Is 'Sexual' a Sub-type of Disgust, or is it a Separate Basic Emotion?

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Declaration

This is to certify that this thesis is all of my own work and my own writing. All the research reported here has not been submitted for a higher degree to any other university or institution. All the research sources reported in the thesis, as well as other sources of information used, have been cited and acknowledged. In addition, all the research proposals and protocols were approved by the Human Research Ethics Committee of Macquarie University (Ref No: 5201400104).

Signed

Kate Hardwick

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Summary

Disgust is a crucial emotion that guides a variety of avoidance and rejection behaviours in humans. These avoidance behaviours function to keep us safe from potentially harmful stimuli. A current adaptationist theory proposes three distinct sub-types of disgust based on their unique adaptive function, called the 'Three Domains of Disgust,' (pathogen, moral and sexual) (Tybur et al, 2013). The function of pathogen disgust is to maintain physical health through the avoidance of infectious and disease-causing agents; the function of moral disgust is to maintain group cohesion by avoiding or punishing moral transgressors and the function of sexual disgust promotes reproductive success through the avoidance of unfit mating opportunities. The theory holds that moral and sexual disgust co-opted pathogen disgust mechanisms to solve new adaptive problems. According to discrete emotion theory, sub-types of a basic emotion share: neural profiles, physiological and behavioural signatures. Therefore, if moral and sexual disgust co-opted pathogen disgust mechanisms, then common behavioural and neural mechanisms should emerge in response to stimuli in the three domains. In this thesis, I undertake four experiments to explore the behavioural and neural correlates of the three domains of disgust. I use linguistic stimuli and manipulate the semantic properties of sentences and words such that each category induces disgust, although still resembling its distinct sub-type. Overall, the results from each experiment reveal that the sexual category differs from both pathogen and moral categories. I tentatively propose that the sexual response is not a form of disgust but could be considered a distinct discrete emotion.

Chapter 1: Introduction and Literature Review

Introduction and Literature Review

Think of a time when you stepped in fresh dog poo, can you recall that pungent smell? Next, imagine a conversation where someone's contribution is a homophobic rant about the sanctity of heterosexual marriage. Now, regardless of whether you are male or female, what thoughts are conjured when thinking of sexual relations with an eighty-year-old man? What sort of emotions are aroused when thinking of these experiences? Disgust perhaps? There is much debate as to what types of situations, events and entities evoke the emotion we call disgust. Consequently, there is considerable contention among disgust researchers as to what constitutes disgust.

Why is it important to study disgust? There are a number of disgust processing disorders, where a better understanding of disgust may help target therapies for those afflicted (Davey, 2011). First, obsessive compulsive disorder, specifically related to contamination phobia, is described as an over sensitivity to disgust-evoking entities. Sufferers show obsessive behaviours toward eliminating potential sources of infection; those behaviours can be deleterious to the patient (Husted, Shapira, & Goodman, 2006; Olatunji, Lohr, Sawchuk, & Tolin, 2007). Second, abnormal perceptions of disgust directed at the self are associated with Bulimia and Anorexia Nervosa (Bell, Coulthard, & Wildbur, 2017). Finally, Huntington's disease, a neurodegenerative disorder, affects a person's ability to perceive disgust and over time, there is a gradual loss of disgust perception altogether (Sprengelmeyer, Schroeder, Young, & Epplen, 2006). It seems vital at this point to further our knowledge of the underlying mechanisms of disgust to aid in the therapies and care for those afflicted with disgust processing disorders.

The basic emotion called disgust was identified as early as Darwin, when he considered emotions in his seminal work *The Expression of the Emotions in Man and Animals* (1872/1998). He described the characteristic facial expression of disgust: the wrinkled nose, the gaping mouth and the furrowed brow. He detailed the types of sensorial experiences of disgust such as foul tastes, pungent smells and the sight of excrement or vomit. He even described scenarios that elicit disgust, such as mere thoughts of eating animals not commonly considered edible, like a dog or human; as well as feelings toward people of 'lower castes' touching one's food. Since this time, researchers have extended these observations to encompass many facets of disgust eliciting stimuli.

Paul Ekman and colleagues (Ekman, 1992; Ekman & Friesen, 1986; Ekman & Friesen, 1971) performed experiments across various cultures investigating responses to facial expressions carrying specific emotional content. They found that the facial expression disgust, as described by Darwin, was recognised universally and thus described disgust as one of six basic emotions (i.e., fear, anger, sadness, happiness, surprise and disgust). They also found distinguishing physiological responses unique to each basic emotion and consequently proposed the now-famous 'Basic Emotion theory' (Ekman, Levenson, & Friesen, 1983; Levenson, 1992).

The Basic Emotion theory suggests that there are several universally recognised emotions (Ekman, 1992; Ekman & Cordaro, 2011; Ekman, Sorenson, & Friesen, 1969), each containing sub-types. Each sub-type will exhibit some minor differences, such as a slightly different facial expression or subjective reports of the elicitors, but overall, the sub-types of a basic emotion should show similar behavioural, physiological and neural signatures. For example, contempt and outrage are sub-types of anger and it has been demonstrated that these

sub-types have similar physiological (Ekman et al., 1983; Levenson, 1992) and neural signatures (Barrett & Wager, 2006; Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012; Vytal & Hamann, 2010).

With respect to the basic emotion of disgust, researchers have embarked on various studies to elucidate the adaptive function and the candidate elicitors of disgust. The Curtis laboratory has extensively studied disgust's function as a behavioural system that prevents disease and infection (Curtis, 2011, 2014; Curtis & Biran, 2001; Curtis, de Barra, & Aunger, 2011). In her earlier work, Curtis found common disgust elicitors across India, Africa and Europe, including bodily excretions, body parts, decayed and fouled food, certain animals, members of out-groups and some moral violations (Curtis & Biran, 2001). The first four of those categories are considered to be sources of potential pathogenic contamination. Proponents of evolutionary accounts of the function of disgust argue that it prevents infection and disease in the organism, aiding its survival (Curtis et al., 2011; Marzillier & Davey, 2004; Rozin, Haidt, & McCauley, 2008; Tybur, Lieberman, Kurzban, & DeScioli, 2013). Therefore, pathogen-related disgust has evolved to motivate avoidance, or rejection behaviours that aid in avoiding infection and disease via contaminating products.

Several questions remain regarding disgust mechanisms. Are there types of disgust other than pathogen-related disgust? If so, do they function in a similar way? That is, do they motivate avoidance behaviours to aid human survival? What are the common behaviours, physiological and neural signatures elicited by different types? And importantly, how do these signatures differ? One overarching theme of this thesis is whether pathogen disgust has further adapted, thus providing the foundation for other types of disgust not linked to pathogen avoidance.

Several theories converge on the idea of 'moral' and 'sexual' as sub-types of disgust (Haidt, Rozin, McCauley, & Imada, 1997; Rozin et al., 2008; Tybur et al., 2013), although clarifying whether these are types of disgust remains under debate (Bloom, 2004; Royzman, Atanasov, Landy, Parks, & Gepty, 2014; Royzman & Sabini, 2001). First, do emotionally adverse reactions to moral transgressors constitute a sub-type of disgust? There have been mixed results in answer to this question. For instance, some research shows that people report feeling 'disgust' when faced with immoral scenarios (Curtis & Biran, 2001; Hutcherson & Gross, 2011). However, others argue that moral disgust is a *metaphorical* adaptation of pathogen disgust terms and does not necessarily reflect disgust mechanisms *per se* (Bloom, 2004; Royzman & Sabini, 2001). Second, do adverse emotional reactions to certain sexual advances constitute a distinct type of disgust? Activities such as the rejection of mating opportunities with those of low genetic health and/or compatibility, purportedly evoke disgust (Tybur et al., 2013). However, there is no empirical evidence in support of this hypothesis. Consequently, there is a need to clarify whether moral and sexual disgust, in fact, constitute sub-types of disgust. I will now discuss two current theories identifying the sub-types of disgust.

A psychological theory of disgust

Paul Rozin and his colleagues spent three decades developing a psychological theory of the sub-types of disgust (Fallon & Rozin, 1983; Haidt, McCauley, & Rozin, 1994; Rozin & Fallon, 1987; Rozin et al., 2008; Rozin, Lowery, Imada, & Haidt, 1999). Throughout his research he identified four domains of disgust (Core, Animal Nature, Interpersonal and Moral) that he suggests evolved in successive stages (Rozin et al., 2008). First to evolve, core disgust, which protects the body from disease and infection by avoiding bodily products and

the ingestion of fouled food. Second to evolve, animal nature disgust, which protects the body and soul by denying one's *mortality* through the aversion of sex, death, hygiene and body-envelope violations (puncture wounds, deformity or where the exterior of the body is breached), all of which are argued to remind us that we are animals and thus, mortal. Third to evolve, interpersonal disgust, which protects social order as well as the body and soul by avoiding direct contact with strangers. Last to evolve, moral disgust, which also protects social order through the aversion of others' moral offences. Rozin and colleagues' (2008) theory of disgust has been very influential in this field and has provoked much research on candidate elicitors of disgust and their manifestation in behaviour.

According to the theory proposed by Rozin et al. (2008), animal reminder disgust is felt in response to animals, and anything that reminds us of our animal nature, such as blood, sex or body envelope violations. The proposed function of animal reminder disgust is such that humans can deny their *debased* role as an animal and thus deny mortality. There is some evidence that humans feel negative emotions toward some animals. For example, it has been argued that due to the large amount of exposure humans have to animals in everyday life, humans have developed strategies to cope with this exposure by viewing them as inferior beings (Kasperbauer, 2015). However, whether these negative emotions constitute a type of disgust is unclear.

There are several challenges to the animal reminder category of disgust due to the potential for this 'type' of disgust to actually reflect a pathogen-related disgust response (Royzman & Sabini, 2001; Tybur et al., 2013). Rozin (2008) suggests that contaminating substances cause animal reminder disgust. Specifically, any sort of contact that is via, or near, a means of entry into the body cause this type of disgust. These include contact such as: hair-to-hair contact,

which causes the spread of lice, genital contact, areas which might harbour sexually transmitted diseases and face-to-face contact, which allows the transmission of viral and bacterial infections. Contamination of these kinds seem to fit more closely with a pathogen type of disgust, causing the withdrawal from infectious and disease carrying agents, rather than anything specifically evoked by an animal reminder.

Other research suggests that humans specifically feel disgusted by certain animals. In a cross-cultural study (Davey et al., 1998), participants were probed about fearful responses by rating their fear toward 51 animals on a four-point scale (0 = not frightened at all, > 3 = makes me feel very frightened). Using a principle component analysis, three prominent components were extracted, one of which represented animals commonly associated with ratings of disgust (e.g., cockroaches, maggots, slugs, flies). The questionnaire focussed on fear specifically, although, based on the observed components, the authors suggest that this fear could be associated with pathogen avoidance strategies. Therefore, it remains uncertain whether 'animal reminder' disgust is distinct or should be considered within the framework of pathogen-related disgust.

Other challenges arise with parts of the definition of animal reminder disgust. Rozin et al. (2008) argue that we consider animals to be unhygienic, therefore we choose only to eat certain kinds of animals. The evidence he provides in support of this notion is that humans only eat herbivores and do not eat insects. However, the avoidance of only some kinds of animals suggests there is not a total aversion of animals and their products. Similarly, in areas with few nutritional resources, insects are a prime food source (de Figueiredo, Vasconcellos, Policarpo, & Alves, 2015; Mbah & Elekma, 2007; Pal & Roy, 2014). If humans were truly disgusted by animals then humans would not eat animals at all. It's also important to

acknowledge that animal reminder disgust has also been implicated in various OCD disorders (Olatunji, B,. Lohr, J., Sawchuk, J., Tolin, D,. 2007 Olatunji B & Ebusutani, 2015,).

Rozin et al. (2008) also argue that the use of animal names commonly used as insults, such as 'maggot' or 'dog,' demonstrate human disgust toward animals. However, on the contrary, we also use animal names as compliments, such as 'she's a fox' or 'wise as an owl,' as well as terms of endearment, such as 'possum' and 'bunny' (Tybur et al., 2013). Therefore, given that animals names are used as similes or metaphors to describe a person's character in both negative and positive ways, the use of animal names as insults is not good evidence for animal reminder disgust.

Finally, Rozin et al. (2008) argue for a general dislike and aversion of almost all animals. However, when looking across cultures, many animals are in fact revered. This can be observed in Hindu religion and the sanctity of the cow (Lodrick, 2005). Practicing Hindus do not eat cow due to its religious status and they worship the cow in many instances. Similarly, in Australian Aboriginal societies, animals feature heavily in the dreamtime, rituals and art. For example, animals are described in the dreamtime as forming parts of the landscape, such as the fish known as Barramundi and the snake known as the Rainbow serpent (Hinchman & Hinchman, 1998). Additionally, in the consumption practices of hunted game within Aboriginal communities, whole animals were eaten, including the offal, bone marrow and blood (Odea, 1991). Many cultures also own and love pets, kissing and cuddling them, with no thoughts of disgust. Together, the evidence of great reverence for animals across cultures is inconsistent with animal reminder disgust proposed by Rozin and colleagues (2008). The difficulties evident with this view of the animal-nature of disgust call for a re-evaluation of this sub-type of disgust.

Despite the challenges raised to the animal reminder disgust category, there is support for other aspects of their theory. The function of core disgust is in line with the pathogen avoidance function described earlier. Interpersonal and moral disgusts, thought to play a role in social cohesion by the rejection of moral offenders has also received support (Chapman & Anderson, 2012, 2013; Schnall, Haidt, Clore, & Jordan, 2008; Wheatley & Haidt, 2005). Next I will discuss a current theory describing the sub-types of disgust that has built on aspects of Rozin and colleagues theory (2008).

An adaptationist theory of disgust

In response to the concerns about the inclusion of the animal reminder category of disgust, Tybur et al. (2013) developed an adaptationist theory, which postulates three domains of disgust (pathogen, moral and sexual). Their theory focusses on the ultimate and proximate functions of these three types of disgust. They explain the function of each of the domains from the view of selection pressures (ultimate function) and how these manifest in the three types of disgust behaviours (proximate function). He outlines the computational processes that arise from the distinct disgust *inputs* (i.e., items, events or scenarios that may be construed as disgusting) together with the *integration systems* that weigh up the costs and benefits of subsequent actions (i.e., the costs of approach versus the benefits of avoidance). The computational processes within the integration system then trigger specific *outputs* for each of the disgust domains. This is an important modification to Rozin and colleague's theory (2008).

First, Tybur et al. (2013) discuss the selective pressures faced by our ancestors for the development of a pathogen disgust mechanism. Whereas pathogens tend to be microscopic and thus not always visible to the naked eye, humans have developed ways to identify

pathogenic colonisation in various entities. Although pathogens are not visible to the naked eye, certain visual cues, such as the colour of rotting fruit or the sight of blood or pus, signals potential pathogenic assault. Bad odours are also informative of the harbouring of pathogens, such as the smell of a dead corpse or the odour of human faeces, both of which suggest the presence of harmful bacteria. Moreover, sour taste buds in humans can detect lactic acid that indicates the increase of bacteria in milk products. These sensorial inputs are associated with an integration system that weighs the costs and benefits of subsequent actions; for example, the cost of eating rotting fruit if resources are scarce compared with the benefits of not eating rotting fruit if resources are abundant. Given the sensorial input and integration, the system then results in outputs such as a disgusted feeling, a disgusted facial expression and importantly, the avoidance of such items.

Although the inputs are different for pathogen, moral and sexual types of disgust, the integration systems are argued to operate in the same way and share similar outputs. The inputs of moral disgust are behaviours viewed by the group as unacceptable and worthy of condemnation. These could be behaviours such as lying, cheating, stealing or 'going against the grain' of one's in-group. The integration system weighs up the costs and benefits of punishing behaviours; for example, the costs of punishment may ruin social ties if the perpetrator is friend or kin, whereas a benefit may be the prevention of future perpetrations. The outputs are a feeling of disgust, a set of condemning behaviours and facial or vocal expressions of disgust.

The inputs of sexual disgust are advances from potential mates that may be genetically incompatible (kin), physically unfit or have low mate 'value.' The integration system weighs up the current environmental conditions, such as the availability of alternative mates. For

instance, the costs of not mating at all would be compared to the costs of mating with those of lower genetic value. The outputs are feeling disgusted when approached by mates of low value, a disgusted facial expression and the avoidance of contact with such potential mates.

While the three-domain theory is plausible from a theoretical perspective, for the cognitive scientist, there is a problem: although there is ample evidence for pathogen disgust, there is debate about the evidence that responses to moral transgressions constitute a type of disgust. Moreover, there is little compelling evidence to support the claim of sexual disgust. In the next sections, I will flesh out the debate around moral disgust, I will then discuss the limited evidence for sexual disgust.

Sub-types of disgust

The substantial evidence in support of pathogen disgust has been covered earlier. Here, I focus on moral and sexual as potential disgust sub-types. According to Tybur and colleagues' (2013) theory, both moral and sexual disgust are said to have co-opted pathogen disgust mechanisms. In this section, I review the evidence and counter-evidence regarding these proposed sub-types of disgust.

Moral disgust

The contention as to the validity of considering 'moral disgust' as a true form of disgust arises from mixed results stemming from almost three decades of study. One of the main arguments against moral disgust is the use of human linguistic abilities in the use of metaphor (Bloom, 2004; Herz & Hinds, 2013; Nabi, 2002; Royzman & Sabini, 2001). The questions are: when we say a person is *revolting* for saying something racist, or we refer to an exploitative bill passed in parliament is *disgusting*, is this really disgust? Or are we merely

using metaphor? In the next section, I first consider the behavioural data, both from subjective and objective measures. I then review the relevant neuroimaging literature that compare pathogen and moral disgust.

Several researchers have suggested that moral disgust should not be considered a form of disgust because the use of the word 'disgust' is merely metaphor. They argue that there is little empirical data showing that responses to moral transgressions are similar to that of typical pathogen disgust responses. Thus, they contest that other than bearing a vaguely similar disgusted facial expression in response to moral transgressions (Royzman & Kurzban, 2011a, 2011b) a similar facial expression is not compelling evidence to call moral disgust a sub-type of disgust. Moreover, Royzman and Sabini (2001) highlight that the data in support of moral disgust relies heavily on self-report. Self-report measures, or direct measures to test hypotheses, tend to be less reliable than indirect measures, therefore, Royzman and Kurzban (2011b) argue against moral disgust as a sub-type of disgust.

For many researchers though, subjective report through surveys or ratings is the measure used to explore moral disgust. Several groups have explored cross-culturally, what sorts of situations and events cause a feeling of disgust (Curtis & Biran, 2001; Haidt et al., 1997). In the Curtis and Biran (2001) study, responses to surveys asking what scenarios or objects are found disgusting were collected from people from several countries: India, Burkina Faso in West Africa, the Netherlands, the United Kingdom and an international airport. There were small differences between the countries, which may have been due to differing hygiene standards (e.g., pollution in India compared with that of the Netherlands and the UK) and cultural influences (e.g., caste systems versus non-caste-systems). The majority of the

reported disgusting items were pathogen related (e.g., vomit, faeces, rotten food) and some were moral related scenarios (e.g., politicians, drunken louts, insulting behaviour).

In a study conducted by Haidt et al. (1997), they gathered surveys from non-native English speaking undergraduate students. They found translations for the word 'disgust' in the respective language of the interviewee and asked what made them feel that emotion. As in the Curtis and Biran study (2001), they also found many pathogen related stories and some moral transgressions. For example, an Israeli interviewee told about feeling disgusted of someone picking their nose and eating it and clipping fingernails in public, similar to disliking a politician. Japanese respondents in both Hiroshima and the United States relayed moral transgressions as disgusting, such as the ill treatment, violence and cruelty toward others. These subjective reports illustrate that moral transgressions cause a feeling of disgust, but it remains unclear whether this constitutes a type of disgust co-opted from pathogen disgust.

Nabi (2002) tested the metaphorical use of disgust language with recall of personally experienced past events. Participants were assigned to one of five emotion groups (angry, disgust, disgusted, revulsion or grossed out) and were asked to recall a personal experience specific to that emotion group. They then filled out a survey probing their consequent feelings in response to their recalled experience. Those who recalled moral violations, such as being lied to, treated unfairly or cheated on, tended to feel more anger and less avoidance behaviours than those who recalled experiences containing vomit, faeces or bugs and rodents. Therefore, moral disgust might not represent a type of disgust *per se*, but rather be more closely linked to 'moral anger.'

Another study investigated taste sensitivities and compared those with disgust sensitivities (Herz, 2011). Participants filled out three disgust sensitivity scales testing pathogen, moral and sexual forms of disgust: (1) a short form of the Disgust Scale (Haidt et al., 1994); (2) the Three-Domain Disgust Scale (Tybur, Lieberman, & Griskevicius, 2009); and (3) the Disgust Propensity and Sensitivity Scale Revised (van Overveld, de Jong, Peters, Cavanagh, & Davey, 2006). Next, participants were given a bitter tasting substance and asked to rate the taste sensation on a scale of 1 (barely detectable) – 100 (strongest imaginable). Each participant was grouped into super-tasters (50-100), tasters (16-49) and non-tasters (below 15). They found that super-tasters and tasters were more sensitive to disease and body products reminiscent of pathogen disgust but found no differences between taster groups on any moral disgust scale sensitivity measures. These results suggest that differences between disgust sensitivities and the visceral properties indicative of pathogen disgust differ from that of moral disgust.

To avoid the issues of subjective report, some researchers have sought to address the problem of the use of metaphor by using indirect or implicit measures. Implicit measures are an effective way to capture psychological attributes that do not rely on self-report. One hypothesis is that if moral disgust is a sub-type of disgust then indirect measures, including button presses measuring reaction times and physiological responses, should show relative similarities across experimental paradigms for pathogen and moral disgust as motivating avoidance behaviours.

One study investigated facial expressions in response to pathogen related disgust items and an ultimatum game which was manipulated to be unfair, which was used to induce moral disgust (Chapman, Kim, Susskind, & Anderson, 2009). They used electromyography (EMG)

to obtain a baseline disgusted facial expression using bad tastes and smells. They then compared the EMG data with the facial expressions from the unfair ultimatum game. They found that the facial activity did not differ between the two conditions. However, this study was challenged where it was argued that the similar facial expression in the two conditions revealed another use of metaphor (Royzman & Kurzban, 2011a, 2011b).

It is possible that facial expressions can be used metaphorically as in language. The function of the disgusted facial expression is argued to promote the rejection of pathogenic substances (Rozin & Fallon, 1987). The wrinkled nose reduces the nostril size preventing inhalation of bad odours and airborne pathogens, the squinted eyes reduces the surface area of the eyes protecting against airborne pathogens and the gaped mouth promotes the expulsion of consumed items that may be pathogenic. A facial expression akin to those just described in response to morally offensive behaviours clearly does not serve the same functions. Presumably, it is a socially informative cue to others signalling dislike or a metaphorical form of rejection.

