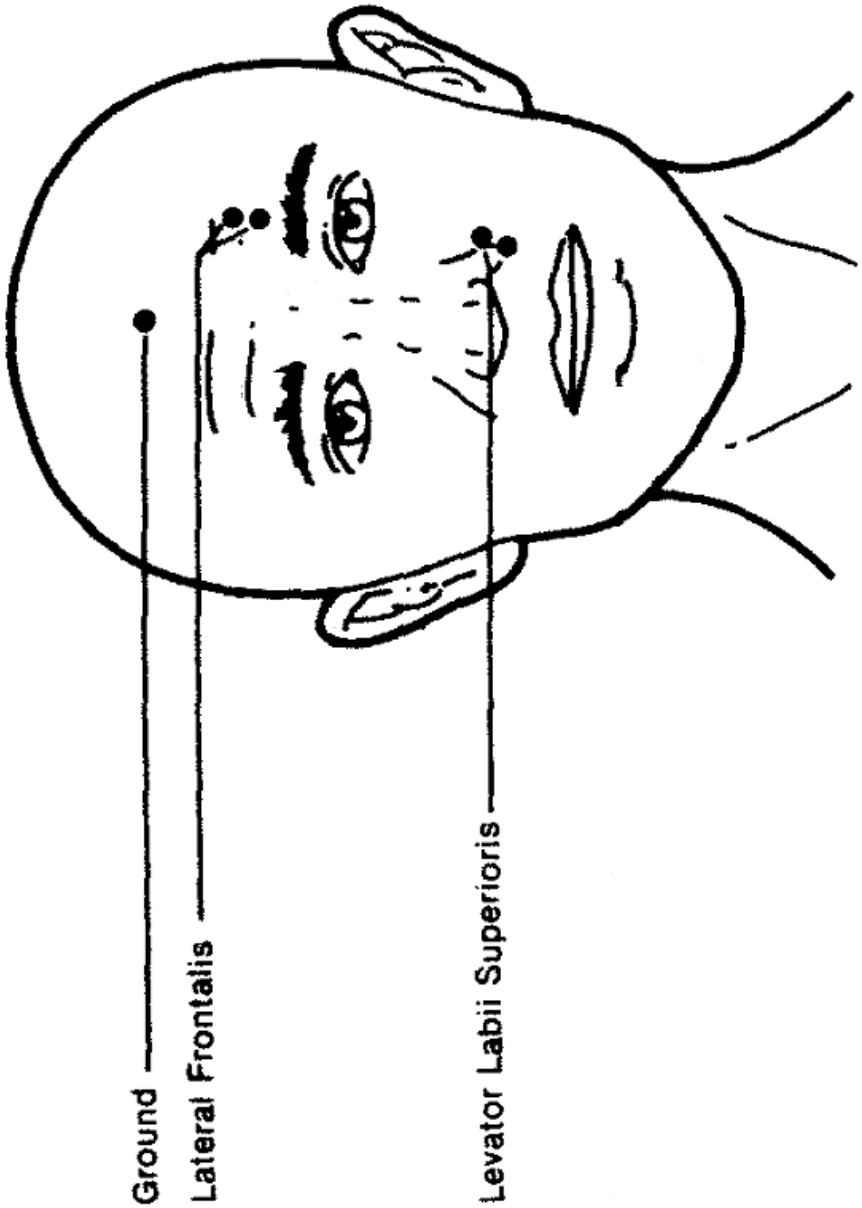

Figure 3. Electrode placements for facial EMG (Fridlund & Cacioppo, 1996).