Other indirect measures, such as the lexical decision task, are an effective way to probe differences between implicitly evoked emotion and their effects on language processing. In a typical lexical decision task, participants must discriminate words from non-words (i.e., a made-up word that is pronounceable in a given language). Reaction times are generally faster to detect a real word from a non-word based on familiarity with actual words (Balota et al., 2007). When the actual words contain emotional content, this can modulate reaction times in a lexical decision task. One group of researchers tested differences between moral and pathogen disgust using lexical decision (Luo et al., 2013). Participants were presented with pathogen related words (e.g., faeces, maggot), immoral related words (e.g., spy, blackmail),

neutral words (e.g., glass, paper) and non-words. They found that participants' reaction times were faster and more accurate when identifying pathogen related words relative to moral words. These differences could be due to different emotions that are evoked by the words in the pathogen and moral disgust categories

Together, the above studies reveal some subjective similarities but objective differences between pathogen and moral disgust, casting doubt upon the existence of a moral disgust category that builds on pathogen disgust mechanisms. However, there are other studies that have attempted to demonstrate a link between these types of disgust such as looking at the effect of pathogen disgust on ratings of moral transgressions. Schnall, Haidt, et al. (2008) induced disgust prior to participants rating moral transgressions in four separate experiments. They induced disgust using: 1) fart spray, 2) creating a disgusting workspace, 3) the recall of a disgusting event and 4) disgusting film clips. The authors found that the induction of pathogen disgust makes responses to moral transgressions more severe compared with their control conditions. In addition, the inverse occurred such that inducing cleanliness with words (e.g., pure, washed, clean) or handwashing prior to rating moral transgressions made moral judgements less severe than the control conditions (Schnall, Benton, & Harvey, 2008). One problem with these accounts linking pathogen and moral disgust is that other negative emotions were not induced as a control. Thus, it is possible that sadness or anger induction could result in the same effect.

An attempt to replicate the disgust induction study (Schnall, Haidt, et al., 2008) did not show the same results, with no significant effects of pathogen disgust induction on the ratings of moral transgressions (Johnson, Cheung, & Donnellan, 2014). This calls into question the link between pathogen and moral disgust. Researchers conducting a meta-analysis searched for all

studies, published and unpublished, that investigated the effects of pathogen disgust induction on responses to moral transgressions (Landy & Goodwin, 2015). They found a small effect of the induction of disgust in modulating responses to moral transgressions, however, when they controlled for publication bias, this effect disappeared. Therefore, the link between moral and pathogen disgust remains unclear.

Tybur et al. (2013) argue that the output of moral disgust is condemning behaviour toward the transgressor, which functions to maintain social order. Disgust is an emotion causing withdrawal or avoidance, whereas anger is an emotion that causes approach and condemnation (Gutierrez, Giner-Sorolla, & Vasiljevic, 2012; Russell & Giner-Sorolla, 2011a, 2011b; Seidel & Prinz, 2013). Therefore, it is important to distinguish between moral anger and moral disgust. The distinction between these moral emotions is yet to be fully elucidated. Some have suggested that moral disgust is predominantly evoked in response to violations against 'nature' (Russell & Giner-Sorolla, 2011a). These include bodily violations, such as incest or necrophilia, and culturally scaffolded taboo acts such as cannibalism or eating dog meat. In contrast, moral violations concerning intentional harm against others and violations of justice evoke anger, contempt and outrage (Horberg, Oveis, Keltner, & Cohen, 2009; Russell & Giner-Sorolla, 2011a., Fessler & Navarette, 2004). Although there may be a type of moral disgust that causes a sense of repulsion or disgust in response to moral violations, not all moral violations evoke disgust. Moreover, if disgust acts as an aversion/avoidance mechanism, moral disgust is unlikely to result in advancing condemning behaviours toward the transgressor with anger or outrage. Thus, Tybur's (2013) argument that moral disgust causes condemning behaviours to maintain social equilibrium may need to be re-evaluated.

Now regarding the neuroimaging literature, much research has investigated the neural correlates of 'disgust' where the primary neural correlate found is the anterior insula. This has been found with disgusted facial expressions (Heining et al., 2001; Phillips et al., 2004) disgusting odours (Wicker et al., 2003) and imagining gross scenarios (Jabbi, Bastiaansen, & Keysers, 2008). If both moral disgust and pathogen disgust recruit similar brain regions, it could be said that moral disgust may have recruited pathogen disgust neural regions to provide the moral disgust foundations. Moreover, if the two conditions recruit different brain areas this could reflect the different disgust eliciting stimuli. This is a good starting point to understand the neural circuitry underlying responses to pathogen and moral stimuli.

There is some preliminary neural evidence that responses to moral transgressions recruit similar regions in the brain as those activated in response to pathogen related stimuli. There are, however, also recruitment of many different areas between the two conditions. In two studies, neural activity was recorded using fMRI in response to: 1) moral versus pathogen related sentences; and 2) moral versus pathogen related images (Moll, de Oliveira-Souza, Bramati, & Grafman, 2002; Moll, de Oliveira-Souza, Eslinger, et al., 2002). Common areas of activation were found in limbic regions of the brain, whereas moral disgust showed greater activation in the frontal and temporal regions. In another study, neural activity was compared between pathogen disgust sentences (e.g., a vomit related story) and sentences said to evoke indignation (e.g., seeing a cockroach in a restaurant). Whereas the authors found insula activity in the indignation condition, the stimuli were confounded. Cockroaches are generally categorised as pathogen related disgust.

Another study using fMRI (Borg, Lieberman, & Kiehl, 2008) compared neural activity of pathogen disgust and moral disgust sentences. Common and distinct regions in the brain were

active for both conditions. Common regions were found in the medial prefrontal cortex and the left temporal lobe. Differences were found such that pathogen sentences showed greater activity in limbic regions of the brain and moral sentences activated regions in the prefrontal and anterior cingulate regions. Overall, common neural activity to both conditions could represent the use of similar 'disgust' mechanisms and the distinct activity found could represent the differing semantic content. However, these researchers did not control for valence and arousal differences in their stimuli. Therefore, we do not know if the distinct activity between the conditions was due to an effect of the difference between the disgust conditions, or an effect of the different valence and arousal of the stimuli.

In sum, the evidence for a link between moral and pathogen disgust mechanisms using self-report and indirect measures is mixed. The finding of common neural architecture underlying the two categories of disgust could suggest that moral disgust has co-opted pathogen disgust mechanisms, however, some of the stimuli were confounded, and valence and arousal was not controlled. It is important to develop well-controlled stimuli when pitting two conditions against each other to ensure that the difference between conditions can only be the result of the manipulation, here, the induction of different types of disgust.

Sexual disgust

As stated previously, the data in support of sexual as a form of disgust is scant. According to the three-domain disgust theory (Tybur et al., 2013), both sexes have disgust mechanisms that are directed toward avoiding sexual advances from mates of low fitness value. Their evolutionary explanation is that relations of this type would result in unhealthy offspring. To my knowledge, no one has directly tested this hypothesis. It is possible that the type of 'sexual' disgust argued for is more closely linked to sexual selection theories. I will therefore

review the literature on sexual selection mechanisms such as mate-choice and kin-selection theories. I will then outline the literature that examines 'disgusted responses' in relation to certain sexual activities such as incest.

There is a lack of data supporting the notion of 'sexual' disgust, although, a link between pathogen disgust and sexual *arousal* has been established. Stimuli such as bad smells, imagining disgusting scenarios, viewing disgusting images, like dirty toilets or garbage dumps, have been shown to modulate sexual arousal in both men and women (Andrews, Crone, Cholka, Cooper, & Bridges, 2015; Fleischman, 2014; Stevenson, Case, & Oaten, 2011). Pathogen disgust has also been implicated in certain sexual dysfunctions (de Jong, van Overveld, Schultz, Peters, & Buwalda, 2009). However, despite this link between pathogen disgust and sexual arousal, this is not the type of sexual disgust proposed by Tybur et al. (2013).

The justification put forward by Tybur et al. (2013) may be more reminiscent of the well-known, mate-choice theory (Buss, 1989; Trivers, 1972), rather than being a specific sub-type of disgust. Proponents of mate-choice theory and sexual selection theory propose that both sexes have mechanisms for identifying mates of high fitness value which will result in beneficial mating outcomes. Specifically, Trivers' (1972) suggests that female and male sexual strategies for finding potential mates are substantially different because of the different parental investment. That is, females invest significantly more in offspring than do males. Because of this sizeable investment, females tend to be very choosy when selecting a mate. Females seek potential partners based on various physical and mental factors, such as masculinity, youth, attractiveness, good health and their potential as a 'father' in support of raising the child. Arguably, the rejection of a potential partner of low fitness value or of low

genetic compatibility may not be a type of sexual disgust, but rather a well-evaluated decision based on maximising reproductive opportunity. To my knowledge, there is no empirical data on mate rejection as a form of disgust on the basis of low genetic fitness or genetic compatibility. Thus, it is difficult to gauge whether the rejection of sexual mates contributes to a type of 'sexual' disgust.

It is possible that 'sexual' disgust is felt in response to sexual advances from genetically incompatible mates (i.e., kin) proposed by Tybur et al. (2013). Studies have investigated kin-recognition systems in humans, a system which motivates avoidance of sexual contact with kin and those of co-residence (Antfolk, Karlsson, Backstrom, & Santtila, 2012; Antfolk, Lieberman, Albrecht, & Santtila, 2014; Lieberman, Pillsworth, & Haselton, 2011; Lieberman & Smith, 2012; Lieberman, Tooby, & Cosmides, 2003, 2007). This is because copulation with close relatives would be deleterious to the offspring. This kin-recognition system related to inbreeding avoidance has also been investigated in other animal species (Brouwer, van de Pol, Atema, & Cockburn, 2011; Lebigre, Alatalo, & Siitari, 2010; Lihoreau, Zimmer, & Rivault, 2007; Nelson-Flower, Hockey, O'Ryan, & Ridley, 2012; Whitehorn, Tinsley, & Goulson, 2009). Other researchers link the pathogen avoidance system with the avoidance of sexual activity with kin members (Bittles & Neel, 1994; Tooby, 1982). From this point of view, kin-recognition systems shape sexual behaviours to avoid inbreeding. Therefore, it seems more plausible to consider the rejection of kin as potential mates to fit within the kin-recognition system rather than a specific disgust mechanism.

In summary, to date, there is no empirical evidence that either males or females feel 'sexually disgusted' toward potentially unfit mates. Given that the Basic Emotion theory proposes that sub-types of a basic emotion will show similar patterns of neural and behavioural activity,

one way to test the idea that sexual is a form of disgust is to pit it against pathogen disgust. Pathogen disgust is complemented by behavioural signatures, such as avoidance, and the neural signatures, such as insula and limbic activity (Jabbi et al., 2008; Moll, de Oliveira-Souza, Bramati, et al., 2002; Moll et al., 2005). If sexual is a form of disgust, then we should observe similar patterns of behaviour and similar neural activity.

Summary

To recap, theories of emotion tend to agree that there are universally recognised emotions (Barrett & Wager, 2006; Ekman, 1992; Ekman & Cordaro, 2011; Lindquist et al., 2012; Panksepp & Watt, 2011). Overall agreement lies with the notion that each of the basic emotions (happy, fear, anger, sad, surprise and disgust) are universally recognised because of their evolved function in keeping the organism responding to its environment in an appropriate way. The prototypical disgust facial expression is recognised across cultures (Ekman et al., 1969) and even in infants (Danovitch & Bloom, 2009). Its characteristic expression features a gaping mouth, wrinkled nose and squinted eyes. In various studies inducing pathogen disgust via images, smells, tastes and tactile stimuli, the disgusted facial expression is often matched. Additionally, Basic Emotion theory proposes that sub-types of a basic emotion share behavioural, physiological and neural profiles (Levenson, 1992; Vytal & Hamann, 2010). Therefore, if moral and sexual are included within the three domains of disgust, then they should show differences subjectively, but similarities in objective measures. There is plenty of behavioural and neural data showing similarities (and differences) among pathogen and moral disgust. There is very little research, however, testing whether sexual disgust exists or whether sexual responses are not a form of disgust. This is the focus of the research in this thesis.

Outline of thesis chapters

In the current thesis, I performed four experiments to investigate behavioural and neural outputs in response to the proposed three domains of disgust. My general hypothesis is that 'sexual disgust' is not objectively similar to pathogen and moral disgust. With respect to my chosen stimuli for the following experiments, although images with emotional content provoke affective reactions, it was difficult to find well controlled images that defined moral and sexual disgust. Therefore, I have used linguistic stimuli to represent the three domains; that is, words and sentences that evoke sensations in their respective categories.

Priming disgust prior to lexical decision (Chapter 2)

In the first experiment, I set out to test for differences between the three domains of disgust using a lexical decision task as an implicit measure of the degree to which the meaning of each word is processed. I also included a sentence prime that was designed to invoke one of the three putative types of disgust.

Traditionally, in a lexical decision task, participants have to identify a real word from a non-word (a word that is pronounceable in a language, but is not an actual word, e.g., waferfall). Typically, participants are faster to identify real words from non-words due to familiarity with the word (Balota & Chumbley, 1984; Balota et al., 2007). In the emotion literature, participant responses on lexical decision tasks are slower for a real word when it contains emotion content compared with a neutral word with no emotional component (Hofmann, Kuchinke, Tamm, Vo, & Jacobs, 2009; Kousta, Vinson, & Vigliocco, 2009). This interference effect is thought to be due to the attentional capture of the emotional content of the word, something that does not occur for neutral words.

Lexical decision reaction times are modulated when participants are primed with emotional content. Positive primes tend to speed lexical decisions whereas negative primes tend to slow lexical decisions (Delgado, Rodriguez-Perez, Vaes, Leyens, & Betancor, 2009; Kissler & Koessler, 2011). This slowing effect of negative valence on lexical decision is thought to reflect a source of interference. Disgust is on the negative spectrum of the valence scale, thus I expected that priming the participants with the different types of disgust would slow their reaction times compared with the control conditions.

The three domains of disgust contain differing semantic content (e.g., pathogen relating to disease; moral relating to corrupt behaviour and sexual relating to certain body parts, body fluids and behaviours). I predicted that lexical decision reaction times would differ for the different domains, reflecting the different attentional capture effects of the categories. Additionally, the sentence primes may elicit negative emotions other than disgust in the participant. Such emotions may slow lexical decision times, reflecting an additional source of interference. I therefore developed a task in which participants read sentence primes prior to making a lexical decision.

I created short sentences pertaining to the three types of disgust stimuli as proposed by Tybur and colleagues (2013), which were used as priming stimuli. These sentences were created to induce the types of disgust as referred in the three-domain disgust theory. For example, the sexual stimuli were to represent types of relations that should be found disgusting according to the three-domain hypothesis. A short sentence prime was presented prior to each word/non-word probe, on which participants had to make a lexical decision. The probe words were: a) semantically related words; b) unrelated words; or c) non-words. The related probes were words that had a perceived association with the sentence prime, (e.g., 'drinking your

own urine' followed by 'swallow'). The unrelated words had no such association (e.g., 'drinking your own urine' followed by 'revolve'). The non-word portion of the experiment (e.g., 'drinking your own urine' followed by 'fulfilp') acted as a filler task. There were three disgust conditions (pathogen, moral and sexual) and three probe conditions (related word, unrelated word and non-word). I used a Latin square design with 3 separate participant groups, such that participants did not see a sentence prime more than once. Sentence primes were matched on number of words and the probe words were matched on lexical characteristics (word frequency, word length and orthographic neighbourhood). I also attempted to match as closely as possible the sentence primes across the three disgust conditions on valence and arousal measures.

Before administering the lexical decision task, a separate set of participants were given an emotions survey to validate the short sentence primes. The survey consisted of each of the sentence primes along with 11 emotional adjectives (disgusted, repulsed, grossed out, embarrassed, ashamed, guilty, angry, indignant, sad and content). Participants could choose as many or as few adjectives as they felt in response to the prime sentences. I did this to ensure that 'disgusted' was chosen in response to all sentence primes. I also used this survey to examine whether emotional adjectives clustered into three groups representing the different disgust emotions. In the main lexical decision experiment, participants also undertook this survey following the completion of the lexical decision task. I did this to confirm that the three domains remained in the same clusters. The results showed that the emotional adjectives selected in response to the prime sentences grouped into three distinct clusters, suggesting that the primes fit into distinct categories.

The results of the lexical decision task showed a trend toward an interaction between word probe and disgust category. Noting the need for replication with greater statistical power, the interaction suggests that participants were slower to make lexical decisions following sexual primes to both related and unrelated probe words, whereas pathogen and moral primes only slowed responses to unrelated probe words. This suggests that the sexual primes affected reaction times differently relative to both moral and pathogen primes. I therefore speculate that there might be something different about sexual stimuli as a domain of disgust.

Colour-naming disgust words using the emotional Stroop task (Chapter 3)

The first experiment showed a marginal interaction between the sexual category relative to both moral and pathogen categories in lexical decision. In this second experiment, I explored the same three potential sub-types of disgust within an emotional Stroop paradigm.

The classic Stroop task is characterised by an interference effect from task irrelevant information (Cohen, Dunbar, & McClelland, 1990). This happens when a colour word (e.g., 'red'), is presented in an incongruent ink colour (e.g., green ink); the word meaning interferes with participants' ability to name the ink colour. The emotional Stroop is an adaptation of this logic which explores the impact of emotionally-laden words. The negative emotional content of words slows colour naming reaction times as compared with neutral words (Algom, Chajut, & Lev, 2004; Larsen, Mercer, & Balota, 2006). Here, I used the emotional Stroop task to explore the weak effects we saw in the lexical decision task.

I selected 24 words in each disgust condition as well as two controls (pathogen, moral, sexual, matched control and neutral control) from internet searches and word databases (Bradley & Lang, 1999; R. A. Stevenson et al., 2011). Prior to the main experiment, I verified

that the words were classified by an independent group of participants into the expected categories: a) illness/disease, b) moral, c) sexual or d) none. This validated the allocation of words to condition. These participants also rated the words on valence and arousal scales, so that we could choose stimuli that were not significantly different on these measures. Stimuli were also matched on lexical characteristics (word frequency, word length and orthographic neighbourhood). After controlling for valence, arousal and lexical characteristics, we were left with 13 words in each condition. For the main experiment, a new group of participants were presented with these words, together with a matched control (i.e., words matched on valence and arousal but not related to disgust) and a neutral control (i.e., words that did not match on valence and arousal with no emotional content). Participants were instructed to name the colour of the font of the presented words as quickly and accurately as possible while ignoring the actual word. Immediately after the emotional Stroop task, they were given an unexpected recall task where they were asked to name as many words as they could from the main task.

The results showed significantly slower reaction times when naming the colour of sexual words compared with any other category. Additionally, in the follow-up word recall task, significantly more sexual words were recalled than words in any other category. These results are consistent with those of the lexical decision task, providing further support that the sexual category is different to both pathogen and moral categories. I suggest that the taboo nature of the sexual words might account for these results, rather than an effect of disgust *per se*. Whereas some sexual stimuli may be construed as disgusting, there may be another component of sexual stimuli which elicit different affective states. I therefore suggest that the proposed 'sexual disgust' may not be a source of disgust if the taboo nature of the words account for the effect.

One of the main hypotheses of Tybur and colleagues' (2013) three-domain disgust theory is that moral and sexual disgusts evolved later by co-opting mechanisms of the more primitive pathogen disgust. My results from two linguistic paradigms show behavioural differences between the sexual domain compared with both moral and pathogen domains. This raises a challenge for the claim that these domains share underlying mechanisms. It has been shown that various experiences of the categories of pathogen, moral and sexual activate common and distinct areas of the brain (Borg et al., 2008; Moll, de Oliveira-Souza, Eslinger, et al., 2002; Moll et al., 2005). I therefore used fMRI to explore the neural correlates of the three domains using linguistic stimuli.

Neural correlates of disgust related words (Chapter 4)

The first two experiments of this thesis demonstrated a difference between the sexual domain compared with both pathogen and moral domains. The next obvious step is to use these linguistic stimuli for the different conditions to explore brain activity. If indeed the moral and sexual domains of disgust co-opt pathogen disgust mechanisms, then we should see common neural activations. In the previous lexical decision and emotional Stroop tasks, the results showed that the sexual category was distinct from both moral and pathogen categories. On the basis of these results, I predicted that neural activity would differ significantly for the sexual category compared with both moral and pathogen categories. I did not expect large differences between the moral and pathogen categories.

I searched for substantially more words in each condition to increase the scope and statistical power of the representative words. I found 90 words in each condition (pathogen, moral, sexual and matched control) and selected stimuli such that the words were not statistically

different on valence and arousal scales. I also matched the stimuli on the lexical characteristics mentioned in the two previous experiments. I was left with 32 words in each condition. I also had a scrambled word control condition, to match the visual aspects of the words without them being actual words. In a passive viewing task, participants were presented with blocks of eight words from each condition. Participants were given an attention task to ensure they were attending to the stimuli. Following the scanning, participants selected a disgust rating for each of the words on a scale of 1 (not disgusting) – 7 (very disgusting).

In the whole brain univariate analysis, when activity in the scrambled word condition was subtracted, there was significantly broader neural activation in the sexual condition compared with moral and pathogen conditions. The sexual condition activated temporal gyri, hippocampus, amygdala and regions in the frontal cortex, and this activity was not observed in the other conditions. In an exploratory analysis which looked at neural regions that were activated in all three conditions, the type of activity (Blood Oxygen Level Dependent (BOLD) signal) differed mostly between the sexual and moral domains. Overall, the differing neural activity observed in the sexual category is indicative of a difference of sexual as a distinct domain relative to at least the moral condition. I take this as further support that the sexual category may not reflect a disgust mechanism.

My first three experiments used objective data to reveal differences between sexual, moral and pathogen-related stimuli suggesting sexual responses are distinct. In my final experiment, I explored the subjective experiences evoked by the three domains.

Bodily sensations of the three domains of disgust (Chapter 5)

Prior work on subjective sensations in response to specific emotions has shown that emotions are represented in the body differently (Nummenmaa, Glerean, Hari, & Hietanen, 2014). According to Basic Emotion theory, whereas sub-types of a basic emotion share behavioural, physiological and neural correlates, subjective reports on those sub-types should be different. Therefore, in the final study I wanted to investigate whether words in each of the categories are represented in the body differently. I expected that words within a category would correlate and words between categories would be different.

I adapted the emBODY software developed by Nummenmaa et al. (2014) for use on the crowd-sourcing platform, Amazon's Mechanical Turk. Participants were asked to 'colour in' two mannequin human bodies on a computer using a mouse. One mannequin was coloured in red, which represented where participants felt an 'activation' or 'hot' sensation in their body in response to a word. The other mannequin was coloured in blue which represented where participants felt a 'deactivation' or 'cool' sensation in their body in response to a word. We gathered data from 280 participants. Each of the domains were reported to be felt in different parts of the body.

Heat maps revealed a different distribution of responses for the three domains of stimuli. Participants coloured pathogen words were red around the mouth, neck and hands and blue around the arms, torso and legs; moral words were red around the head, chest arms and hands and blue around the torso; sexual words were red around the genital, chest and head. A modelled dissimilarity matrix for each of the words revealed no correlations within the categories which we did not expect. When we averaged the conditions together, which increased our statistical power, the categories were reported to be experienced differently.

The results from this experiment illustrate that subjectively reported bodily sensations in the three domains are represented in different regions of the body. This could speak to the idea that the different emotions evoked by the three domains motivate different kinds of behaviours. However, these results do not confirm, nor deny that sexual may be considered differently from pathogen and moral disgusts. Nor do they tell us whether the domains are related to disgust. However, because Basic Emotion theory predicts that sub-types of basic emotions are subjectively different, this experiment is informative that at least the domains proposed by Tybur et al. (2013) are reported to be different.

General discussion

The experiments performed in the current thesis involved both objective and subjective measures of responses to the three domains of disgust. The subjective data reveal that bodily sensations differ for all three domains. Additionally, when the word stimuli and priming sentences were subjectively categorised, they were classified mostly into their respective categories. This supports the idea that the subjective appraisal of each of the domains are distinct. Considering Ekman's (1992) Basic Emotion theory, these results provide support for the hypothesis that each of the proposed domains are sub-types of disgust given their different subjective profiles. However, the objective data obtained does not support this hypothesis. In the final chapter, I consider some reasons why sexual may not be classified as a specific type of disgust and discuss the plausibility of the three-domain disgust theory.

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Chapter 2: Priming the Three Domains of Disgust Affects Lexical Decisions in the Sexual Domain

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Priming the Three Domains of Disgust Affects Lexical Decisions Differentially

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Abstract

Disgust is an emotion that causes avoidance or aversion of particular entities. The literature identifies three domains of disgust: 1) pathogen – avoiding potentially infectious or disease-causing items, 2) moral – avoiding morally reprehensible individuals and 3) sexual – avoiding certain sexual stimuli or situations. These three distinct forms of disgust are thought to have evolved because of their different adaptive functions; thus, we may have mechanisms to detect these forms of disgust rapidly. We explored this hypothesis by testing implicitly evoked disgust using an indirect measure. We presented participants with disgust and control sentences prior to lexical decisions on related or unrelated probe words vs. non-words (e.g. 'drinking your own urine' => 'swallow' (related probe) or 'revolve' (unrelated probe) or 'fulfilp' (non-word)). Participants were also asked to identify emotional adjectives evoked by the sentences in an emotions survey after the main task. The lexical task results showed participants were significantly slower at responding to related probe words following sexual disgust sentences compared with related probe words following pathogen and moral disgust sentences. The emotions survey revealed that different emotional adjectives were elicited by all three disgust domains. These results provide support for Basic Emotion theory suggesting that the sexual response may be a candidate for consideration as a separate basic emotion.

Key words: disgust, pathogen, moral, sexual, lexical decision.

Introduction

The smell of fouled milk, the sound of someone vomiting, or the sight of maggot infested meat, are the sorts of incidents that evoke a disgusted response in humans. These responses typically cause withdrawal or avoidance of such articles and are referred to as core or pathogen disgust. This type of disgust mechanism serves to maintain one's health by causing behaviours that aid in avoiding these contaminating substances. In addition to pathogen disgust, typical responses to racial slurs, exploitative behaviour and outright disrespect are forms of moral disgust. This type of disgust has a tendency to cause withdrawal from individuals displaying these malevolent behaviours to maintain one's social and moral integrity. Finally, incest is an example of a behaviour that evokes sexual disgust, which is said to trigger the avoidance of mating opportunities that may be deleterious to offspring. There are several theories based on these three domains of disgust, with the evolutionary justification playing a strong role (J. Borg, Lieberman, & Kiehl, 2008; Tybur, Lieberman, & Griskevicius, 2009; Tybur, Lieberman, Kurzban, & DeScioli, 2013).

There has been research on all three proposed domains of disgust, linking each to evolutionary explanations. The experience of pathogen disgust has been shown to cause avoidance of pathogenic substances, presumably to assist survival (Curtis, 2011, 2014; Curtis & Biran, 2001; Curtis, de Barra, & Aunger, 2011). In the domain of moral disgust, researchers have claimed that it promotes group cohesion by shunning and punishing those who transgress, thus maintaining the integrity of one's social group (Haidt, 2007; Tybur et al., 2009; Tybur et al., 2013). Regarding sexual disgust, research examining mating strategies propose that typical pathogen disgust responses to bodily fluids can be down-regulated by erotically arousing stimuli, thus promoting copulation (Andrews, Crone, Cholka, Cooper, & Bridges, 2015; Antfolk, Lieberman, Albrecht, & Santtila, 2014; C. Borg & de Jong, 2012;

Fessler & Navarrete, 2003; Stevenson, Case, & Oaten, 2011). Moreover, responses to sexual acts, such as incest, help to avoid copulation that may be deleterious to the offspring. This research suggests that sexual disgust could play a role in modulating certain behaviours that impact sexual strategies. Taken together, an evolutionary account of the different types of disgust could explain these results. Although it is challenging to provide direct tests of such evolutionary theories, one prediction is that if domains of disgust have different adaptive functions, they may have distinct underlying cognitive and affective mechanisms that may be detectable in behaviour.

Very little research has compared all three domains of disgust using the same measure, although there are some comparative studies involving two domains. Research comparing moral and pathogen disgust has obtained mixed results. For example, one can measure electromyography (EMG) signals from the facial muscles that are involved in expressing disgust and look for activation of this muscle when presented with either pathogen or moral disgust stimuli. Chapman, Kim, Susskind, and Anderson (2009) used EMG to record facial expressions in response to bitter tastes and pictures of contaminants, which were said to represent pathogen disgust. In this condition activation of the levator labii muscle was present. EMG was then recorded when participants played an *unfair* ultimatum game, which was designed to evoke moral disgust. They found that the levator labii muscle was similarly activated in the moral condition. They argued from these findings that these are indeed similar forms of disgust. In another study, Zhong and Liljenquist (2006) asked participants to remember events of past moral transgressions. Subsequently, participants were asked to select from a range of products, either neutral products like a pen, or cleaning related products, such as soap. Participants tended to select cleaning related products when

remembering their past transgression. The authors argue that cleaning products reminds them of pathogen disgust and therefore, moral and pathogen disgust are related.

In contrast to the above studies, Simpson, Carter, Anthony, and Overton (2006) found participants reported different emotions in response to pictorial images of pathogen versus moral disgust, and that over time, disgust responses became stronger for moral disgust but attenuated for pathogen disgust. They suggested that this is support for the distinction of the two emotions. As these studies use different measures and approaches, the relationship between pathogen and moral disgust is still unknown. Moreover, there are no relevant behavioural studies that include sexual disgust; experimental focus has been limited to comparing moral and pathogen disgust.

To our knowledge, the only study comparing the three domains of disgust is an fMRI study (J. Borg et al., 2008). The researchers embedded sentences pertaining to pathogen disgust, moral transgressions and incestuous acts within blocks of neutral sentences. In a subsequent recall task, participants had to identify whether one of two presented sentences came in the previous block. The authors found distinct, as well as common, neural underpinnings for incest, pathogen and moral sentences, although they found that incestuous acts elicited activation in more brain regions than moral and pathogen sentences. This research is an important beginning to disentangling the neural underpinnings of the three domains of disgust. If each of the disgust types functions as an adaptive avoidance system then these neural differences should manifest in behaviour.

One way to assess behavioural effects of different types of disgust is to use an indirect measure. Indirect measures, where one looks at the effect of an emotion (here disgust) on an

orthogonal task, can provide useful indices of the degree to which the emotion influences language processing. Lexical decision tasks, where participants have to discriminate a word from a pronounceable non-word, are popular tasks for this purpose (Balota et al., 2007). Typically, participants are quicker to detect real words compared with non-words due to the familiarity of the words stored in a mental lexicon. Importantly, response times are slower for words containing negative emotion-invoking content such as, 'disaster' or 'hate' compared with neutral words such as 'table' or 'hat' (Hofmann, Kuchinke, Tamm, Vo, & Jacobs, 2009; Kousta, Vinson, & Vigliocco, 2009; Larsen, Mercer, Balota, & Strube, 2008). This modulatory, or interference effect on lexical decision, is thought to be due to the emotional words capturing attention.

There are two competing theories to account for the effect of emotion words on language processing. The Basic Emotion theory, originally proposed by Ekman (1992), suggests that there are six basic emotions (happy, anger, sadness, fear, surprise and disgust), each with distinct behavioural and autonomic profiles. There is support that basic emotion theory can account for effects on language processing, such that the variance in reaction time to emotionally laden words can be explained by the six basic emotion categories. For example, Briesemeister, Kuchinke, and Jacobs (2011) used a lexical decision task and presented emotionally laden words controlling for valence and arousal. They found that differences in reaction times across five basic emotions (happy, anger, sadness, fear and disgust) were predicted by those emotion categories, that is 'happy' words were identified the fastest, disgust words the slowest and anger, sad and fear words lie in between.

The basic emotion theory also predicts that each of the six basic emotions contain sub-categories within that emotion (Ekman, 1992). Within the sub-categories of a basic emotion,

common profiles exist. For example, a number of different anger facial expressions have been identified, however, they all share common features, such as furrowed brows and tightened lips. Moreover, similar physiological profiles are found within sub-categories of a basic emotion (Levenson, 2003). Thus, if sub-categories of disgust exist (pathogen, moral and sexual) we would predict that behavioural responses to those sub-categories may vary to a degree but would primarily share common profiles specific to the basic emotion of disgust.

In contrast to basic emotion theories, dimensional theories of emotion suggest that the continuous dimensions of valence and arousal explain the emotional effects on behavioural (reaction times) and autonomic (physiological) profiles. According to this theory, the differences in valence and arousal in emotional content explain the effects on word processing (Bradley & Lang, 1994; Lang, Bradley, & Cuthbert, 1990). For example, high arousal negative words are processed faster than low arousal negative words (Hofmann et al., 2009).

The dimensional theory of emotion would predict that if a task contained emotion words from the five basic emotion categories matched on valence and arousal the response times would not differ (Russel & Gina-Sorolla., 2011). This is because variance due to valence and arousal has been eliminated, thus there should be no difference in response times. On the other hand, if responses in the emotion words task differed, then we would find support for basic emotion theory. This is because any variance cannot be due to valence and arousal and therefore, the variance is most likely explained by the emotion category. An indirect measure, such as lexical decision, is a good starting point to disambiguate the two theories.

Lexical decision tasks are one method of indirectly testing the extent to which processing of words is affected differentially by purportedly different types of disgust. For instance, Luo et al. (2013) used a lexical decision task where subjects were presented with pathogen disgust words (e.g., maggot, faeces) moral disgust words (e.g., spy, blackmail), neutral words (e.g., glass, paper) and non-words. They found that pathogen disgust words were detected faster than neutral and moral words, and participants were more accurate on pathogen disgust words compared with moral disgust words. This study provides a basis for studying the three types of disgust and their effects on behaviour using lexical decision.

Lexical decision is a simple word vs non-word decision. There is evidence that words associated with pathogen disgust are discriminated faster than those associated with moral disgust, or neutral words (Luo et al., 2013). This suggests that a word related to a disgusting concept could influence the time it takes a participant to decide if it is, in fact, a word. Here, we took this idea further by asking whether an indirect task, like lexical decision, could index differences between types of disgust. We presented participants with sentence primes related to pathogen, moral or sexual disgust and recorded lexical decision times in response to a subsequent probe stimulus. The probe could be a 'related' word, which had a semantic relationship with the prime sentence, an 'unrelated word', which had no such relationship, or a pronounceable non-word. We inferred that the difference in reaction times to the lexical decision task reflect different underlying affective processes due to the different types of disgust. In a second task, participants were asked to select emotions that the disgust primes evoked, forming a direct subjective measure of the disgust prime sentences. We predicted that: 1) the type of disgust prime would differentially affect reaction times to detect related and unrelated words; and 2) that evoked emotions in response to the primes would differ.

Methods

Participants were recruited from Macquarie University's psychology and cognitive science participant pools. The aim of this study was to explore whether lexical decision could index differences between types of disgust. In three validation studies, we aimed to match our disgust sentences on ratings of valence, arousal, as well as exploring emotional adjectives evoked by the sentences (see below). These validations were conducted on one group of 16 participants from the department of cognitive science at Macquarie University. For the main experiment, we tested three groups of 20 (n = 60) participants (age 26.6 ± 7.5, F = 40) each, in a mixed-subjects design. We chose this sample size based on previous lexical decision experiments (Hofmann, et al., 2009). Participants received course credit or were reimbursed $15AU for their participation. This study was approved by the Macquarie University Human Research Ethics Committee and all participants gave written informed consent.

Validation studies of disgust prime sentences

Three categories (pathogen, moral and sexual) of disgusting stimuli were developed for the current experiment. Short sentences were created to use as priming stimuli in the lexical decision task, 40 in each of the three domains. We developed the sentences and probe words based on the three-domain disgust theory (i.e., pathogen sentences related to disease causing stimuli, moral sentences related to transgressive behaviour and sexual related to relationships that are deleterious to offspring health). We had an initial group of participants rate the sentences on three questions, presented in counterbalanced order (n = 16). In one question, participants were asked to rate the valence of each sentence on a scale of 1 (negative) – 7 (positive). In another question, participants were asked to rate how much each sentence grabbed their attention on a scale of 1 (not at all) – 7 (very much so) to get an estimate of arousal. The third question, we asked participants to report their response to each disgust

prime out of 11 emotional adjectives (disgusted, repulsed, grossed out, embarrassed, ashamed, guilty, angry, indignant, sad and content). These pilot ratings were conducted to match the valence and arousal of the disgust primes as closely as possible. We also wanted to ensure that each prime sentence elicited the emotion of disgust gathered from the third question. We then selected the stimuli for the experiments based on disgust being evoked by each sentence and closely matching the valence and arousal ratings of all the sentences.

We selected stimuli for the main experiment by eliminating sentences in all three disgust types that did not closely match in valence and arousal, leaving 63 sentences (21 in each disgust domain). We then performed two one-way ANOVAs with the factor of disgust type (pathogen, moral and sexual) on the ratings for valence and arousal separately. There was a significant main effect of valence ($F_{2, 60} = 21.053$, $p < 0.001$). A Tukey's HSD post hoc test showed that this arose from a significant difference between pathogen versus sexual and pathogen versus moral primes ($p < 0.001$). There was no significant difference between sexual and moral primes ($p = 0.521$). There was a significant main effect of arousal ($F_{2, 60} = 24.334$, $p < 0.001$). A Tukey's HSD post hoc test showed that pathogen versus sexual and moral versus sexual primes differed ($p < 0.001$), but there was no significant difference between moral and pathogen primes ($p = 0.448$, see Table 1). Thus, despite our initial attempt to reduce the variance of the valence and arousal of all disgust sentences, there was sufficient remaining valence and arousal variability in the stimuli to warrant using a correction of reaction times using the residuals of the variance for each of the disgust prime items (see Statistics below).

Stimuli

The selected priming stimuli consisted of short written sentences pertaining to the three types of disgust (three – seven words in length). Examples include: 'drinking your own urine' (pathogen), 'you punching a woman' (moral), 'you swallowing semen' (sexual). Also included were matched neutral controls for each of those disgust sentences. Examples include: 'drinking from your water bottle' (control pathogen), 'you helping a woman' (control moral) and 'you swallowing juice' (control sexual). Each condition contained 21 items (disgust sentences and controls), 126 items altogether. The number of words in each prime sentence was matched across disgust conditions as well as control conditions.

Following the presentation of a prime sentence, there was a letter string target that corresponded to a real word in English or a non-word (a made-up word that is pronounceable in English). In the lexical decision task, we had two categories of real words: related and unrelated. The 'related' words were selected based on their perceived association of the word with the prime sentence. The 'unrelated' words had no obvious association with the prime sentence. For example, the disgust prime sentence 'drinking your own urine' was followed by probe word: 'swallow' (related), 'revolve' (unrelated) or 'fulfilp' (non-word).

Each prime was only seen once by each participant. We therefore used a latin square design with three separate groups. Each sentence (21 prime sentences) was seen in each of the three conditions (related word prime, unrelated word prime, non-word prime) by one group of participants. For example, the sentence 'drinking your own urine' was followed by 'swallow' (related) for one group, 'revolve' (unrelated) for the second group and 'fulfilp' (non-word) for the final group (see appendices I and II for all stimuli and groupings). Each of the primes deliberately included the words 'you' or 'your' to imply that the participant was the

perpetrator to avoid ambiguity in the sentences (i.e., whether 'self' or 'other' was involved in the 'disgusting' act).

The related and unrelated probes (one for each prime sentence) were matched on orthographic neighbourhood, word length and word frequency using the 'English Lexicon Project' (Balota et al., 2007 http://elexicon.wustl.edu/). Similarly, non-words were matched on orthographic neighbourhood and word length. One third of the probes were related, one third unrelated and the final third were non-words. Thus, two thirds of the stimuli were words, which created a bias for participants to select the word response. Importantly, however, our hypotheses relate to interactions between probe type (related vs unrelated) and disgust type (pathogen, moral, sexual), all of which are performed on the word data. The non-word items were fillers; therefore, we do not analyse data from those trials.

Apparatus

The task was performed on a Samsung monitor with a standard keyboard. The lexical decision task was programmed in MATLAB (version 7.11.0) using PsychToolbox-3 (Kleiner, Brainard, & Pelli, 2007). Participants saw a prime sentence (disgust or neutral) for 2500ms and then a probe stimulus (related or unrelated word, or non-word). Participants were instructed to press the left arrow key when the probe corresponded to a real word and the right arrow key when the probe corresponded to a non-word, as quickly and accurately as possible. The letter-string remained on the monitor until the participant responded. The task took approximately 12 minutes.

Demographics and the Three Domain Disgust Scale (TDDS)

For the main experiment, participants were asked to complete a disgust survey that examines individual's disgust sensitivity in pathogen, moral and sexual disgust domains (the Three Domain Disgust Scale (TDDS) (Tybur et al., 2009)). Participants returned the completed form at least two days prior to the experiment to avoid priming the participants with disgusting stimuli on the day of the experiment. Also included in the TDDS survey was a rating scale probing participants' political attitudes. We did this based on prior research suggesting that political attitudes interact with disgust sensitivities (Terrizzi, Shook, & McDaniel, 2013). Participants were instructed to select one from four options: extreme left, mid-left, mid-right or extreme right and we coded this as a liberalism score. We also recorded participant's sex, as disgust sensitivities, particularly for pathogen disgust, tend to be higher for women than men (Simpson et al., 2006). The TDDS scores, liberalism score and sex were used as covariates in the ANOVA on lexical decision reaction times.

Emotions survey

The same participants were asked to complete a survey after the lexical decision task using the online survey software "SurveyMonkey" (1999-2016). We did this to explore whether the types of emotional adjectives evoked by the disgust prime sentence differed. The survey presented every disgust prime sentence (63 total) and participants were asked to report which of 11 emotional adjectives those disgust primes evoked (the same as in the emotions survey validation study). Pathogen disgust was expected to evoke endorsements of: disgusted, repulsed, and grossed out (Nabi, 2002). Moral disgust was expected to evoke endorsements of: embarrassed, ashamed, guilty, angry, indignant, and contempt (Rozin, Lowery, Imada, & Haidt, 1999). For the sexual sentences, we expected a combination of these emotions. We also included a control for a negative emotional adjective (sad) and a positive emotional

adjective (content). Participants could choose as many or as few adjectives as they felt in response to the primes. Participants were instructed to read the primes as though they themselves were the perpetrator.

Statistics

We used repeated measures ANOVAs with disgust sensitivities, liberalism scores and sex as covariates. As there were differences between the stimuli valence and arousal ratings across conditions we accounted for this variance by normalising reaction times using the residuals of the variance for each of the disgust items. These were then calculated, by subtracting the variance due to the difference in variance according to each item. This subtraction method was used to reduce any variance due to valence or arousal. We did not obtain valence and arousal ratings for the control sentence stimuli; thus, we report on the statistics for the corrected RT data. Results for the raw RT data, including the control conditions, can be found in Appendix III.

Results

The aim of the present study was to test whether prime sentences invoking different types of disgust can elicit a measurable behavioural difference in lexical decision time. Additionally, we wanted to explore whether emotional adjectives differed in response to the different disgust primes.

TDDS survey

We collected disgust sensitivity scores and liberalism data for 53 of the 60 participants (7 datasets lost due to technical errors in form collection). Each of the 53 participants' responses to the TDDS disgust survey were broken down into individual disgust sensitivities in each of

the domains. Therefore, each participant had an average sensitivity ranking in pathogen, moral and sexual disgust. These disgust sensitivity rankings, as well as participants' liberalism scores and gender were used as covariates in the lexical decision task analysis.

Lexical decision task

We recorded reaction times (RT) to detect related probes (words that had an association with the prime sentence), unrelated probes (words that had no obvious association with the prime sentence) and non-words (made up words that are pronounceable in English) after priming with a disgusting or a neutral control sentence. Incorrect responses were eliminated from analysis as well as responses that were 2.5 SDs away from the mean of each participant's data.

We performed a 2-way repeated measures ANOVA (3 x 2) on the corrected RT data with the factors of Disgust Category (pathogen, moral, sexual) and Probe Type (related, unrelated). The results showed a main effect of Disgust Category ($F_{2,94} = 3.839$, $p = 0.025$), no main effect for Probe Type ($F_{1,47} = 0.469$, $p = 0.497$) and a trend toward an interaction between the two factors ($F_{2,94} = 2.981$, $p = 0.056$). Acknowledging the borderline statistical significance of this interaction, we conducted post-hoc comparisons which revealed significantly faster responses to *related* probes in pathogen ($p = 0.011$) and moral ($p = 0.007$) categories compared with the sexual category, whereas there was no difference between the categories for *unrelated* probes (Figure 1).

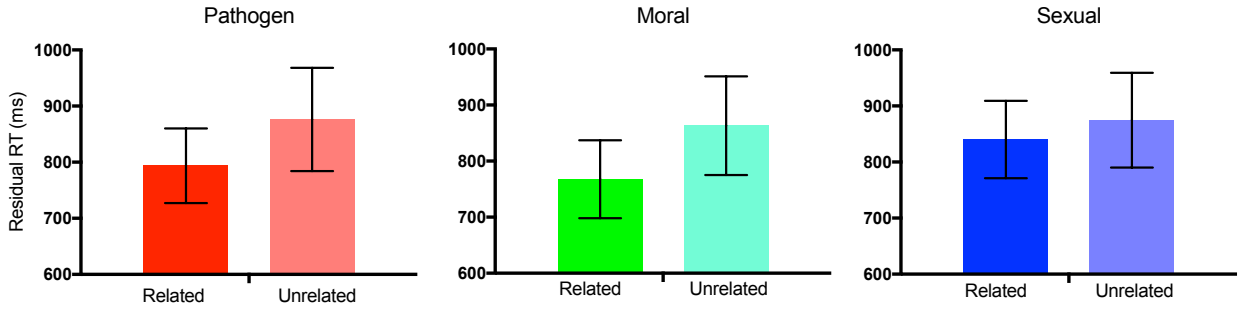

Figure 1. Corrected reaction time data from the primed lexical decision task. Averaged reaction time data in response to different probe types (related and unrelated) for the three primed conditions. There was a trend toward an interaction between disgust category and probe type such that participants were slower at identifying related probes in the sexual disgust condition compared with both moral and pathogen disgust conditions.