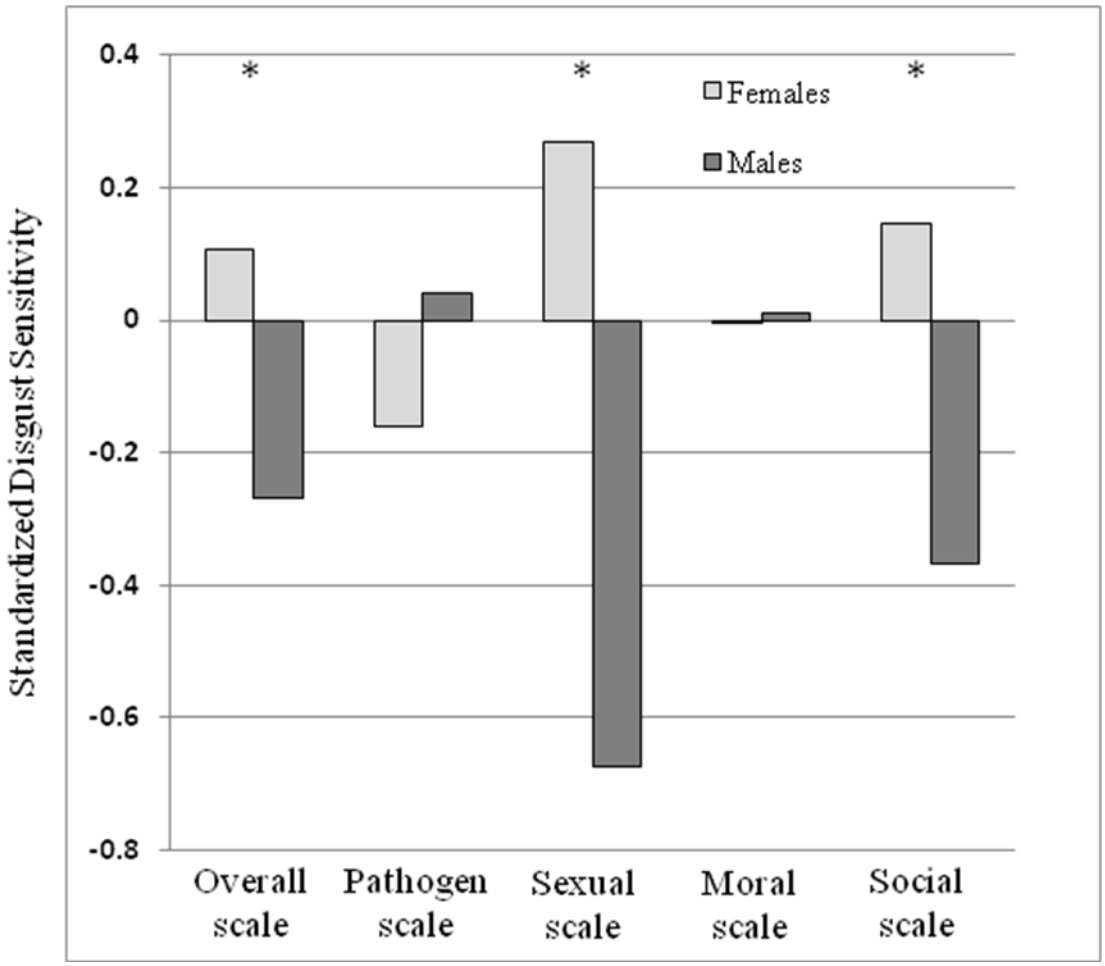

Figure 4. Sex differences in standardized disgust sensitivity ratings in the overall Three Domain Disgust Scale and for the pathogen- and social- disgust statements
Note: * indicates significance at the $p = 0.05$ level

Appendix A. List of stimuli used (from Tybur et al., 2009; * denotes items added to the Three Domain Disgust Scale)

Pathogen Domain

Sitting next to someone who has red sores on their arm

Standing next to someone on the bus who has strong body odor

Shaking hands with a stranger who has sweaty palms

Accidentally touching someone's bloody cut

Stepping on dog poop

Seeing mold on some leftovers in your refrigerator

Seeing a cockroach run across the floor

Finding maggots crawling near your garbage*

Putting your hand into an unflushed toilet*

Seeing someone's bone sticking out of their leg*

Drinking spoiled and curdled milk*

Popping a pimple on a stranger's back*

Sexual Domain

Bringing someone you just met back to your room to have sex

Watching a pornographic video

Performing oral sex

Hearing two strangers having sex

Having anal sex with someone of the opposite sex

An opposite sex stranger touching your thigh in an elevator

Finding out that someone you don't like has sexual fantasies about you

Hearing your parents having sex*

Having sex with a close relative*

Tongue-kissing someone who is thirty years older*

Having sex with someone who is extremely obese*

A brother watching his sister masturbate*

Moral Domain

Intentionally lying during a business transaction

Forging another person's signature on a legal document

Deceiving a friend

Stealing from a neighbor

Shoplifting a candy bar from a convenience store

Cutting to the front of the line to purchase the last four tickets of a show

A student cheating to get good grades

A mechanic purposely overcharging elderly people*

A husband beating his wife with a belt*

Killing parents to get an inheritance*

A woman drowning her children in the bathtub*

Firing a talented worker because they are black*

Appendix B. The Religious Concept Survey (Gorsuch, 1968; * denotes item is scored on the Wrathfulness subscale, all others are scored on the Kindliness subscale)