We then analysed the correlations between the covariates and the corrected RT data. We obtained the correlation coefficients of the covariates: disgust sensitivities, liberalism scores and sex against the corrected RT data of the 53 participants we had collected data. Pathogen disgust sensitivity correlated with related probes in both the pathogen and the sexual condition. Both correlations were negative, such that participants higher in pathogen disgust sensitivity were faster to detect related words in both pathogen (Pearson's correlation = -0.280, $p = 0.040$) and sexual (Pearson's correlation = -0.272, $p = 0.047$) conditions relative to participants lower in pathogen disgust sensitivity. There were no other correlations between disgust sensitivities and related or unrelated probes. Additionally, there were no correlations between lexical reaction times and participants' sex or liberalism scores.

Emotions survey

Once participants completed the lexical task, they were asked to select from eleven emotional adjectives (disgusted, repulsed, grossed out, embarrassed, ashamed, guilty, angry, indignant,

sad and content) to describe their response to each of the 63 (21/condition) disgust sentences. All participants' data were collated into the number of responses for each emotional adjective for each of the sentences in the disgust conditions. We performed multi-dimensional scaling which resulted in a small stress measure (stress = 0.1049) which indicates a good representation of the sentences within their disgust category. We then performed k-means clustering to delineate the groups of disgust primes into 3 clusters. Both moral and pathogen primes fit within their own clusters, whereas five sexual primes were mis-classified into either the moral or the pathogen cluster, see Figure 2.

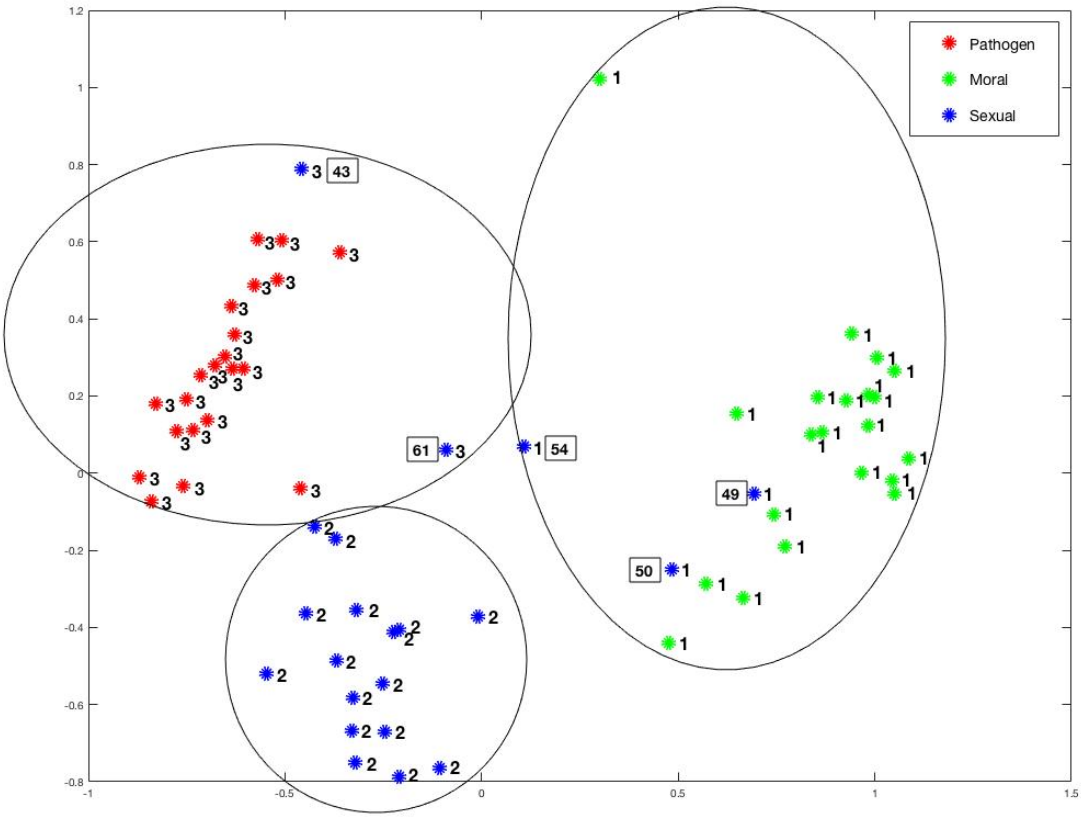

Figure 2. K-means clustering of emotional adjectives elicited by prime sentences in the three disgust categories. All pathogen sentences were grouped into one cluster (3) as were all moral sentences grouped into one cluster (1). Five sexual sentences were misclassified outside of

cluster 2. The numbers within a border next to each mis-classified data point corresponds to the sentence number (see Appendix I).

Discussion

In the present study, we primed participants with three types of disgust and tested whether this priming effect affected reaction times in a lexical decision task. Our direct report data on evoked emotional adjectives confirmed that the prime sentences elicited responses consistent with our designated disgust categories. In the main experiment, lexical decisions were slower for words regardless of whether they were related or unrelated probes when primed with sexual disgust sentences compared with moral and pathogen prime sentences. Further, we found a trend toward an interaction between disgust category and probe words with slower responses to the related than unrelated words in the sexual condition relative to the moral and pathogen conditions. This is the first study to investigate the three domains of disgust using priming on a lexical decision task. The results suggest a different response profile for sexual disgust compared with pathogen and moral disgust. It is possible that a greater sample size might reveal a more robust effect.

Regarding the marginal interaction showing that participants take longer to make a lexical decision on related and unrelated words when primed with sexually disgusting stimuli compared with moral and pathogen disgust stimuli, we suggest there are several potential explanations. First, is a dimensional emotion theory account, second, a basic emotion theory account and third, that sexual stimuli are perceived as more threatening which is explained by the automatic vigilance hypothesis. I will detail these accounts in turn.

First, we cannot completely rule out a dimensional theory of emotion to explain our data. Although we tried to match our priming stimuli in all three categories on valence and arousal, we were only able to match sexual and moral primes on valence, and moral and pathogen primes on arousal, leaving the potential that valence and arousal differences could account for some difference between conditions. However, we used a method to correct the RTs by the difference in valence and arousal ratings, which reduces the contribution of these factors. Without correction, there was a significant interaction between disgust category and probe type ($p = 0.007$, see appendix III for the raw data); with correction, there remained a trend ($p = 0.056$). If our results were just an effect of differences in valence and arousal ratings, it should not interact with probe word relatedness. We acknowledge that the interaction was marginally significant, although, this result suggests there is something different about our sexual category relative to pathogen and moral categories. However, we cannot rule out the influence of the difference in valence and arousal of the stimuli. Therefore, we cannot rule out dimensional theories of emotions (Barrett & Wager, 2006; Bradley & Lang, 1994) accounting for our results.

A second explanation for our results showing slowed reaction times due to sexual priming, is that 'sexual' as a disgust emotion might motivate different aversive behaviours from that of moral and pathogen disgust. This implies that the affective or cognitive processes underlying sexual disgust priming may be underpinned by different motivational strategies. In other words, it may be plausible to include the 'sexual response' as a basic emotion category.

Recognising that these results need to be replicated, here we outline why, using basic emotion theory (Ekman, 1992; Ekman & Friesen, 1971; Ekman, Levenson, & Friesen, 1983), the sexual response could be considered a distinct emotion. The basic emotion theory holds

that each of the basic emotions (fear, anger, happiness, sadness, surprise and disgust) are distinct because of their unique adaptive functions. Thus, each emotion has its correlate: 1) facial expression (Ekman & Friesen, 1971), 2) behavioural repertoire (Ekman, 1992), 3) physiological signatures (Ekman et al., 1983), 4) goals and action tendencies (Roseman, Wiest, & Swartz, 1994), 5) and neural signatures (Vytal & Hamann, 2010) each of which contribute to motivating the organism's behaviour in a specific way. Additionally, sub-types of a basic emotion will also share these behavioural and neural profiles. If the sexual response repertoire differs from that of moral and pathogen disgust, then it may be reasonable to consider the sexual response as a distinct basic emotion.

The notion of including the sexual response as a separate basic emotion is supported by research performed by R. A. Stevenson et al. (2011). In their study, participants were asked to subjectively rate sexual and non-sexual emotion words on 11 different measures. Three of those measures were emotional dimension scales (valence, arousal and dominance), five of those measures were basic emotion scales of whether the word elicited a particular emotion (happiness, fear, anger, disgust and sadness) and the final three measures were sexual emotional scales (sexual valence, sexual arousal and sexual energy). The researchers found that none of the basic emotions could positively predict ratings on the sexual words. Their research and the results from our study suggest that the 'sexual response' could be deemed a basic emotion.

Further evidence that the sexual response could be deemed a separate basic emotion comes from evidence that it has both negative and positive valence (Both, Laan, & Everaerd, 2011; Everaerd, 2006; R. A. Stevenson et al., 2011). For example, in the right context, a sexual act such as 'fellatio' could be perceived positively, whereas in the wrong context, it could be

viewed as negative. Support for this idea comes from one study showing that different contexts affect the perception of the same sexual stimuli thus altering participants' experience of it; viewing it as aversive or appetitive depending on the instruction (Koukounas & McCabe, 2001). In basic emotion theory, anger, sadness, fear and disgust all lie on the negative end of the valence continuum, and happiness lies at the positive end of the continuum with little variance in valence within emotion categories (Ekman & Cordaro, 2011). However, surprise is the only basic emotion that has both positive and negative valence. Thus, when considering this divergence in valence for sexual stimuli, potential adaptive functions could include, on the one hand, avoiding courtships with unfit partners when negatively valent (related family members or immune compromised partners) and on the other hand, the promotion of mating with partners of high fitness when positively valent. This variability in valence in the sexual response, might be reason to deem the sexual response as a separate basic emotion; particularly with respect to humans' need to seek appropriate mates and weigh up the costs of *mating* versus *not mating*, however, we remain tentative with this speculation.

In a different theory of emotion, the automatic vigilance hypothesis, suggests that negative words interfere with normal cognitive processes because of their nature as a potential threat and the importance of attending to such stimuli (Estes & Adelman, 2008a, 2008b; Pratto & John, 1991). This idea has been supported by showing that negative stimuli indeed capture more attention than positive stimuli creating an interference effect in experimental tasks (Hofmann et al., 2009; Pratto & John, 1991). In our study, we did our best to eliminate variance in valences, nevertheless, we cannot rule out the automatic vigilance effect. It may be that, regardless of the valence of the emotional words, the identification of words following sexual disgust priming is interfered with more significantly because of the taboo

nature of the sexual stimuli (Schmidt & Saari, 2007). If the sexual response captures attention more than other categories of disgust, this provides another plausible reason for it being considered a separate basic emotion.

There are at least three potential explanations for our findings using an implicit task to probe the different domains of disgust. Given that this is the first study to use priming in a lexical decision task to disentangle the three domains of disgust we remain tentative about these discussions. First, our results suggest that sexual disgust may be considered a separate basic emotion, especially with respect to its variance in valence. However, the interaction was not strong, suggesting we need to find a more sensitive task to test the hypothesis that the sexual response is distinct. Second, our results could be explained by the automatic vigilance hypothesis, which suggests that the nature of the sexual primes were more threatening than moral and pathogen primes. Sexual stimuli may capture more attention due to an effect of taboo-ness. Given that the pattern of results in the lexical decision task did not differ between pathogen and moral conditions, it is possible that moral is a sub-type of disgust which adaptively functions as an avoidance mechanism within a social context rather than a disease prevention context. In other words, the fact that these disgust types elicited significantly different emotions does not mean that they do not function equally as disgust avoidance mechanisms. It may simply mean that these different emotions drive a similar action, that is, to avoid certain items or events. In order to evaluate these hypotheses, future research should focus on comparing behavioural, autonomic and neural correlates of pathogen, moral and sexual disgust. Future studies may therefore support the idea of the sexual response as a candidate for consideration as a separate basic emotion.

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Chapter 3: The Emotional Stroop Reveals that 'Sexual' is more 'Taboo' than 'Disgusting'

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The Emotional Stroop Reveals that 'Sexual' is more 'Taboo' than 'Disgusting'

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Abstract

The basic emotion of disgust functions to keep us safe from disease and infection. The three-domain disgust theory proposes that humans have three distinct and adaptive disgust mechanisms: pathogen, moral and sexual. According to basic emotion theory, sub-types of a basic emotion will vary slightly in physiological and behavioural measures, although those sub-types show generalised profiles for that basic emotion. We tested the three domains of disgust theory using an emotional Stroop design; we recorded reaction times to name the colour of words in the three categories of disgust. Participants also undertook an unexpected memory task, recalling any words that they saw in the emotional Stroop task. Results showed that colour naming of sexual words was significantly longer than in any other category. Additionally, recall of sexual words was greater than any other category. These results reveal that sexual may not be a category of disgust *per se*, but rather a separate category created by its taboo nature.

Key words: Emotion, disgust, emotional Stroop, pathogen, moral, sexual

Introduction

The basic emotion of disgust, is elicited by various items and events. Happening upon a pile of fresh vomit will likely cause you to retreat from the area in sheer revulsion. Similarly, listening to someone's racist rant might cause you to retreat from that conversation if it does not align with your moral belief. Certain events in life that cause particular emotional reactions result in physiological changes, differing mental states as well as behavioural changes (Ekman & Cordaro, 2011; Levenson, 1992). These changes resulting from emotional affect are adaptive and can often aid the survival of the individual. In the Basic Emotion theory pioneered by Paul Ekman (Ekman, 1992; Ekman & Cordaro, 2011; Ekman & Friesen, 1971), each basic emotion (fear, anger, happy, sad, surprise and disgust) includes sub-types.

The sub-types of a basic emotion will vary to a small extent in facial expression, and behavioural signatures, but these variations are synonymous with the respective emotion category. Considering the emotion disgust, certain physiological and behavioural responses occur which cause the avoidance or aversion of certain entities. Three sub-types of disgust have been identified in the literature: pathogen, moral and sexual (Tybur, Lieberman, & Griskevicius, 2009; Tybur, Lieberman, Kurzban, & DeScioli, 2013). These types of disgust are argued to facilitate the avoidance of infectious agents (pathogen), moral transgressors (moral) and unfit sexual mates (sexual). These avoidance behaviours have adaptive value in that they keep us alive and healthy, maintain our social group integrity and benefit the health of our offspring. There are empirical studies investigating the behavioural, physiological and neural mechanisms associated with both pathogen (Curtis, 2011, 2014; Curtis & Biran, 2001; Schaller & Park, 2011) and moral disgust (Chapman & Anderson, 2012; Haidt, Rozin, McCauley, & Imada, 1997; Moll et al., 2005; Rozin, Haidt, & McCauley, 2008; Rozin, Lowery, Imada, & Haidt, 1999). Little data, however, exists to support the notion of 'sexual'

as a distinct sub-type of disgust. Although some preliminary data exists that suggests that sexual may be a distinct emotion, separate from moral and pathogen disgust (Hardwick, Rich, & Williams, In preparation, Chapter 2). To investigate the idea of sexual as a form of disgust, comparable with moral and pathogen types of disgust, we used the emotional Stroop task (Algom, Chajut, & Lev, 2004) to compare reaction times to respond to ink colours of words representing the three domains of disgust.

The emotional Stroop task is a variation of the classic Stroop task (Stroop, 1935). In the classic Stroop task, when a colour word, such as 'red', is presented in congruent coloured ink, colour naming times are faster when identifying the ink colour than when it is presented in an incongruent ink colour (e.g., the word 'red' presented in green ink). This is called the classic Stroop effect (MacLeod & MacDonald, 2000). In the emotional Stroop task, the congruency manipulation is based on the effect of emotionally salient words on colour identification (Algom et al., 2004; Williams, Mathews, & MacLeod, 1996). Emotionally negative words, such as 'kill' or 'panic,' usually result in longer colour naming times compared with innocuous words such as 'plate' or 'bread' (McKenna & Sharma, 1995). This is thought to be because emotionally negative words capture more attention than do neutral words, due to the potentially threatening nature of such stimuli. Therefore, utilising the emotional Stroop paradigm might be a useful way to investigate differences between response times to words in the three domains of disgust.

Interference effects due to the threatening nature of negative stimuli can be explained with the Automatic Vigilance Hypothesis (Estes & Adelman, 2008; Ohman, Flykt, & Esteves, 2001; Pratto & John, 1991). According to the Automatic Vigilance Hypothesis, humans are hypervigilant to threatening stimuli, paying greater attention to potential threats than to

innocuous stimuli. Disgust is known to function as a threat detection emotion to facilitate the avoidance of threatening entities (Pratto & John, 1991) and this avoidance in turn keeps us safe from potential harm within the three-domains of disgust framework (Tybur et al., 2013).

The proposed sub-types of disgust as potential threats have been outlined: pathogen disgust causes the avoidance of pathogenic agents, moral disgust causes the avoidance of moral offenders, and sexual disgust causes the avoidance of reproductive opportunities with unfit mates (Tybur et al., 2013). If these three threat detection mechanisms are all types of disgust, then we would expect similar reaction times on the emotional Stroop task. However, there is preliminary support that 'sexual disgust' is distinct from both pathogen and moral disgusts (Hardwick et al., In preparation, Chapter 2). The literature on the emotional Stroop clearly shows that words that carry emotional content can affect colour naming times, even when those words themselves have no relationship to colour (Algom et al., 2004). Here, we explored the degree to which this also occurs for the three putative sub-types of disgust.

The taboo Stroop task is another variation on the classic Stroop task. Similar to the emotional Stroop task, it measures the interference produced by naming the colour of words that are taboo in nature such as 'queer' or 'shit' compared with innocuous words such as 'boar' or 'hawk' (MacKay & Ahmetzanov, 2005). Although not all taboo words are sexual in nature, most sexual words are taboo. However, not all sexual words are necessarily threatening. Therefore, if we find longer reaction times to sexual words, this may be because of their taboo nature rather than their threatening nature. Consequently, the source of longer reaction times in the sexual condition may be difficult to reconcile as a distinct category of disgust.

The aim of the current study was to investigate behavioural responses made when identifying the coloured font of words associated with the three types of disgust. Words were chosen based on their association with the categories of pathogen, moral and sexual disgust. Participants' reaction times were recorded. If significant differences are found between the three disgust categories, this might provide support for the Automatic Vigilance Hypothesis, such that more threatening stimuli might capture more attention. One might postulate that pathogens pose the greatest threat to survival, therefore, reaction times to naming the colour of pathogen disgust words should be longer. On the other hand, sexual words might produce more interference than either moral or pathogen words resulting from their taboo nature.

Immediately following the emotional Stroop task, participants undertook an unexpected recall task. They were asked to recall as many words as they could from the emotional Stroop task. The number of words recalled within a category is an exploratory analysis that might help us to disambiguate the reaction time results of the emotional Stroop task. One prediction is that a greater number of pathogen words are recalled because of their threatening nature. Alternatively, greater recall could be higher for sexual words because of their taboo nature. The number of words recalled within a category may help to disentangle the hypotheses of *threat* compared with *taboo*.

Methods

Participants

Participants were recruited from Macquarie University's psychology and cognitive science participant pools and the Department of Cognitive Science at Macquarie University. In three validation studies, we matched the disgust words on ratings of valence and arousal with 27 participants. A separate group of 10 participants categorised the words into the different

disgust types. These surveys were conducted with volunteer members of the Department of Cognitive Science, Macquarie University. For the main experiment, we tested a separate group of 22 participants (age 23.4 ± 6, F = 11) recruited from the participant pools. Participants received course credit or were reimbursed $10AU for their participation. This study was approved by the Macquarie University Human Research Ethics Committee and all participants gave written informed consent.

Stimuli

The stimuli were English words chosen from word databases and internet searches on the basis of an association with one of three types of disgust: pathogen, moral and sexual (experimental stimuli). These stimuli were chosen based on their association with the three-domain disgust theory. For example, pathogen words were chosen based on their disease association, moral words were chosen based on their moral reprehensibility and sexual words were chosen based on their association of undesirable mating opportunities. We also chose words for a 'matched' control condition which consisted of negative words that had no disgust connotation but were not significantly different on valence and arousal ratings with the disgust categories. We also chose a set of 'neutral' words that were not matched on valence and arousal. In a validation study, we selected the word stimuli for pathogen, moral, sexual and matched conditions by eliminating words that were statistically different on valence and arousal ratings (N = 27) using the same rating scales as Hardwick et al. (In preparation). That left us with 13 words in each of those categories. Additionally, all words, including the neutral words, were matched on lexical characteristics: word length, log word frequency and orthographic neighbourhood (see Table 1) using the 'English Lexicon Project' (Balota et al., 2007 http://elexicon.wustl.edu/). The words were presented in lowercase using Arial font and participants sat approximately 60cm from the display monitor.

Table 1. Emotional Stroop word stimuli.

Pathogen	Moral	Sexual	Matched	Neutral
poisonous	malevolent	pervert	hostage	revision
rotten	monstrous	pimp	maim	stove
decaying	murder	polygamy	catastrophe	suitcase
toxic	prejudice	promiscuous	ferocious	sweeping
virus	robbery	semen	shock	symposium
cockroach	thief	sperm	slash	undertake
contaminated	torture	impotence	tsunami	wooden
vermin	victim	whore	horrific	accord
fungus	violence	adultery	worst	graph
infected	blackmail	anal	agony	gravity
excrement	corrupt	bondage	hideous	lightest
sweat	brutal	brothel	disaster	marker
disease	extortion	testicle	panic	portray

Table 2. The mean ratings and standard errors for the valence, arousal, log word frequency (LF), word length (WL) and orthographic neighbourhood (ON) of the word stimuli. No significant differences were found between pathogen, moral, sexual and matched stimuli on valence and arousal and all stimuli were matched on the three lexical characteristic parameters. Note, we did not collect valence and arousal ratings for neutral words as we expected they would differ from the matched control stimuli and the three disgust conditions.

	Valence		Arousal		LF		WL		ON	
	Mean	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*
Pathogen	3.6	0.1	4.5	0.11	7.6	0.4	7.3	0.58	0.8	0.32
Moral	3.4	0.14	4.5	0.2	8.1	0.35	7.5	0.43	0.3	0.17
Sexual	3.8	0.15	4.7	0.18	7.1	0.28	6.8	0.58	1	0.49
Matched	3.7	0.15	4.4	0.19	7.8	0.35	6.6	0.56	1.6	0.66
Neutral	_	_	_	_	8	0.27	7.1	0.38	1.2	0.58

Two one-way ANOVAs on the final word stimuli, one for valence ($F_{3,51} = 1.493$, $p = 0.228$) and the other for arousal ($F_{3,51} = 0.658$, $p = 0.582$) found no differences. Additionally, we wanted to ensure that all words were categorised within the appropriate disgust category. We therefore asked 10 separate participants to classify each word into either: a) illness/disease, b) moral, c) sexual or d) none. Participants could choose only one classification per word. Using

K-means clustering, we found that participants mostly chose the congruent classifier for the respective word categories (Figure 1). We did not exclude the words that were misclassified. Whereas participants did not choose 'illness/disease' for two words in the pathogen category (sweat and cockroach) these words have been consistently implicated in pathogen-related disgust (Curtis & Biran, 2001). We have also included the three other misclassified words (maim, extortion, impotence) because they were close in distance to their respective categories.

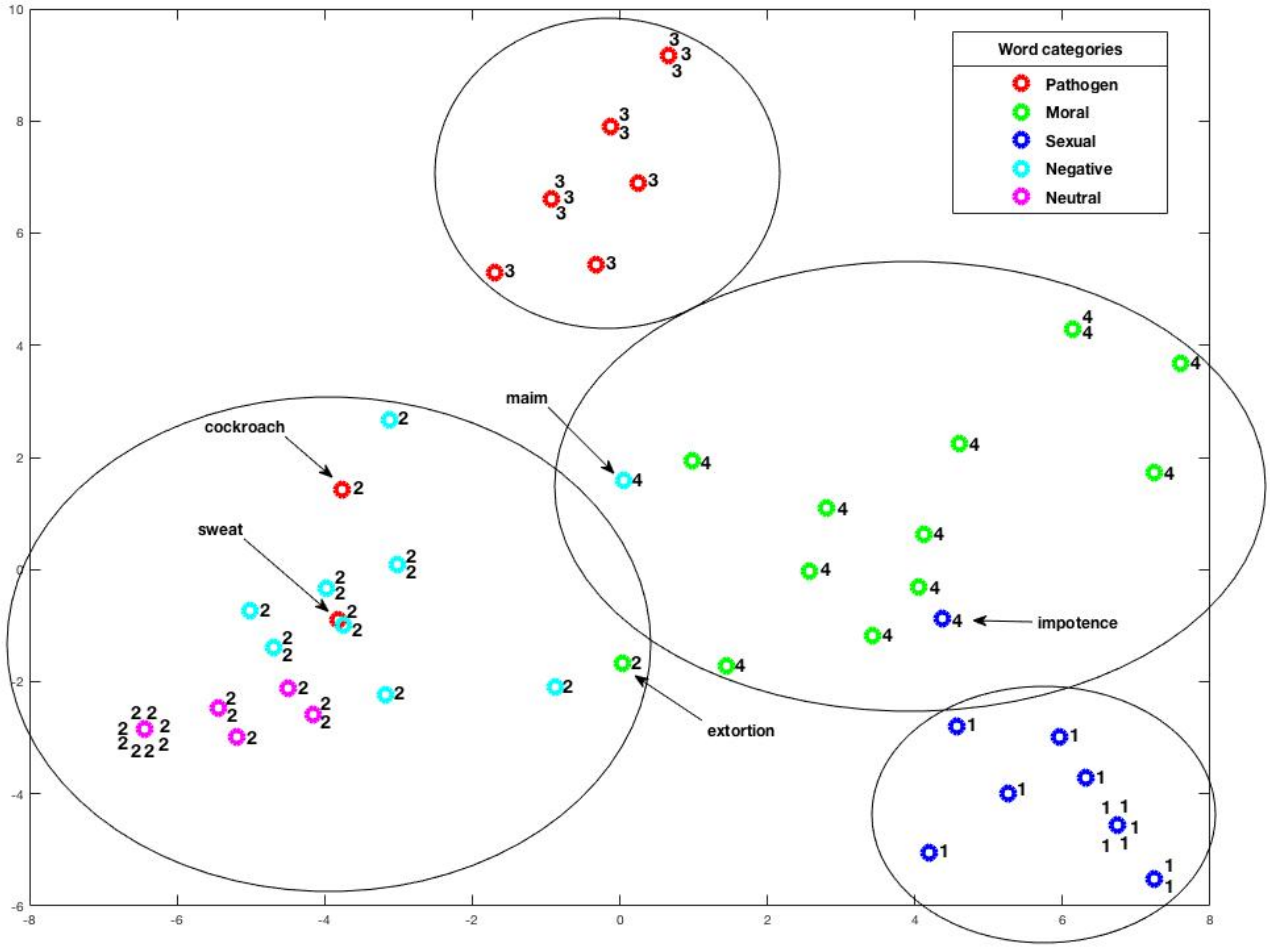

Figure 1. K-means clustering of the classification of words used in the emotional Stroop task. We specified four clusters to represent the four classification options for the Stroop stimuli (illness/disease, moral, sexual or none). Multiple numbers surrounding a coloured dot represents the number of dots occupying that data point.

Procedure

The task was performed on a Samsung monitor with a standard keyboard. The colour naming task was programmed in MATLAB (version 7.11.0) using PsychToolbox-3 (Kleiner, Brainard, & Pelli, 2007). Before the main experiment, there were 80 practice trials using words not included in the main experiment. This was done to ensure participants were familiar with the keys that corresponded to the four colours. For the main experiment each participant was tested individually in a dimly lit testing room. We chose a sample size (N = 22) based on previous emotional Stroop designs (MacKay & Ahmetzanov, 2005). A fixation cross was presented at the beginning of the experiment for 2500ms then the first word was presented. The word stimuli remained on the screen until the participant made a button press. In between each word stimulus was a fixation cross that lasted 500ms. Each word was presented once in each of the four colours: red, green, blue and yellow, and were presented randomly in intermingled order: that is, 13 (words) x 5 (categories) x 4 (colours) = 260 trials. Half way through the main experiment, participants were presented with a screen offering a break. They could then press the space bar at any time to continue the experiment. For the main experiment, participants were instructed to ignore the words and identify as quickly and accurately as possible the font colour in which the words were written. Participants pressed the corresponding key to the colour of the word. Keys F, V, N and J on a standard keyboard were used and were labelled R, G, B and Y ([R]ed, [G]reen, [B]lue and [Y]ellow) to correspond with the colour. Keys were counterbalanced across participants and the task took approximately 12 minutes. They were instructed to keep their fingers hovering over those buttons throughout the experiment for fast reactions. Immediately following the colour naming task, participants undertook an unexpected recall task where they were asked to recall in two minutes as many words as they remembered from the colour naming task. Participants

were not told about this task until the end of the colour naming task to ensure attention was on the colour of the words and not the actual words.

Results

Emotional Stroop task

Incorrect responses were discarded from analysis (mean number of errors = 5.3%) and reaction times (RT) that exceeded 2.5 standard deviations from the mean of each participant's RT were also discarded as outliers. A one-way repeated measures ANOVA on the factor of Word Category on mean correct RTs revealed a significant main effect of Word Category ($F_{4,84} = 4.852$, $p = 0.001$). Post hoc pairwise comparisons showed that RTs were significantly slower in the sexual compared with the pathogen ($p = 0.01$), moral ($p < 0.001$), matched ($p = 0.005$) and neutral ($p = 0.046$) categories. These last 4 conditions did not differ from each other (all $ps > 0.05$) (Figure 2).

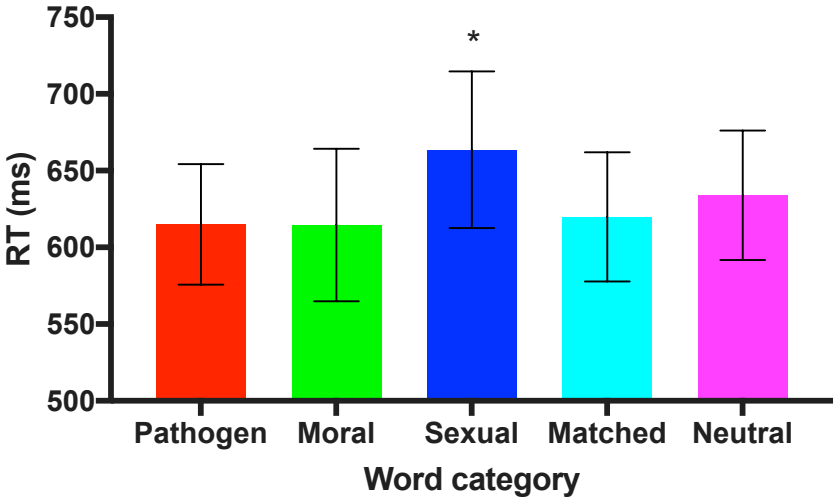

Figure 2. Emotional Stroop task. Averaged correct reaction times for identifying the font colour of words. Participants were significantly slower to identify the colour of words in the

sexual category compared with the moral and pathogen categories (bars represent standard error of the mean, $p < 0.01$*).

Post-hoc exploratory analysis was then performed to test for attenuation by repeated exposure to the different word categories (Schmidt, 2012). It has been suggested that emotional Stroop effects attenuate for some categories of emotionally salient words. For example, a lack of attenuation to moral words has been observed (Simpson, Carter, Anthony, & Overton, 2006) and attenuation has been observed for pathogen and taboo related words (Ben-Haim, Mama, Icht, & Algom, 2014; Simpson et al., 2006). Therefore, we divided the data based on the first 130 trials (block 1) versus the second 130 trials (block 2). This division of blocks was built on the assumption that the randomly intermingled stimuli made it likely that appearance of each individual word was roughly evenly distributed across the experiment. A two factor repeated measures ANOVA with the factors of Condition (x 5) and Block (x 2) on the correct RTs revealed main effects of both Condition ($F_{4,84} = 7.593$, $p < 0.001$) and Block ($F_{1,21} = 4.860$, $p = 0.039$). Additionally, there was a significant interaction between block and condition ($F_{4,84} = 3.581$, $p = 0.01$). Post hoc comparisons revealed that colour naming RTs were shorter in the second block compared with the first block in the sexual ($p = 0.01$) and the matched control ($p = 0.001$) conditions. There was a borderline effect for the RTs to be shorter in the pathogen condition ($p = 0.062$) in the second block compared to the first block. There was no difference in RTs for the moral words across blocks ($p = 0.499$) and the neutral words ($p = 0.499$) (Figure 3).

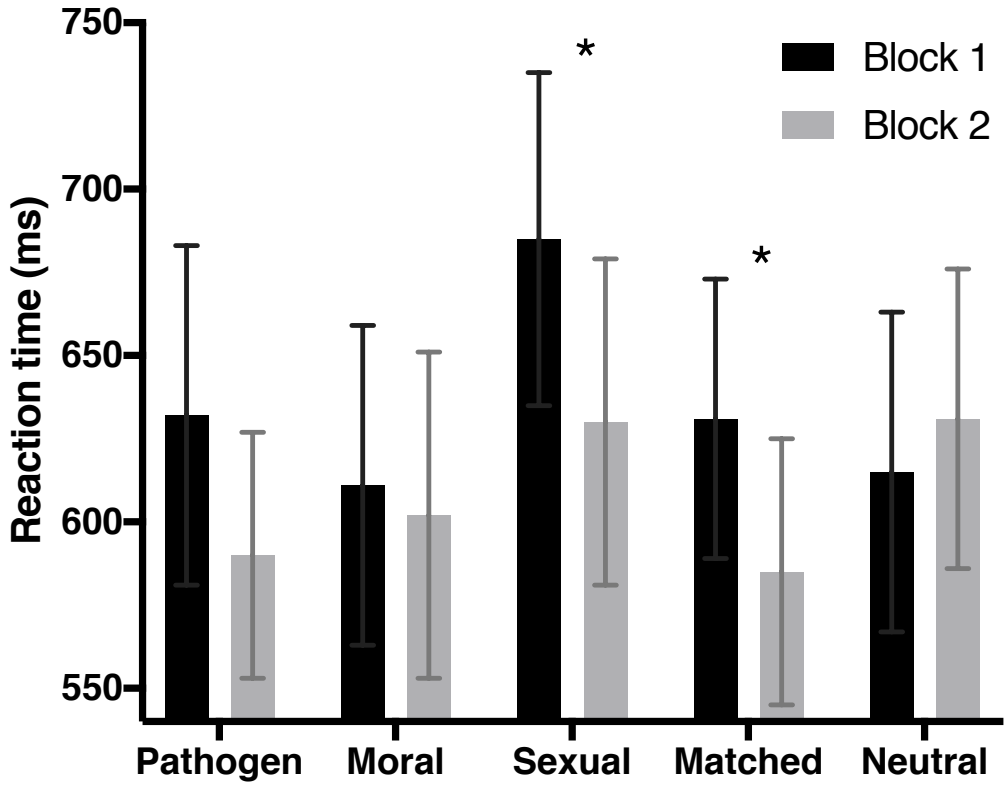

Figure 3. Averaged correct reaction times divided into two blocks, the first block of the first 130 trials and the second block of the final 130 trials. Significant differences between the same category are represented by *. Error bars are standard error of the mean.

Word recall task

In the word recall task, participants were asked to recall as many words as they could from the main experiment. Participants recalled on average 9.5 words of the total 65 words presented in all categories. Recalled words were divided into each category and any words that were not actual stimuli were not included in the analysis. A one-way repeated-measures ANOVA on the number of words recalled revealed a significant main effect of Condition ($F_{4,109} = 19.373$, $p < 0.001$). Post hoc pairwise comparisons showed that word recall was significantly greater in the sexual compared with the pathogen, moral, matched, and neutral

categories (all ps < 0.001). These last 4 conditions did not differ from each other (all ps > 0.05) (Figure 4).

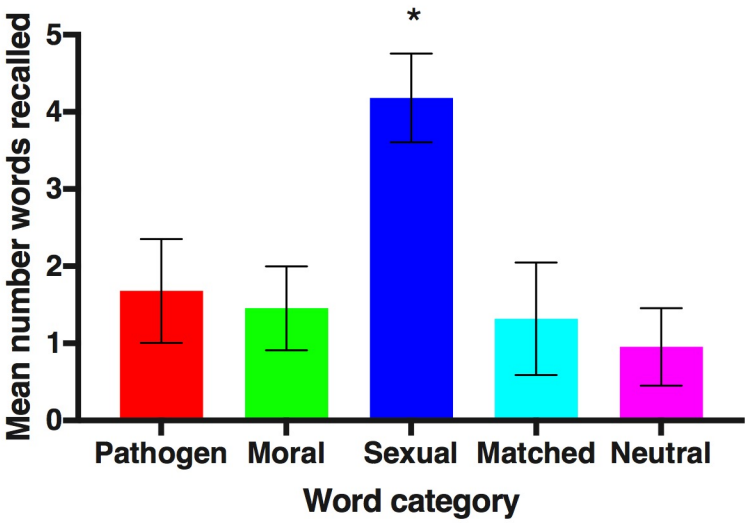

Figure 4. Word recall task. The number of words recalled following the emotional Stroop task. Participants recalled significantly more words in the sexual category than any other category (p < 0.001*).

Discussion

The present study investigated the effects of naming the coloured font of words associated with different types of disgust. In the emotional Stroop task, we found that reaction times were slower for the sexual category compared with all other categories. In the blocked analysis, we saw a significant decrease in reaction times in the second block to name the colour of the sexual words, suggesting attenuation of the effect; whereas this did not occur in the other conditions. In the word recall task that immediately followed the emotional Stroop task, participants recalled significantly more words in the sexual category than in any other

category. These results tentatively support the hypothesis that 'sexual' as a category differs from typical responses in the moral and pathogen categories.

The impact of sexual words over other disgust-related category words could be due to several potential differences between the types of words that occur in each category. This could include the extent to which a word is threatening. The automatic vigilance hypothesis states that humans attend to threatening stimuli over and above neutral or innocuous stimuli (Cohen, Dunbar, & McClelland, 1990; Estes & Adelman, 2008; Ohman et al., 2001; Pratto & John, 1991). Increased attention to threatening stimuli has adaptive implications in that it guides behaviour to attend to such threats in order to keep us alive. Thus, if our sexual category had more threatening words than the other categories, this attentional capture could account for the findings. In our experiment, however, there were few sexual threatening words (pervert) which makes this this account unlikely.

A more plausible account of our effect is that our sexual category contains more 'taboo' words than the other categories. Stroop-type studies using words defined as 'taboo' versus 'not taboo' show the same type of effects as we see here for sexual words, including the attenuation over repeated presentations and greater recall of taboo than non-taboo stimuli (MacKay et al., 2004; Schmidt & Saari, 2007). The sexual words in this experiment overlap with those typically used in taboo experiments. Thus, it seems possible that our effects may reflect the taboo nature of the sexual stimuli.

Another possible explanation of our results is to consider the 'sexual response' as a separate basic emotion. The basic emotion theory was developed through studies of facial expressions across cultures. A set of universally recognised emotions corresponding to specific facial

expressions was identified which are: happy, sad, anger, surprise, fear and disgust (Ekman, 1992; Ekman & Cordaro, 2011; Ekman & Friesen, 1971; Ekman, Sorenson, & Friesen, 1969). These authors proposed that the basic emotions are functionally adaptive, causing physiological and behavioural responses which guide future actions appropriate to each of those emotions. Moreover, the theory accounts for sub-types within those basic emotions. For instance, anger includes the sub-types of contempt and indignation and while these may have different semantic properties, ultimately, sub-types of emotions will show similar physiological and behavioural responses to its parent emotion. If pathogen, moral and sexual disgust were all sub-types of the same basic emotion, we would expect similar behavioural profiles in line with basic emotion theory (Ekman, 1992). In this study, reaction times in the sexual condition were slower than both the other conditions, which did not differ from the control conditions. Therefore, these results might suggest that 'sexual response' could be considered a distinct basic emotion.

There is support for the idea that the 'sexual response' should be considered a basic emotion. One study asked 1, 099 participants to rate sexual words and short phrases on dimensional measures (e.g., valence and arousal) and basic emotion scales (anger, happiness, disgust etc.) (Stevenson et al., 2011). Their factor analysis and subsequent logistic regression showed that sexual as a category could not be predicted by the dimensional scales nor by the basic emotion scales. They propose that sexual as a category should be characterised as a separate basic emotion. The current finding is consistent with the findings of Stevenson et al. (2011) that sexual may be a basic emotion.

We speculate, on the basis of these findings, that the sexual response could be considered a distinct basic emotion. One way to test this hypothesis is to find a facial expression, a

behavioural profile, physiological changes, and neural correlates of such sexual responses. Because the literature is quite sparse on the sexual response as a specific basic emotion, we are cautious in the interpretations of the results in the current study. One limitation in the study could be the arousal ratings we obtained for the sexual stimuli. We only had a small sample size (n = 10) conducting these ratings therefore, there may be a potential issue with the reliability of ratings. In future studies, arousal ratings could be improved by using a much larger sample of participants. Otherwise, measures for arousal such as heart rate variability or galvanic skin responses, might provide a more objective measure of arousal given the physiological changes normally seen with arousing stimuli. Thus, we are cautious to discount the fact that the arousing nature of the sexual stimuli might have influenced our results.

In sum, the proposal that the three sub-types of disgust consist of: pathogen, moral and sexual seems problematic, given the results of the current study. We did not find a similar behavioural profile across the disgust conditions. The longer reaction times and greater recall of words in the sexual condition compared with both pathogen and moral conditions, are grounds to consider the sexual response as a distinct emotion category. An alternative suggestion is that the taboo nature of the sexual words may account for our results. Future research could disentangle these ideas by exploring the neural profiles in response to words in the three proposed domains of disgust. This study is an important contribution to research on disgust mechanisms which suggests the preclusion of sexual as a form of disgust.

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Chapter 4: The Neural Correlates of Words Related to Pathogen, Moral and Sexual Disgust

The Neural Correlates of Words Related to Pathogen, Moral and Sexual Disgust

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Abstract

The three-domain disgust theory proposes three distinct sub-types of disgust: pathogen, moral and sexual. Each sub-type is said to have their distinct adaptive value. However, recent work using behavioural measures has revealed that the 'sexual' domain may not be a sub-type of disgust, but rather a distinct basic emotion. If this category is a separate basic emotion, the neural correlates of the 'sexual' domain should differ from both 'pathogen' and 'moral' domains. To test this hypothesis, we investigated the neural activation responding to words associated with the three domains using fMRI. Participants were presented with 'disgust' words, a matched control and scrambled words (visual control). Significantly greater neural activation for the sexual condition compared to the scrambled condition was observed in frontal and temporal regions, as well as the amygdala and hippocampus. An exploratory analysis looking at common activity among the three categories revealed that the activity profile (BOLD response) differed for sexual words compared with moral words in the left fusiform gyrus, two regions in the inferior frontal gyrus (IFG) and an area in the right middle superior frontal gyrus (MFG). One area in the IFG was different for sexual and pathogen words. These results might indicate that the sexual response is a distinct category of emotion.

Keywords: fMRI, emotion, disgust, insula, amygdala, semantic

Introduction

The emotion we call disgust is typically defined as an aversive feeling that causes the avoidance or rejection of certain stimuli. For example, a feeling of disgust will manifest in behaviours to cause withdrawal from particular items (e.g., spoiled food, others' bodily secretions), settings (e.g., waste sites, public toilets) or people (e.g., those carrying communicable diseases). This type of disgust functions to keep the organism safe from disease and infection and is usually defined as 'core' or 'pathogen' disgust (Curtis, 2011, 2014; Curtis, de Barra, & Aunger, 2011). More recently, researchers have suggested the co-option of pathogen disgust mechanisms into other areas of human behaviour. More specifically, Tybur, Lieberman, Kurzban, and DeScioli (2013) have proposed the three-domain disgust theory, which identifies two extra domains of disgust: moral and sexual. They argue that each of these domains are sub-types of disgust in that they typically cause rejection or aversion.

What makes the sub-types of disgust distinct are their unique adaptive functions. The proposed function of pathogen disgust is to maintain the health and survivability of the organism through behaviours such as the oral rejection of bitter and potentially toxic substances, nausea and vomiting and a characteristic facial expression (Curtis & Biran, 2001; Curtis et al., 2011; Rozin, Haidt, & McCauley, 2008; Sarabian & MacIntosh, 2015). Moral disgust promotes social group cohesion through behaviours directed at fellow humans whose transgressions warrant a form of withdrawal or punishment (Haidt, Rozin, McCauley, & Imada, 1997; Rozin et al., 2008; Tybur et al., 2013). Finally, sexual disgust promotes reproductive success through the rejection of mating opportunities that may result in unhealthy offspring, such as mates exhibiting ill health, or genetic incompatibility (Tybur, Lieberman, & Griskevicius, 2009). Thus, the proposal is that environmental pressures over

time (i.e., group living and reproductive opportunities) caused the co-option of disgust mechanisms into other domains of behaviour that promote social group integrity and offspring health.