The following is a survey to determine what descriptive words apply to God. Please print a "1," "2," or "3" on the line before each word according to how well you think it describes what the term "God" means to you. There are no right or wrong answers; we are interested in what this concept means to each person. Use the following scale

1. The word does not describe "God."
2. The word describes "God."
3. The word describes "God" particularly well.

1. ____ Avenging*
2. ____ Blunt*
3. ____ Charitable
4. ____ Comforting
5. ____ Considerate
6. ____ Critical*
7. ____ Cruel*
8. ____ Damning*
9. ____ Fair
10. ____ Forgiving
11. ____ Gentle
12. ____ Gracious
13. ____ Hard*

14. ____ Jealous*
15. ____ Just
16. ____ Kind
17. ____ Loving
18. ____ Merciful
19. ____ Patient
20. ____ Punishing*
21. ____ Severe*
22. ____ Sharp*
23. ____ Stern*
24. ____ Tough*
25. ____ Wrathful*

Appendix C. The Religious Fundamentalism Scale (Altemeyer & Hunsberger, 1992; * denotes item is reverse-scored)

This survey includes a number of statements about general religious opinions. You will probably find that you *agree* with some of the statements and *disagree* with others, to varying extents. Please indicate your reaction to each of the following statements by marking your opinion to the left of each statement, according to the following scale.

Mark a -4 if you *very strongly disagree* with the statement.

-3 if you *strongly disagree* with the statement.

-2 if you *moderately disagree* with the statement.

-1 if you *slightly disagree* with the statement

Mark a +1 if you *slightly agree* with the statement

+2 if you *moderately agree* with the statement.

+3 if you *strongly agree* with the statement.

+4 if you *very strongly agree* with the statement.

If you feel exactly and precisely *neutral* about a statement, mark a "0" next to it.

___ 1. God has given mankind a complete, unfailing guide to happiness and salvation, which must be totally followed.

___ 2. *All* of the religions in the world have flaws and wrong teachings.*

___ 3. Of all the people on this earth, one group has a special relationship with God because it believes the most in his revealed truths and tries the hardest to follow his laws.

___ 4. The long-established traditions in religion show the best way to honor and serve God, and should never be compromised.

___ 5. Religion must admit all its past failings and adapt to modern life if it is to benefit humanity.*

___ 6. When you get right down to it, there are only two kinds of people in the wor Righteous, who will be rewarded by God and the rest, who will not.

___ 7. Different religions and philosophies have different versions of the truth and may be equally right in their own way.*

___ 8. The basic cause of evil in this world is Satan, who is still constantly and ferociously fighting against God.

___ 9. It is more important to be a good person than to believe in God and the right religion.*

___ 10. No one religion is especially close to God, nor does God favor any particular group of believers.*

___ 11. God will punish most severely those who abandon his true religion.

___ 12. No single book of religious writings contains all the important truths about life.*

___ 13. It is silly to think people can be divided into "the Good" and "the Evil." Everyone does some good, and some bad, things.*

___ 14. God's true followers must remember that he requires them to *constantly* fight Satan and Satan's allies on this earth.

___ 15. Parents should encourage children to study all religions without bias, then make up their own minds about what to believe.*

___ 16. There *is* a religion on this earth that teaches, without error, God's truth.

___ 17. "Satan" is just the name people give to their own bad impulses. There really is *no such thing* as a diabolical "Prince of Darkness" who tempts us.*

___ 18. Whenever science and scared scripture conflict, science must be wrong.

___ 19. There is *no* body of teachings, or set of scriptures, which is completely without error.*

___ 20. To lead the best, most meaningful life, one must belong to the one, true religion.

Appendix D. The Religious Commitment Inventory-10 (Worthington et al., 2003; * denotes items scored on the Intrapersonal Commitment subscale, all others scored on the Interpersonal Commitment subscale)

Please indicate how true the following items are for you.