It is difficult to test evolutionary theories, but we can use both behavioural and neuroimaging tools to explore the extent to which the purported three domains share either outcomes (e.g., behaviour) or underlying neural circuits (e.g., using fMRI). There is only one study that we are aware of that has compared all three domains of disgust (J. Borg, Lieberman, & Kiehl, 2008). Borg and colleagues collected fMRI data during an adapted memory task that had one sentence pertaining to either pathogen disgust (e.g., eating your sister's scab), socio-moral disgust (e.g., burglarising your sister's home) or incestuous acts (e.g., you fondling your sister's nipples) within a block of four sentences containing three neutral sentences (e.g., you holding your sister's groceries). In this memory phase, participants read the four sentences. In the recall phase, participants were presented with two sentences and had to identify whether one of those sentences had appeared in the memory phase. There were a number of common brain regions identified in all three disgust domains, including the middle frontal gyrus (MFG), bilateral temporal poles, postcentral gyrus, precuneus, bilateral lingual gyrus, anterior cingulate cortex (ACC) and regions in the basal ganglia. Distinct activations were also observed for each condition. The pathogen related sentences activated the inferior frontal gyrus (IFG) and orbitofrontal cortex (OFC). The moral related sentences activated the temporal-parietal junction (TPJ) and inferior temporal gyri (ITG). Finally, distinct activations for the incestuous sentences were the bilateral ACC, right IFG, bilateral middle temporal gyri, bilateral superior frontal gyri and the anterior insula. Although this is a good beginning to disambiguating the domains of disgust, one limitation of this study is that they did not control for the valence nor arousal of the sentences. Thus, we cannot be sure if the neural

activity is due to the items themselves or the differences in valence and arousal of those items.

Others have investigated the domains separately. There are many studies on the neural underpinnings of pathogen disgust, which implicate the anterior insula. Researchers have presented disgusted facial expressions (Heining et al., 2001; Phillips et al., 1997), disgusting smells (Wicker et al., 2003) and imagining disgusting scenarios (Jabbi, Bastiaansen, & Keysers, 2008). The results consistently show that the anterior insula is a primary neural correlate of pathogen disgust. Depending on the paradigm used, other areas are also activated when evaluating disgusting things. These include areas in the basal ganglia, visual cortices, medial and lateral prefrontal cortices and the thalamus (Moll et al., 2005; Phillips et al., 1997; Stark et al., 2005; Wicker et al., 2003). Varying neural activity is observed in different instantiations of pathogen disgust, although the general consensus still remains that the insula is the neural hub of pathogen disgust.

Studies investigating neural activity in the moral disgust domain have shown activity in the frontal and temporal cortices. For instance, morally charged pictures such as physical assaults and war scenes, or sentences, such as 'the elderly are useless,' show activation in the OFC, the MFG and superior temporal sulcus (STS) (Moll, de Oliveira-Souza, Bramati, & Grafman, 2002; Moll, de Oliveira-Souza, Eslinger, et al., 2002). Others have investigated emotionally charged moral judgements and have similarly found activity in the MFG, but also in the angular gyrus, posterior cingulate and areas in the basal ganglia (Greene, Nystrom, Engell, Darley, & Cohen, 2004; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001). Importantly, the insula does not seem to be activated by moral tasks whereas it is involved in pathogen disgust tasks.

There is sparse literature on the neural correlates of sexual disgust, however, some have explored neural activity in sexual arousal. In two studies testing women using sexually evocative images, activations were present in the inferior temporal gyri (ITG) extending into the parietal lobe, precentral gyri, IFG and post thalamus (C. Borg, de Jong, & Georgiadis, 2014; C. Borg et al., 2014). In a study testing sexual arousal in men using erotic films, activity was observed in the ITG, insula, caudate nucleus, IFG and cingulate (Stoleru et al., 1999). Moreover, a study testing sexual arousal in both men and women focussed on regions of interest typically evoked in emotion processing and found activity in ventral striatum, amygdala, hypothalamus and thalamus (Stark et al., 2005). Together, these results suggest that sexual arousal activates a number of brain regions including the insula. However, sexual arousal is not the same as sexual 'disgust,' which has not been tested with neuroimaging thus far (with the exception of the J. Borg et al. (2008) study reviewed earlier). Thus, it is important to evaluate the three-domain disgust theory with stimuli that induce sexual disgust.

The aim of our current study is to investigate the neural correlates of the three domains of disgust using a passive viewing paradigm. We presented words pertaining to each of the domains in a block design. By using a passive viewing task, we can assume that any neural activation is implicitly instantiated from the difference in the semantic properties relevant to the distinct disgust categories. The main thesis of Tybur et al. (2013) is that moral disgust and sexual disgust have co-opted the mechanisms of pathogen disgust. Given that the insula is commonly active to pathogen disgust and sexual arousal, this leads to a clear prediction that we should observe insula activation in all three conditions. We additionally expect to observe other common areas of activation such as regions in the basal ganglia (caudate nucleus),

amygdala, hypothalamus, STS, MFG and IFG. We also expect distinct neural activity in each condition, which would reflect the different adaptive functions of each of the domains.

Methods

Participants

Participants were recruited from the Cognitive Science participant pool and the Department of Cognitive Science at Macquarie University, Sydney, Australia. We tested 16 female participants (age 19-30, M = 25.4 ± 4.6). We did not include male participants because of sex differences in pathogen-related disgust and sexual arousal (Koukounas & McCabe, 1997; Tybur, Bryan, Lieberman, Hooper, & Merriman, 2011), although we will use the same paradigm with a male population in a future study. Participants were reimbursed $30AU for their participation. This study was approved by the Macquarie University Human Research Ethics Committee and all participants gave written informed consent.

Stimuli

We selected 90 words in each condition (pathogen, moral, sexual and matched control) from two databases: the Affective Norms of English Words (ANEW, Bradley & Lang, 1999) and the Indiana Sexual and Affective Word Set (ISAWS, Stevenson et al., 2011). We reduced the number of words so that there were no significant differences on five measures: 1) valence and 2) arousal (both measures used data from ISAWS and ANEW databases) and lexical characteristics: log frequency, word length and orthographic neighbourhood, which left us with 32 words in each condition (a full list of the word stimuli can be found in Appendix IV). Of the remaining 32 words in each condition, valence was measured on a scale of 1 (negative) – 9 (positive) and was not significantly different ($F_{3, 127} = 1.832$, $p = 0.144$). Arousal was measured on a scale of 1 (unpleasant) – 9 (pleasant) and was also not significantly

different ($F_{3,127} = 1.184$, $p = 0.318$). We used data from the 'English Lexicon Project' (Balota et al., 2007 http://elexicon.wustl.edu/) to evaluate the lexical characteristics and found no differences: word log frequency ($F_{3,127} = 2.091$, $p = 0.104$), word length ($F_{3,127} = 1.275$, $p = 0.285$) and orthographic neighbourhood ($F_{3,127} = 0.336$, $p = 0.799$). Means and standard errors of the mean can be found in Table 1.

Table 1. The mean ratings and standard errors for the valence, arousal, log word frequency (LF), word length (WL) and orthographic neighbourhood (ON) of the word stimuli. No significant differences were found between pathogen, moral, sexual and matched stimuli on valence and arousal and no significant differences were found on the three lexical characteristic parameters.

	Valence		Arousal		LF		WL		ON	
	Mean	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*	*Mean*	*SEM*
Pathogen	3.26	0.15	5.07	0.11	7.28	0.24	6.24	0.27	2.02	0.67
Moral	3.3	0.14	5.3	0.09	7.63	0.31	6.74	0.39	1.67	0.62
Sexual	3.7	0.18	5.23	0.1	6.86	0.26	7.03	0.38	1.5	0.5
Matched	3.32	0.11	4.97	0.21	7.74	0.26	7.09	0.3	1.27	0.34

Disgust ratings of all 128 words were obtained from each participant following the scanning session. Participants rated all words on a scale from 1 (not at all disgusting) – 7 (extremely disgusting). On average, disgust ratings were on the lower end of the scale: pathogen ($M \pm SD$, 3.1 ± 1.1), moral ($M \pm SD$, 2.1 ± 1.1), sexual ($M \pm SD$, 2.6 ± 1.3) negative control ($M \pm SD$, 1.5 ± 0.6). A one-way ANOVA revealed that moral words were considered less disgusting than pathogen words, and matched words were considered less disgusting than both pathogen and sexual words ($F_{3,127} = 13.488$, $p < 0.001$; Table 2).

Table 2. Disgust ratings; participants rated each word on a scale from 1 (not at all disgusting) – 7 (extremely disgusting). Ratings corresponding to one letter are not significantly different from each other.

Disgust ratings (1 = not at all > 7 = very much)

Word	*A*	*B*	*C*
Matched	1.50		
Moral	2.12	2.12	
Sexual		2.58	2.58
Pathogen			3.09

fMRI data acquisition

Scanning was performed on a Siemens Verio 3T (Erlanger, Germany) scanner at Macquarie Medical Imaging, Macquarie University Hospital, Sydney, Australia. Prior to the functional scans, anatomical scans were obtained using a 3D-MPRAGE (magnetisation prepared rapid gradient echo) sequence. Functional scans were performed using the 32-channel receiver only head coil (Erlanger, Germany) and a gradient echo planar imaging (EPI) sequence (TR = 3000ms, TE = 32ms, isotropic voxel size 2.4 x 2.4 x 2.4, inter-trial interval 500ms, SNR > 100, slice angle ~ 20°). Transverse sections were acquired with the aim to capture amygdala, insula and frontal brain regions. One hundred and two volumes were acquired per block for each participant.

fMRI experiment protocol

We implemented a block design consisting of six conditions. Four conditions were blocks of eight words from each of the key conditions: pathogen, moral, sexual and matched words. Our fifth condition was a scrambled condition (words scrambled to match visually the grey and black components of the word stimuli). Our final condition was a fixation cross which appeared at the beginning and end of each experimental run. Embedded within each

condition block was a single target word, not part of any other condition, to which participants pressed a button. This embedded target word was used was to ensure that they remained awake and that their attention was on the stimuli. Each run consisted of four sets (4 x 8 words in each condition) of the five conditions (pathogen, moral, sexual, matched control and scrambled) plus the two fixation blocks totalling 22 blocks. Each block within each run lasted 13.5s with each stimulus shown for 1000ms and a fixation cross between each word lasting for 500ms. Participants saw 9 runs in total which lasted approximately 55 minutes in the scanner. All blocks were randomised within each run and words were randomised within each block to ensure participants could not predict condition or word. Each condition was presented on a BOLD screen 32" LCD monitor (Cambridge Research systems, http://www.crsltd.com) positioned at the end of the bore, viewed via a mirror placed over the participant's head.

fMRI data analysis

fMRI images were pre-processed using the Statistical Parametric Mapping software (SPM12, Wellcome Department of Neuroimaging, London, UK; http://www.fil.ion.ucl.ac.uk/spm/). Volumes were converted from DICOM files to NIFTII files and slice time corrected. We spatially realigned to the mean EPI image, coregistered and normalised to the participant's anatomical image and smoothed with an 8mm full width half maximum (FWHM) isotropic Gaussian kernel. In the first level analysis, we regressed out the fixation crosses and the button presses to the specified target word, to eliminate any activity due to these parameters. We also built into the model each participant's realigned scans to account for any observed movement.

For the second level analysis, we calculated the mean of all the participants' structural scans and overlaid the functional scans. We first performed a whole brain analysis to explore the brain regions active in each condition. We contrasted each condition of interest with the matched control. This did not yield significant results once corrected using family wise error (FWE). We then contrasted each condition with the scrambled condition which did yield differences that survived FWE correction.

Because it is not ideal to compare neural activity with the baseline, we also performed an exploratory analysis. This analysis investigated activity in brain regions that were common in all three conditions. We wanted to compare whether the Blood Oxygen Level Dependent (BOLD) signal was different for the three domains. We performed two more 2nd level analyses to do this. The first was to create a contrast of a 'disgust difference,' such that each condition was contrasted against each other using the one-way ANOVA within-subjects design. We also created a contrast using the one-way ANOVA (not within) to model each condition separately. Using the software MarsBaR, we defined 'Regions of Interest' (ROI) with a binary image created in the image calculator from the 'disgust difference' contrast in SPM. We set the design parameters to the separate conditions. We limited the cluster sizes to at least 100 voxels and set alpha at 0.005, FWE corrected. We identified five brain regions significantly activated in each of the three conditions.

Results

Whole brain analysis

In the present study, we investigated the neural activation in response to words related to the three domains of disgust. We tested 16 female participants, however, we had to discard data from two participants. During data acquisition, one participant stated that she had fallen

asleep and another participant had excessive head movement. We therefore report the results on 14 participants. In a whole brain analysis, we examined neural activity responding to each condition subtracting the scrambled condition. Figure 1 shows each of the conditions overlaid. There was significantly broader neural activation in the sexual condition compared with pathogen and moral conditions. This included bilateral visual association areas, left MFG, right hippocampus, left MTG, right IFG (pars orbitalis), left precentral gyrus, left superior temporal gyrus (STG), right amygdala and left IFG (pars triangularis). In the pathogen condition, we observed activity in bilateral visual association areas and the right IFG (pars orbitalis). Unlike the sexual condition, we also observed activity in two regions of the left fusiform gyrus (FG). In the moral condition, we only observed activity in bilateral visual association areas (see Table 2. for Brodmann's areas and MNI coordinates). Because we lacked the power to directly compare the three disgust conditions with the matched control stimuli, and instead needed to rely on each condition minus our scrambled baseline we also performed an exploratory analysis to look at the BOLD response of regions that were active in all three conditions.

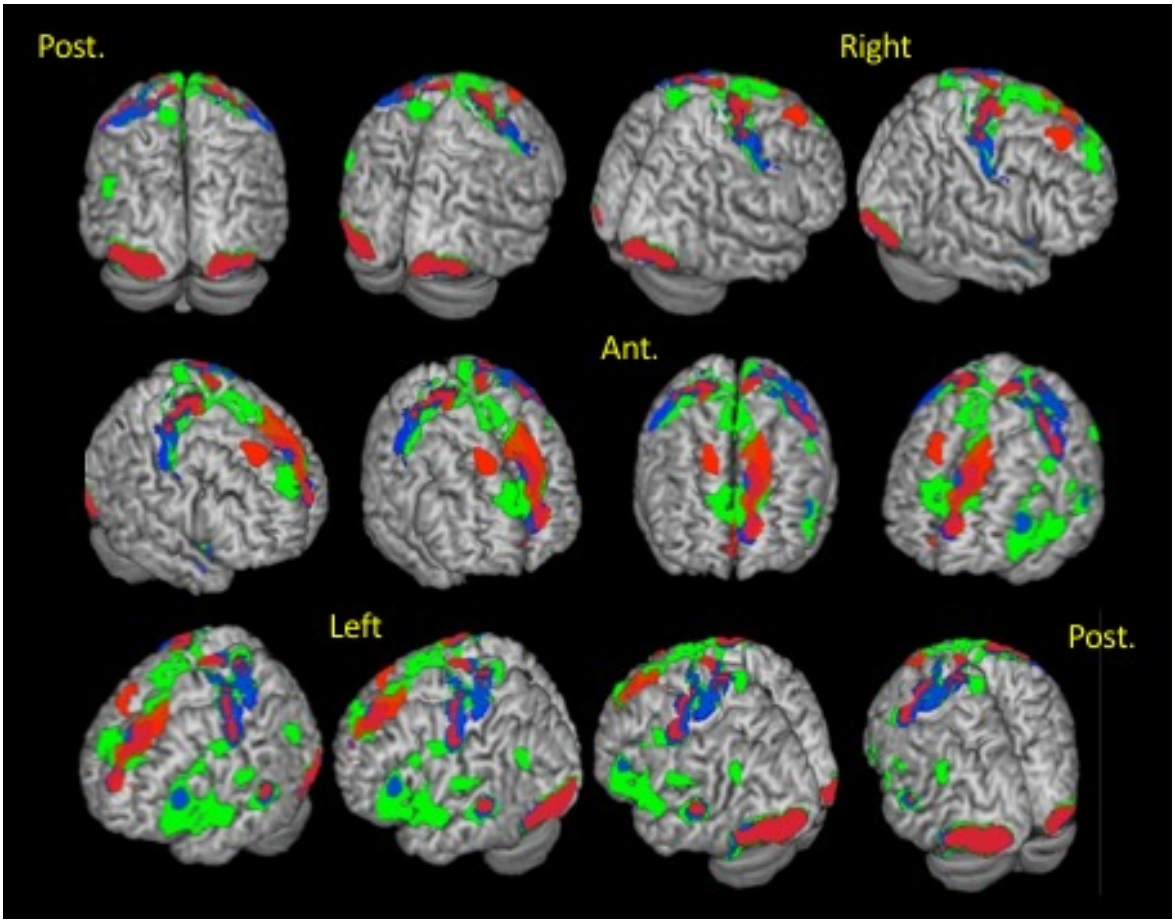

Figure 1. Neural activity responding to each of the conditions with the scrambled condition subtracted: moral related (red), pathogen related (blue) and sexual related (green) analysed separately and overlaid. Alpha was set at 0.001 and FWE corrected (Post. = posterior view, Ant. = anterior view).

Table 2. Brain regions showing neural activation with each condition minus the scrambled condition. Brodmann's area (BA) and inferior frontal gyrus (IFG).

			MNI coordinates				
Brain Region	**BA**	**Hemisphere**	**x**	**y**	**z**	**Voxels**	**P (FWE corr.)**
Sexual related words > scambled							
Middle occipital gyrus	18	left	-26	-96	-8	633	< 0.001
Middle frontal gyrus	9	left	-10	52	34	85	< 0.001
Inferior occipital gyrus	19	right	44	-84	-10	26	0.002
	18	right	24	-98	-4	14	0.005
Hippocampus	54	right	28	-14	-14	40	0.001
Middle temporal gyrus	21	left	-54	-32	4	21	0.003
IFG (p. orbitalis)	47	right	30	10	-10	10	0.008
Precentral gyrus	6	left	-22	-26	80	3	0.023
Superior temporal gyrus	22	left	-58	-2	-6	3	0.023
Amygdala	53	right	26	-4	-16	5	0.016
IFG (p. triangularis)	45	left	-50	28	12	1	0.034
Pathogen related words > scrambled							
Middle occipital gyrus	18	left	-26	-96	-10	233	< 0.001
Inferior occipital gyrus	19	right	44	-84	-10	6	0.014
	18	right	24	-98	-4	4	0.019
Fusiform gyrus	37	left	-40	-44	-18	16	0.004
	37	left	-44	-58	-14	3	0.023
IFG (p. orbitalis)	47	right	32	12	-18	4	0.019
Moral related words > scrambled							
Middle occipital gyrus	18	left	-26	-96	-10	232	< 0.001
Inferior occipital gyrus	19	right	44	-84	-10	2	0.027
	18	right	22	-98	-4	5	0.016

Exploratory analysis

In the exploratory analysis, we wanted to identify neural regions active in response to all three domains of disgust and investigate how the BOLD response differed. Using FWE correction and an 8mm smoothing Gaussian kernel, five brain regions survived correction. Figure 2 shows anatomical regions active in all three conditions. Visual associative cortices that extended from V1 to V4 showed the largest BOLD signal in all three conditions. We also saw smaller clusters in the left fusiform gyrus, the right middle frontal gyrus (MFG) and two areas in the left inferior frontal gyrus (IFG) the pars triangularis and pars opercularis (see Table 3 for Brodmann's areas and MNI coordinates). An ANOVA performed on the percent signal change in those regions revealed a marginal significant difference between sexual and moral words in the left fusiform gyrus ($F_{3,55}$= 1.380, p = 0.054). Significant differences were found in the left pars triangularis ($F_{3,55}$= 2.196, p = 0.016) and the right MFG ($F_{3,55}$= 2.669, p = 0.007) between sexual and moral words. Finally, differences were found between the three categories in the left pars orbitalis ($F_{3,55}$= 4.276, sexual and moral, p = 0.002, sexual and pathogen, p = 0.009). See Figure 3 for differences in percent signal change.

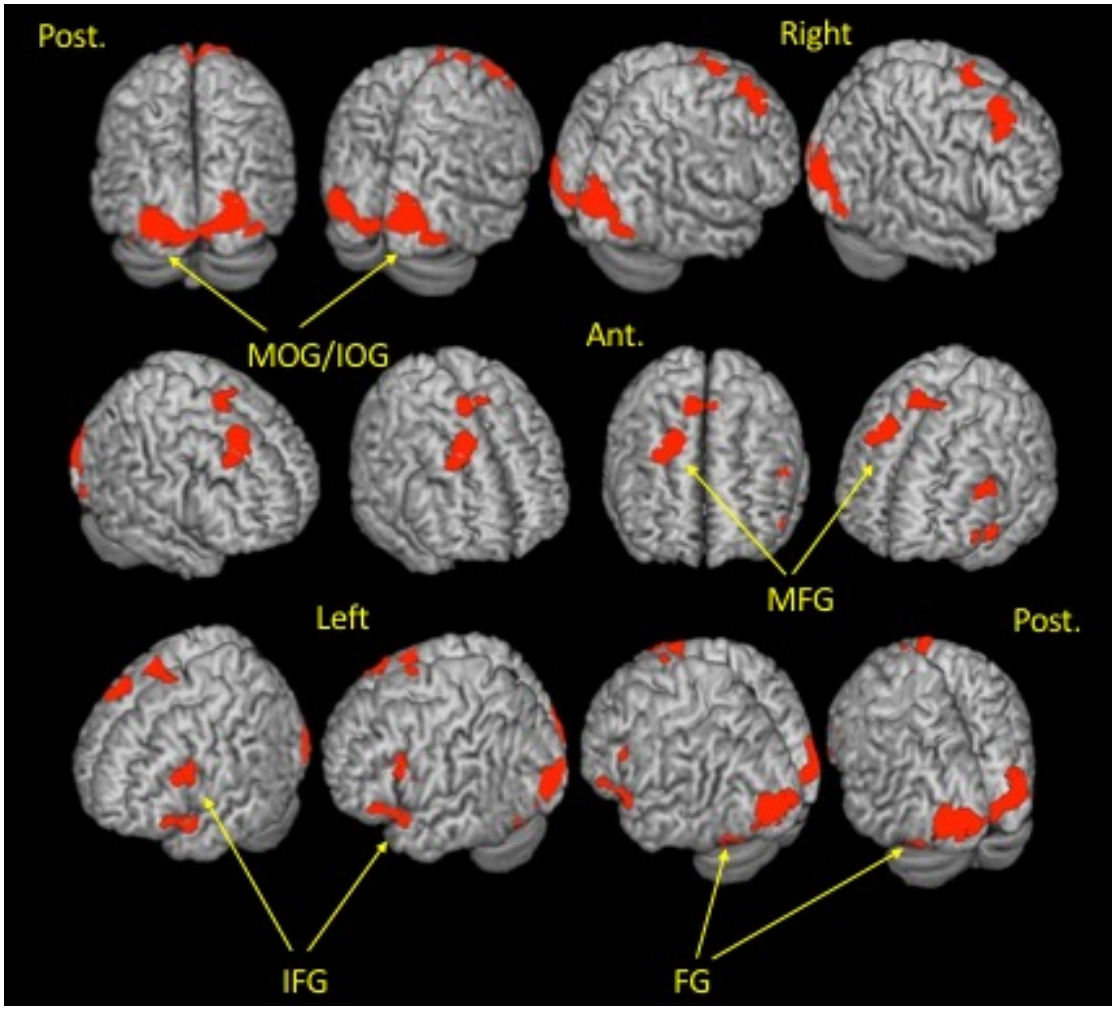

Figure 2. An exploratory analysis revealed brain activation in response to all three conditions. Activity was bilateral for middle occipital and inferior occipital gyri (MOG/IOG), there was left lateralised activity in the left fusiform gyrus (FG) and two locations in the left inferior frontal gyri (IFG) and in the right superior middle frontal gyrus (MFG) (Post. = posterior, Ant. = anterior).