1=not at all true of me

2=somewhat true of me

3=moderately true of me

4=mostly true of me

5=totally true of me

1. I often read books and magazines about my faith.* 1 2 3 4 5
2. I make financial contributions to my religious organization. 1 2 3 4 5
3. I spend time trying to grow in understanding of my faith.* 1 2 3 4 5
4. Religion is especially important to me because it answers many questions about the meaning of life.* 1 2 3 4 5
5. My religious beliefs lie behind my whole approach to life.* 1 2 3 4 5
6. I enjoy spending time with others of my religious affiliation. 1 2 3 4 5
7. Religious beliefs influence all my dealings in life.* 1 2 3 4 5
8. It is important to me to spend periods of time in private religious thought and reflection.* 1 2 3 4 5
9. I enjoy working in the activities of my religious organization. 1 2 3 4 5
10. I keep well informed about my local religious group and have some influence in its decisions. 1 2 3 4 5

Appendix E: Sample self-report scale for subjective disgust ratings. Similar scales were used for anger, fear, and appeal ratings for the same stimuli.

Please rate how *disgusting* you find the following acts. 0 = not disgusting at all, and 6 = extremely disgusting.

		Not disgusting at all						Extremely disgusting
1	Tongue-kissing someone who is thirty years older	0	1	2	3	4	5	6
2	Putting your hand into an unflushed toilet	0	1	2	3	4	5	6
3	Hearing two strangers having sex	0	1	2	3	4	5	6
4	Bringing someone you just met back to your room to have sex	0	1	2	3	4	5	6
5	Stealing from a neighbor	0	1	2	3	4	5	6
6	Sitting next to someone who has red sores on their arm	0	1	2	3	4	5	6
7	Accidentally touching someone's bloody cut	0	1	2	3	4	5	6
8	A mechanic purposely overcharging elderly people	0	1	2	3	4	5	6
9	Hearing your parents having sex	0	1	2	3	4	5	6

25	Cutting to the front of the line to purchase the last four tickets of a show	0	1	2	3	4	5	6
26	Intentionally lying during a business transaction	0	1	2	3	4	5	6
27	Finding out that someone you don't like has sexual fantasies about you	0	1	2	3	4	5	6
28	Shaking hands with a stranger who has sweaty palms	0	1	2	3	4	5	6
29	Popping a pimple on a stranger's back	0	1	2	3	4	5	6
30	Having anal sex with someone of the opposite sex	0	1	2	3	4	5	6
31	Seeing mold on some leftovers in your refrigerator	0	1	2	3	4	5	6
32	Seeing someone's bone sticking out of their leg	0	1	2	3	4	5	6
33	Standing next to someone on the bus who has strong body odor	0	1	2	3	4	5	6
34	Finding maggots crawling near your garbage	0	1	2	3	4	5	6
35	Performing oral sex	0	1	2	3	4	5	6
36	Watching a pornographic video	0	1	2	3	4	5	6

10	An opposite sex stranger touching your thigh in an elevator	0	1	2	3	4	5	6
11	Stepping on dog poop	0	1	2	3	4	5	6
12	Killing parents to get an inheritance	0	1	2	3	4	5	6
13	Drinking spoiled and curdled milk	0	1	2	3	4	5	6
14	Deceiving a friend	0	1	2	3	4	5	6
15	A student cheating to get good grades	0	1	2	3	4	5	6
16	Seeing a cockroach run across the floor	0	1	2	3	4	5	6
17	A husband beating his wife with a belt	0	1	2	3	4	5	6
18	Shoplifting a candy bar from a convenience store	0	1	2	3	4	5	6
19	Having sex with a close relative	0	1	2	3	4	5	6
20	Having sex with someone who is extremely obese	0	1	2	3	4	5	6
21	Firing a talented worker because they are black	0	1	2	3	4	5	6
22	A woman drowning her children in the bathtub	0	1	2	3	4	5	6
23	A brother watching his sister masturbate	0	1	2	3	4	5	6
24	Forging another person's signature on a legal document	0	1	2	3	4	5	6