Table 3. An exploratory analysis revealed five active neural regions in all three domains. inferior frontal gyrus (IFG).

			MNI coordinates				
Brain region	**Hemishpere**	**BA**	***x***	***y***	***z***	**voxels**	**P (FDR corr.)**
Middle and inferior occipital gyrus	Bilateral	18/19	-2	-90	1	1786	< 0.001
Fusiform gyrus	Left	37	-41	-56	-16	476	0.002
IFG (p. triangularis)	Left	45	-43	15	22	408	0.003
IFG (p. opercularis)	Left	44	-46	22	-9	362	0.005
Middle frontal gyrus	Right	9	25	31	51	516	0.002

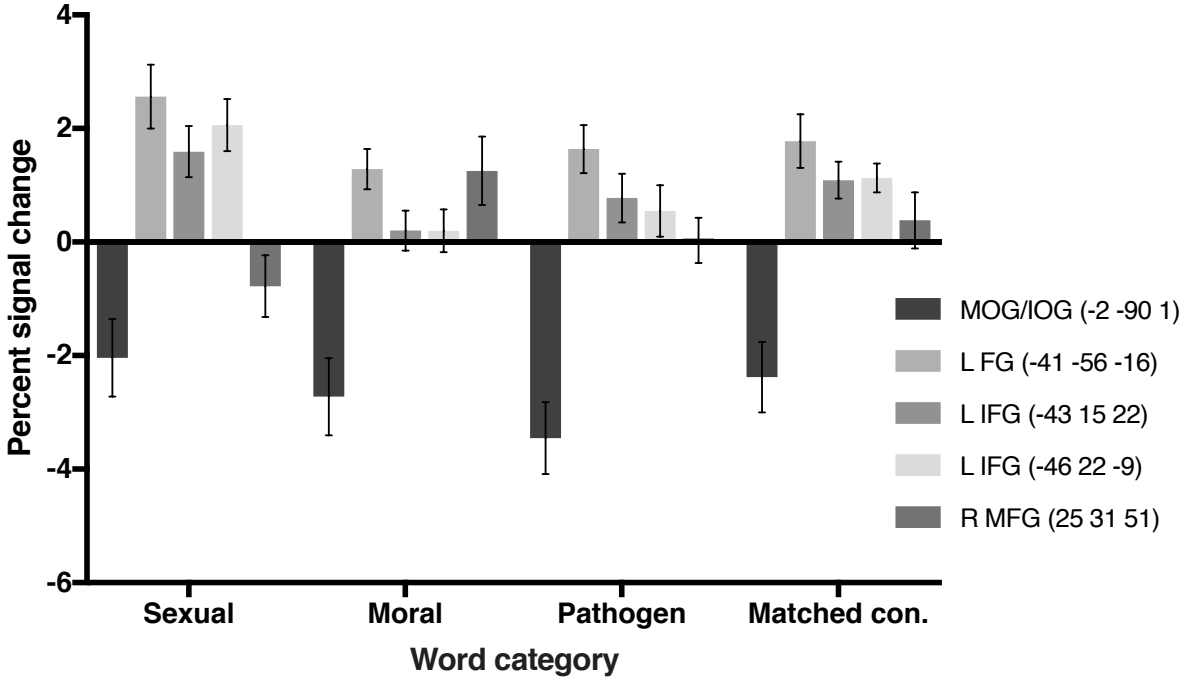

Figure 3. Percent signal change in the five regions active in all three disgust categories and the matched control condition (middle occipital and inferior occipital gyri (MOG/IOG), fusiform gyrus (FG), inferior frontal gyri (IFG), middle frontal gyrus (MFG), right (R) and left (L)).

Discussion

The present study investigated the neural activity in response to words presented in three proposed domains of disgust: pathogen, moral and sexual. In the whole brain analysis, all three categories of words relative to the scrambled word condition revealed activity in the occipital cortices. However, broader activity was found in the sexual condition compared with moral and pathogen conditions including regions in the: left middle frontal gyrus (MFG), right hippocampus and amygdala, left middle temporal gyrus (MTG), regions in the right and left inferior frontal gyrus (IFG), left precentral gyrus and left superior temporal gyrus (STG). Activity for pathogen words were found in the right IFG and two regions in the left fusiform gyrus, whereas the moral words only activated occipital cortices. The broader neural activation in response to the sexual words compared with moral and pathogen words could support our hypothesis that the sexual response may not be considered a domain of disgust.

In the exploratory analysis, significant activation was observed for all three types of disgust in the occipital regions, the left fusiform gyrus, regions in the left IFG and a cluster in the right MFG. Although these clusters revealed a BOLD signal in all three conditions, the BOLD signal in these regions differed significantly between the sexual and moral domains. This further supports the idea that the sexual condition differs from at least the moral condition.

Whole brain analysis

There was broader neural activity in the sexual condition compared with both moral and pathogen conditions, particularly in the amygdala and hippocampus. The amygdala has

commonly been associated with the processing of emotional content, activating in response to both positive and negative stimuli (Vytal & Hamann, 2010). However, one proposal of the function of the amygdala is its role in threat detection (Adolphs, 1999; LeDoux, 2000). Our sexual words were highest in disgust ratings, suggesting the sexual words could reflect a greater source of threat compared with the moral and pathogen words. This could account for the amygdala activity, and potentially, the broader activation overall.

Our sexual words, despite being matched on arousal, might be perceived as greater sources of threat to our participants. Activation of the hippocampus is generally involved in autobiographical memory encoding and retrieval (Taylor, Kornblum, Lauber, Minoshima, & Koeppe, 1997). We did not ask our participants to perform memory tasks. However, the emotional component of the words may have automatically initiated processes involved in setting up a memory trace. Participants primed with negative (e.g., aggression) words prior to making a lexical decision on a neutral word (e.g., map) showed an increase in activity in the right hippocampus (Sass et al., 2012). The negative emotional component of their primes likely induced this activity. Thus, it is possible that negative semantic information of our sexual words was being accessed and that this automatically involved the hippocampus to a greater degree.

Several active regions in the frontal cortex, specifically the right MFG, were observed for the sexual words, but not the pathogen or moral words. The words in all three experimental conditions were negative in valence and had high arousal. However, previous work has suggested that words in the sexual condition are more likely to be taboo than those in the pathogen and moral conditions (Hardwick & Williams, In preparation, Chapter 3), which could be another factor leading to greater neural responses. Taylor et al. (1997) presented

participants with emotional Stroop stimuli during scanning using fMRI. Participants had to identify the font colour of colour words (e.g., red, green) or taboo words (e.g., shit). They found increased activity in the right MFG only with the taboo words, suggesting a role of this region in processing taboo stimuli. Activity in this region in our study was different for our sexual words relative to pathogen and moral words which potentially indicates the processing of the taboo nature of our sexual words.

Two different regions in the frontal cortex were active in response to sexual words in the left and right IFG. There are studies that suggest these areas are also active when participants are presented with emotion evoking stimuli. Participants viewed facial expressions (e.g., happy and sad expressions) overlaid with congruent or incongruent words (e.g., 'happy' and 'sad') (Ovaysikia, Tahir, Chan, & DeSouza, 2011). Increased activity in the left IFG occurred when attending to both happy and sad, congruent and incongruent conditions. Severens, Kuhn, Hartsuiker, and Brass (2012) tested participants with word pairs associated with neutral or taboo words. They found an increase in the right IFG only in response to taboo word pairs suggesting that this area represented the inhibition of socially undesirable stimuli. We thus conjecture that activity in the left and right IFG found in our study may represent the taboo nature of the sexual words.

Exploratory analysis

In our exploratory analysis, the active regions we observed have been associated with the processing of aspects of word stimuli, particularly emotional words. The largest BOLD signal found in all three conditions was in the occipital cortex. It extended from the primary visual cortex (V1) into the associative visual cortices (V2, V3 and V4). It is surprising to find a large activation in the visual cortex, given that we subtracted the visual information from the

scrambled images (images of words that were scrambled such that they contained the visual characteristics i.e., greyscale and black images, but did not look like a word). Therefore, the activity found here may not be due to visual characteristics but could be due to other information contained in the word stimuli.

There is obviously a lot of information present in words that is not present when one scrambles these stimuli. Others have shown the visual areas are involved in processing orthographic and phonological aspects of words. One study focussed on the ventral occipito-temporal region and tested orthographic (syntactic) and phonological (semantic) inputs of neutral written words (Twomey, Duncan, Price, & Devlin, 2011). In the orthographic task, participants were asked to identify real words from pseudohomophones (non-words that sound like a real word e.g., brane). In the phonological task, participants identified whether the pseudohomophone, if sounded out, could be a real word. They found differential activity for the orthographic and phonological tasks suggesting that the occipito-temporal region is an integrative hub of different aspects of word form. They suggest that this activity is due to feedback from areas in the left frontal cortex that process higher order properties of words. It is possible that the activity we found in these visual areas is processing both orthographic components and semantic information of the words that is fed back from higher cortical regions such as the IFG and MFG.

The semantic, or emotional component of a word could modulate activity in the visual cortices. Murray and Kensinger (2014) presented participants with semantically unrelated negative and neutral word pairs. Next, they were asked to recall words pairs that they had previously seen embedded with new word pairs. They saw an increase in visual processing areas when the stimuli contained emotional content compared with neutral content,

suggesting that the emotional properties of the words are processed via visual routes. They suggest that activity in the prefrontal cortex modulates the activity seen in the visual areas. These findings are consistent with an interpretation of the current visual cortex results as reflecting the emotional content of our disgust words relative to our scrambled condition.

The type of neural activity in the left inferior frontal gyrus (IFG) was significantly greater for sexual words compared with both moral words and pathogen words. The left IFG activates during semantic processing. For example, Grindrod, Bilenko, Myers, and Blumstein (2008) presented three word strings that were either concordant (famine, fast, starve) or unrelated (canal, loan, starve). They found greater activation in the left IFG with concordant stimuli/semantically related, compared with unrelated word strings. The difference in semantic, probably taboo, information in our sexual words compared with both moral and pathogen words could explain why the BOLD signal in this region differed. Although there was no difference between moral and pathogen conditions, statistical power was low due to a small sample size. The current study may not have been sensitive enough to pick up a difference between moral and pathogen words (see Limitations section below).

We chose to use word stimuli to represent the 'disgust' domains so we could have well-controlled stimuli across all conditions. A meta-analysis investigated the impact on neural responses of participants' emotional experiences which were induced by a range of emotional stimuli (Brooks et al., 2017). They looked at studies that explicitly used words as stimuli or words within instructions and compared them with studies that did not use any words to induce emotions. In the studies investigating participants' experience of emotion, when emotion words were present, they found activity in the left IFG. They did not find left IFG activity in studies that induced emotion that did not use words. Given the emotional content

of the words used in our study, it is likely the emotional difference of the conditions is represented differentially in the left IFG.

Now turning to the activity found in the right middle frontal gyrus (MFG). We found the BOLD response in the MFG differed between moral and sexual words, but no difference was found for pathogen words. In a study comparing neural activity in response to positive, negative and neutral words, the authors found activity in this area only to the affectively valent words (positive or negative) but not the neutral words (Kuchinke et al., 2006). This suggests a role of this region in processing the valence of a stimulus. However, we matched our stimuli in each category on valence, therefore, we suggest alternatively, that activity in the MFG could be processing the different emotionality of the two conditions, that is affective information not related to valence.

One limitation of our study is the small sample size of 14 participants. Emotion induction experiments like these generally use much larger sample sizes (J. Borg et al., 2008). We suggest that a larger sample size of around 40 participants used in the J. Borg et al., (2008) study would likely yield differences not seen in the current study. It would also increase the power of the exploratory analysis, such that the differences in activity in the five brain regions identified might be more pronounced. An appropriate sample size for this type of study would make investigating the differences between the proposed three domains of disgust in neural activity more robust. However, it is still very interesting that, even with this small sample size, we were in fact able to see significant differences between the categories at both the whole brain and the exploratory levels. This is a promising beginning to teasing apart the neural and cognitive mechanisms underlying the proposed domains of disgust.

Now we turn to the implications of the results for the theory of three domains of disgust. We have data suggesting that the sexual category is distinct from pathogen and moral categories. We observed differences between sexual and moral words in four of the five regions explored, whereas we only observed a difference between sexual and pathogen in one region. In the whole brain analysis, we observed marked differences between the categories in the number of regions, with sexual words activating the most brain areas. If each of these categories are indeed sub-types of disgust, then each should activate common neural areas with only some distinctions between them. The large differences, particularly between moral and sexual conditions, as well as differing BOLD responses in common regions, are not consistent with the sexual domain being a sub-type of disgust. There is evidence for the candidacy of the 'sexual response' to be considered a separate basic emotion (Both, Laan, & Everaerd, 2011; Everaerd, 2006; Stevenson et al., 2011). Based on our fMRI results and our behavioural data (Hardwick, Rich, & Williams, In preparation; Hardwick & Williams, In preparation, Chapters 2 & 3), we agree that the sexual response is a candidate for a separate and distinct basic emotion.

In sum, the sexual words activated a broader number of brain regions commonly found in emotion induction studies, whereas this did not happen with the pathogen or moral conditions. We take this as support that 'sexual' is distinct from both moral and pathogen, thereby potentially constituting a separate basic emotion. We found few differences between moral and pathogen words, although our study may not have been sensitive enough to ascertain a difference given the low sample size. Regarding the five brain regions observed in the exploratory analysis, the BOLD signal differed, particularly for the sexual and moral words. We suggest that this difference can be explained by the different emotional properties of the stimuli. This study therefore forms a good starting point for future research to

disentangle aspects of the emotion of disgust and for the consideration of the sexual response as a separate basic emotion.

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Chapter 5: Disgust Related Words Evoke Different Subjective Feelings in the Body

Disgust Related Words Evoke Different Subjective Feelings in the Body

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Abstract

Basic emotions are represented in subjective bodily sensations differently. However, it is unclear whether bodily sensations differ between sub-types of a basic emotion. To address this issue, we gathered data on subjective bodily sensations in response to words associated with different domains of disgust. We adapted the emBODY software developed by Nummenmaa, Glerean, Hari, and Hietanen (2014) for use on the crowd-sourcing platform, Amazon's Mechanical Turk. This software enables participants to colour in two mannequin bodies, one mannequin represented an 'activation,' or a hot feeling, and was painted red; the other mannequin represented a 'deactivation,' or a cool feeling and was painted blue. We tested 350 participants and found that the reported bodily sensations were represented differently for each individual word within the three domains of disgust. When we averaged the words within a condition the categories did not correlate with each other. This provides support that bodily sensations differed between the disgust related word categories. We propose that subjective bodily sensations are represented differently for the proposed domains of disgust, which might reflect physiological changes that occur with different affective states.

Keywords: emotion, disgust, pathogen, moral, sexual

Introduction

Human emotions motivate behaviours that aid the survivability of the organism. The basic emotions described by Ekman and colleagues (Ekman, 1992; Ekman & Cordaro, 2011; Ekman, Levenson, & Friesen, 1983; Ekman, Sorenson, & Friesen, 1969; Levenson, 1992) are said to have distinct physiological responses that modulate the motivating behaviours. Much research has explored the autonomic nervous system responses to these basic emotions (Damasio & Carvalho, 2013; Ekman et al., 1983; Kreibig, 2010; Levenson, 1992, 2003; Panksepp & Watt, 2011). The resulting physiological changes include alterations in hormonal release, increased or decreased blood flow, contraction or retraction of visceral and striated muscle, all of which function to maintain homeostasis in the organism (Damasio & Carvalho, 2013). Although these changes occur at the autonomic and central nervous system levels, they can be experienced subjectively in bodily sensations (Nummenmaa et al., 2014).

The physiological changes that occur in humans when experiencing an emotion interact with the central nervous system to guide behaviour accordingly (Panksepp & Watt, 2011). For example, increased heart rate, sweaty palms and dilated pupils, are characteristic of dread and fear and prepare the organism for fight or flight. When falling in *love* we may feel a 'flutter in our heart', or during a sordid break-up, it may literally feel as if our 'heart were broken.' Feelings of *anxiety* moments before giving a public talk might cause us to say we have 'butterflies in our stomach.' On the one hand, these latter examples may be a metaphorical or conceptual representation of bodily 'feelings' or they may represent actual physiological changes (Lakoff, 2016). When we have a physiological reaction to an emotion, whether it be love, fear or anger, we physically experience these changes in our bodily sensations.

Importantly, there are known physiological changes that occur in response to pathogen disgust. Typically, temperature and heart rate decrease (Ekman et al., 1983) which can be accompanied by nausea and vomiting. These responses help the organism to reject the offending disgusting item that is likely to cause infection or disease. According to the three-domain disgust theory, *moral* disgust and *sexual* disgust have evolved from the foundations of pathogen disgust mechanisms (Tybur, Lieberman, & Griskevicius, 2009; Tybur, Lieberman, Kurzban, & DeScioli, 2013). These authors argue that primitive disgust mechanisms of rejection and avoidance could provide the neural, physiological and behavioural foundations for these two types of disgust. As yet, it is unclear how moral and sexual disgust have adopted the functions of pathogen disgust.

Basic emotion theory proposes a set of six emotions that are primitive and universal (Ekman & Cordaro, 2011; Ekman et al., 1969; Panksepp, 1992). The theory also predicts sub-types of a basic emotion. Typically, a sub-type of a basic emotion gains its status because – although the feelings are subjectively different – physiologically and neurologically they are proposed to be similar. Therefore, if we are to consider moral and sexual as forms of disgust, we would expect that the subjective experience of each domain would be represented differently in subjective bodily sensations.

Nummenmaa et al. (2014) explored the subjective changes in bodily sensations in response to a variety of emotional stimuli. Participants were presented with an outline of a human body (mannequin) on the left and right-hand sides of the screen. In the centre of the screen was a word, a story, a movie, or a facial expression; each pertaining to one of 13 emotions (six basic emotions: anger, fear, disgust, happiness, sadness and surprise and seven non-basic emotions: anxiety, love, depression, contempt, pride, shame and envy). Participants were

instructed to colour in regions of the mannequin to reflect where in their bodies they 'felt' the emotional response. The left-hand mannequin represented where they felt bodily sensations becoming stronger or more active (red) and the right-hand mannequin represented bodily sensations becoming weaker or less active (blue). They tested two populations: Western European (Finland and Sweden) and East Asian (Taiwan) and found consistent colouring of bodily regions across those populations in response to the 13 emotions. For example, stimuli relating to anger resulted in stronger activity around the hands, arms and chest, sadness produced weaker activity around the arms and legs, and disgust resulted in stronger activity around the gut, oesophagus and oral regions. These results suggest that subjectively, emotions manifest in bodily sensations differently.

If pathogen, moral and sexual disgust motivate behaviours according to their adaptive function, then bodily sensations might differ in response to stimuli between those types of disgust. Disgust is one emotion reported in response to moral transgressions (Gutierrez, Giner-Sorolla, & Vasiljevic, 2012; Hutcherson & Gross, 2011), as is anger, reflected in regions around the chest and arms (Nummenmaa et al., 2014). Feelings evoked by transgressions in the moral domain therefore might induce bodily sensations that reflect either disgust and/or moral anger. Nummenmaa and colleagues (2014) found a stronger activation in response to stimuli invoking the positive emotion 'love' around the chest and genital regions. The proposed 'sexual' disgust is negative in valence therefore we expected 'weaker' feelings in genital regions. We therefore predicted that reported bodily sensations would be experienced differently between the disgust categories.

In the current experiment, we were interested in exploring whether bodily sensations differ between the three proposed domains of disgust. We used a subset of words taken from

Hardwick and Williams (In preparation, Chapter 3) in each of pathogen, moral and sexual disgust domains. We also used a control condition which were words matched on valence and arousal but containing no disgust related content. Based on the findings of the Nummenmaa et al. (2014) study, we predicted that pathogen disgust words would provoke stronger activation around the oral and gut regions. For the moral disgust words, we expected stronger activity around the head, chest and arm regions, more closely representing anger. Finally, we expected weaker activation around the genital region in response to the sexual disgust words. We wanted to explore these subjective bodily sensations to clarify whether there are indeed reliably different subjective experiences representing the three domains of disgust.

Methods

Participants

We recruited participants (n = 350) from the crowd-sourcing platform Mechanical Turk (MTurk) hosted by Amazon.com. We did not include data from 70 participants due to incomplete datasets. We were left with 280 participants with an age range from 18 – 69 (M = 32.6 ± 9.0, males = 165, females = 115), they were predominantly right-handed (right = 249, left = 31) and most had reached tertiary education level (tertiary = 201, secondary = 76, incomplete secondary = 3). Regarding the broader demographics of the MTurk population, studies have shown that they are typically more liberal, younger, less wealthy, more educated and more geographically diverse than a typical undergraduate psychology cohort (Berinsky, Huber, & Lenz, 2012; Mason & Suri, 2012; Paolacci, Chandler, & Ipeirotis, 2010). Participants were given instructions about the study and were informed of the disgusting nature of the stimuli. They could opt out of the study at any time without penalty. Participants were reimbursed $4US for their participation. This study was approved by the Macquarie

University Human Research Ethics Committee and all participants gave informed consent with a button press.

Stimuli

We chose a sub-set of words taken from Hardwick and Williams (In preparation, Chapter 3) that were not statistically different on valence and arousal measures. These words had already been classified into their disgust categories and were also matched on lexical characteristics according to Hardwick and Williams (In preparation, Chapter 3). We had five words in each of the categories: pathogen (contaminated, fungus, rotten, disease, toxic); moral (malevolent, robbery, murder, corrupt, thief); sexual (promiscuous, bondage, anal, pervert, brothel) and a control (catastrophe, maim, hideous, panic, horrific) matched on valence, arousal and lexical characteristics.

Procedure

We modified the emBODY software developed by Nummenmaa et al. (2014) to function on the MTurk platform using the software, Python. Participants saw an instruction screen outlining the details of the experiment and the task (full instructions can be found in appendix V). As in the original emBODY software, their task was to colour in bodily regions on the left-hand side body where they felt activity becoming stronger, or more active, and on the right-hand body if they felt activity becoming weaker or less active, to a word in all four conditions (for an example of what the participant saw, see Figure 1). Participants took on average 20 minutes to complete the task.

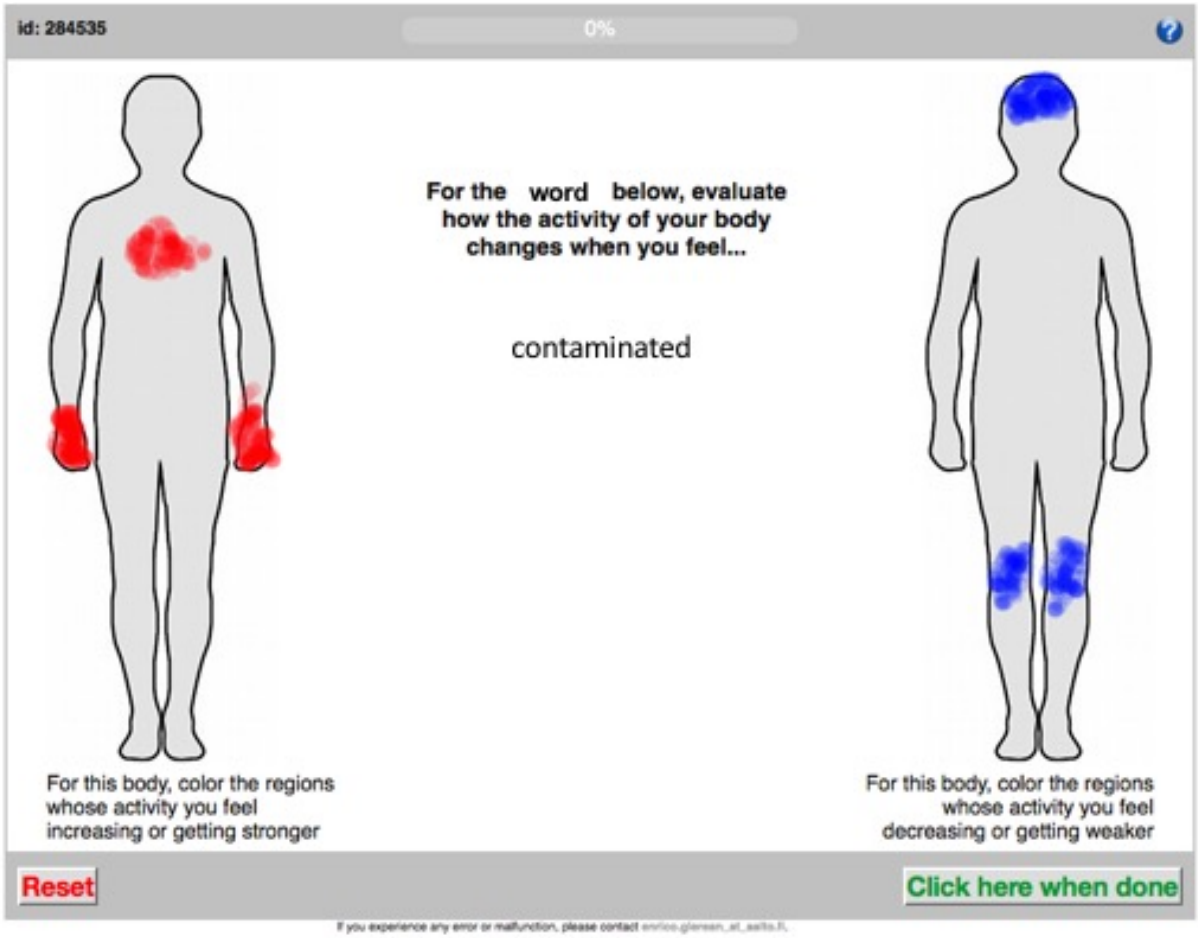

Figure 1. An example page of what the participant saw (the colouring of the mannequin is mock colouring to indicate how the mouse cursor draws colour onto the mannequins). Participants could reset the colouring with the bottom left-hand button.

Analysis

We extracted the data from MTurk and placed each participant's data into a single data file. Each data point had a corresponding x and y value which represented a pixel location on the mannequin mask (outline of the human body). Negative values corresponded to the weakening activity (blue) and positive values corresponded to strengthening activity (red). We collated the data such that we had a 3-dimensional (3D) matrix of values representing the participant (280) x word (20) x pixel location (50,364). We converted this 3D matrix into a 2-dimensional (2D) matrix representing a word (20) x pixel location (33,964) averaged across

participants. The multi-dimensional scaling procedure we used relies on data points that contain variance. We therefore eliminated values corresponding to 'infinity' and 'not a number' as these values did not contain variance. We used the converted 2D matrix to calculate the distances between the words in a dissimilarity matrix. We performed a K-means clustering to investigate whether the words were classified into their respective categories according to bodily sensations represented by the pixel values. We also performed Spearman's correlations to test our predictions that words within the same disgust category correlated. We also produced averaged heat maps to visually represent participants' reported bodily sensations of each word. Additionally, we averaged words in each condition to explore the differences between the disgust categories and produced heat maps of the averaged conditions.

Results

In the present study, we investigated how feelings are represented in the bodily space in response to words associated with the three disgust domains and a matched control. To test for differences among word types, we calculated a dissimilarity matrix measuring the Euclidean distances between each word. We expected that words within a category would correlate with each other. Using Spearman's correlations, and contrary to our predictions, we did not find any significant correlations within word categories ($ps > 0.05$) (see Figures 2 & 3). We then performed K-means clustering to examine whether the pixel values of each word within a category clustered together, which revealed no clustering of the categories (Figure 4). These null results are consistent with the results of the Spearman's correlations of words within a category. To account for a potential lack of statistical power in the within word category analysis, we then averaged the words in each condition and calculated a dissimilarity matrix measuring the Euclidean distances between the averaged categories

(Figures 5 & 6). No correlations were found between the categories and we take this as support that the reported bodily sensations for the categories are different.

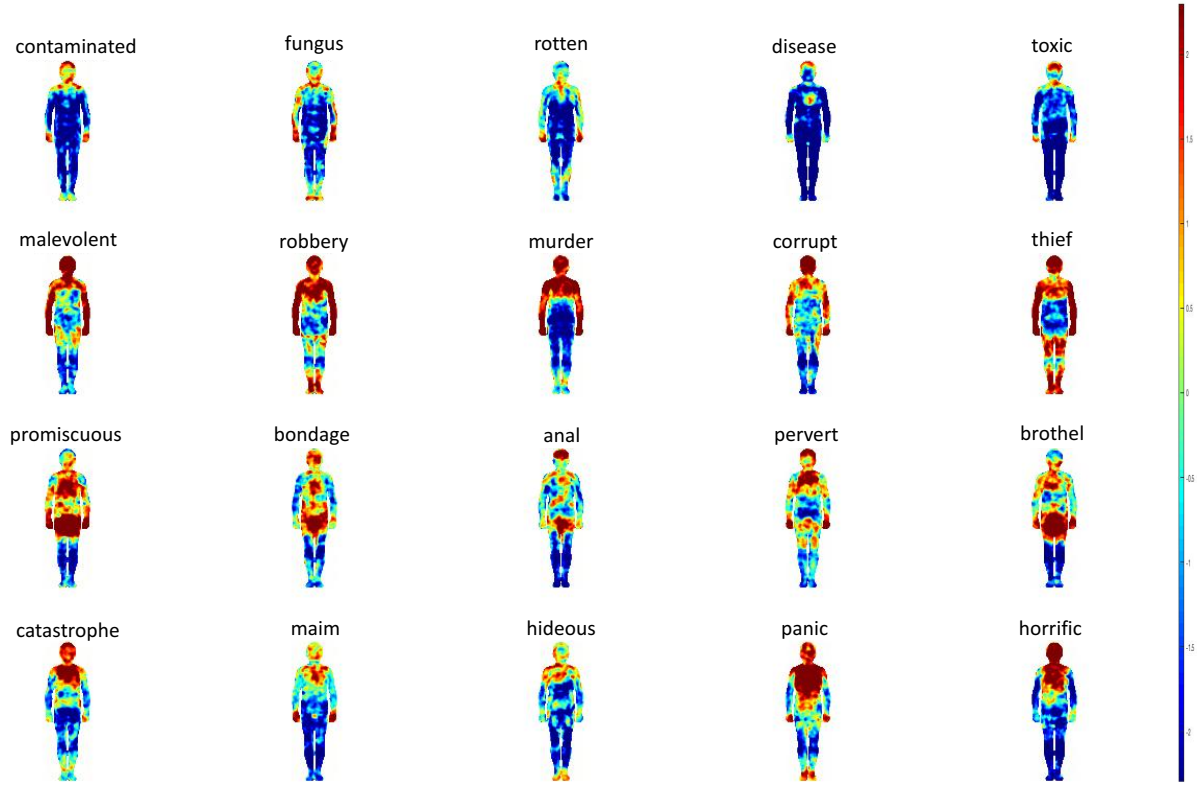

Figure 2. Heat maps in response to the individual words. The top row are pathogen words, the second row, moral words, the third row, sexual words and the fourth row are the matched controls. The side bar are t values, negative values are in the blue spectrum and positive values are in the red spectrum.

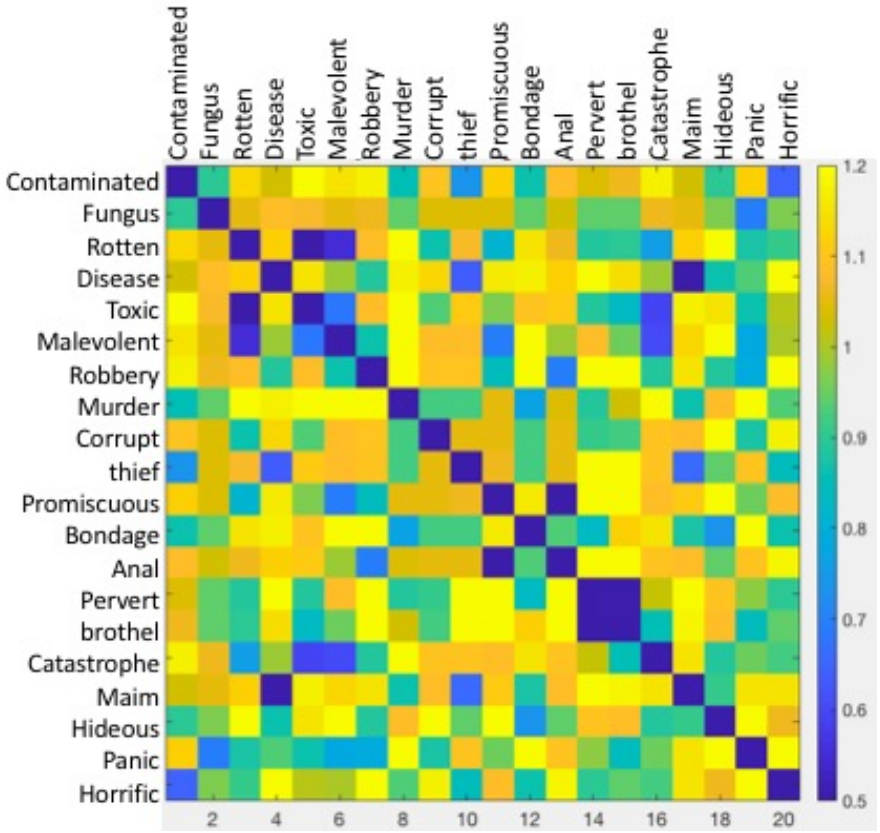

Figure 3. Dissimilarity matrix measuring the differences between the 20 words using the Euclidean distance. Colours in the blue spectrum are closer in distance (more similar) than colours in the yellow spectrum (more different). Words 1-5 are pathogen related words, 6-10 are moral related words, 11-15 are sexual related words, and 16-20 are matched controls.

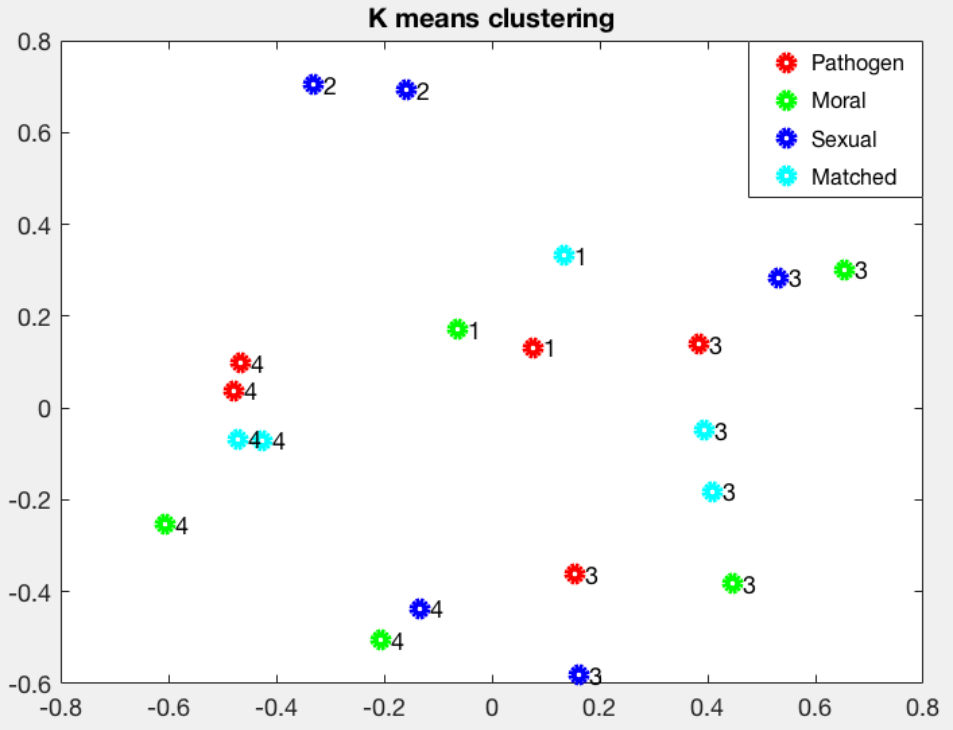

Figure 2. We specified 4 clusters to represent each word category (pathogen, moral, sexual and matched) using K-means clustering, there was no distinct clustering of the categories.

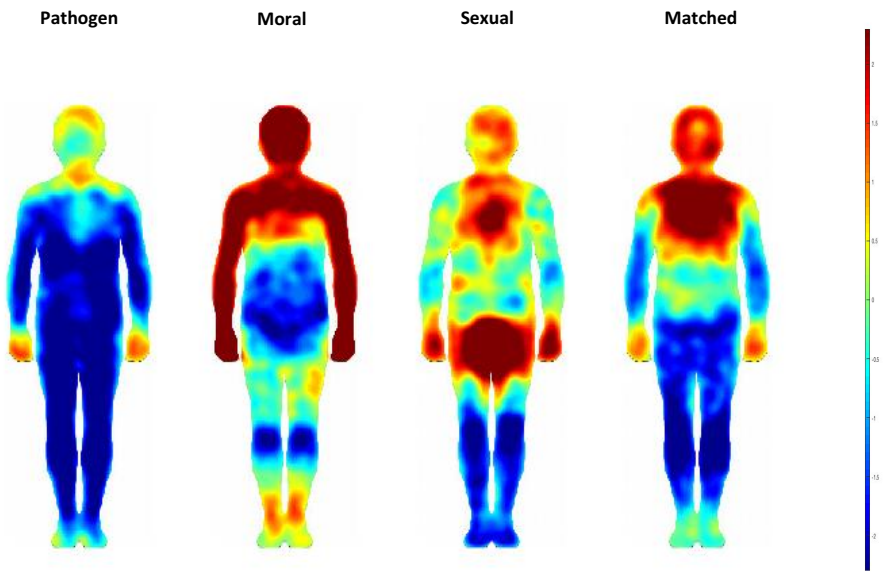

Figure 5. Heat maps of the averaged conditions. The side bar are t values, negative values are in the blue spectrum and positive values are in the red spectrum.

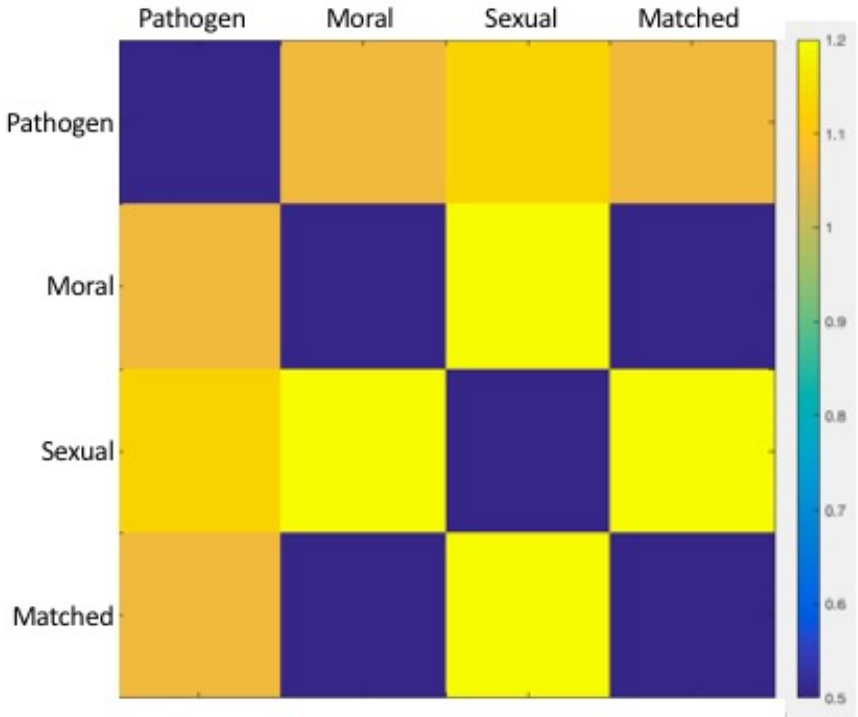

Figure 6. Dissimilarity matrix measuring the differences between the averaged conditions using the Euclidean distance. Sexual words and moral words are more different represented by yellow and the matched and moral condition are more similar represented by blue.

Discussion

In the current experiment, we investigated the subjective reports of bodily sensations of 280 participants in response to a set of words categorised within the sub-types of disgust, plus a matched control. The heat maps visually represent differences in where bodily activations and deactivations occurred with respect to the different words within the disgust categories. We predicted to find correlations between the pixel values of words within the same category however, this did not happen. There are a number of potential explanations for the null results found within word categories: a) subjective experiences of emotions are the result of environmental experiences (i.e., recalling a past experience that roused similar emotions) which may be individually variable, leading to a lack of consistency across our group; b) that the wording of the instructions was unclear or the words themselves caused confusion, which could have led to misunderstandings by participants about what they were actually doing; c) that the power of the analyses of the within word categories was insufficient to detect an effect. To increase the power of the experiment, we therefore averaged the pixel values of words in each condition and there were differences between the categories which we expected. We interpret this as support that the different proposed sub-types are subjectively different. We will discuss these ideas in the following sections.

Bodily sensations in response to the individual words in the present experiment may reflect individual experiences of the participant. The somatic marker hypothesis proposes that areas within the ventromedial prefrontal cortex are responsible for coordinating appropriate emotional responses (Damasio, 1996). This occurs when a new stimulus triggers a memory that evoked that same feeling in the past. Therefore, coordinating responses to the new stimulus relies on the recall of the original stimulus. Thus, one participant's memory of a

'contamination' event may produce different sensations than another's memory of a 'contamination' event presumably involving different sensations between participants. This could explain the variability seen in the heat maps to each of the words.

There is likely great variability among participants' subjective experiences of the same stimuli. We think that this variability may have hindered our ability to find reliable differences between the conditions. A sample size of 280 people sourced from MTurk is not a robust sample size when testing universality of emotional experiences. The Nummenmaa et al. (2014) study tested more than 700 participants from two populations, using 4 different types of stimuli (words, movies, stories and recollections). Therefore, testing a greater sample size might reduce this variability. Another alternative is to provide questionnaires regarding particular instances of the three domains of disgust and asking whether bodily sensations arise when thinking about those answers. Those answers could be quantified with similar colouring methods used in the current design.

Another possible reason why we did not find differences is that some of the 280 participants may not have followed the instructions properly. For example, if one participant had coloured in both mannequin bodies in the same region (both red and blue) then these data would have cancelled each other out. This would ultimately confound 'experiences felt' in different bodily regions. Despite the fact that we instructed participants not to do this, it is possible that they did not follow this instruction. Thus, the reliance on subjective evaluation by participants must be considered in an experiment such as this.

To account for potential lack of statistical power in the within condition analysis, we averaged the words in each condition in a between condition analysis and the dissimilarity

matrix showed differences between conditions. Prominent theories of the *embodiment of emotions,* link subjective bodily sensations with actual physiological changes (Damasio, 1996; Kreibig, 2010). Feeling 'heated' when angered and 'cold' when depressed, are typically associated with physiological changes such as temperature and heart rate fluctuations. Typical responses to pathogen disgust items (images, words, stories and/or reflections) tend to slow the heart rate, increase heart rate variability and reduce body temperature (Kreibig, 2010). With respect to the between condition analysis, heat maps obtained for words associated with pathogen disgust do seem to reflect this pattern of physiological activation with more deactivation (represented by blue), which could reflect a reduced body temperature over the majority of the body and an increase in activity around oral regions (in red) reflecting oral rejection. There is notably much less 'red' activity in response to pathogen disgust words compared with 'moral' and 'sexual' words depicted by both individual word heat maps and the averaged condition heat maps. These reported feelings may reflect those physiological changes reported in the literature for pathogen disgust.

In comparing the differences between the pathogen condition, with the moral condition there is a great deal less red over the whole body in the pathogen condition. In fact, the moral condition showed a strengthening in activation in the head and arm regions, whereas, this did not occur for both pathogen and sexual words. It is possible that 'anger 'was felt in response to the moral words and has manifested in the arms and head, as in the Nummenmaa et al. (2014) study. Clenched jaws and fists could explain the physical correlates of anger which would explain the different heat maps for the moral words compared with the other conditions.

With respect to the heat maps of the sexual words, there was more strengthened activity around the genital region. We predicted that there may be a weakening of activity around this region due to the negative valence of the words. We suggest this stronger activity could reflect the fact that the stimuli are sexual in nature. Other studies that have investigated responses to sexually arousing stimuli implicate activity in the genital region due to physiological changes that occur when sexually aroused (Both, Laan, & Everaerd, 2011; Everaerd, 2006). We did not obtain measures from our participants regarding sexual arousal in response to our stimuli, therefore, we cannot rule out sexual arousal as an explanation.

An alternative approach to account for the 'felt' bodily sensations found in the present study is the use of metaphor. Terms such as a 'broken heart' or 'butterflies in the stomach,' makes it possible that bodily sensations reflect conceptual changes in felt emotions (Lakoff, 2016). However, a rigorous exploration of this hypothesis would include a full historical analysis of metaphorical expressions and their correlate bodily sensations, which to our knowledge has not been investigated as yet. However, it is plausible that metaphorical expressions are reflected in emotional states which could be modulated by physiological changes.

In sum, subjective bodily experiences are 'felt' in regions of the body that might represent physiological changes in response to the 'disgust' conditions. Research that attempts to clarify these subjective experiences with respect to actual physiological changes might help to disentangle the three proposed domains of disgust. Additionally, investigating the use of bodily metaphor in modulating 'felt' experiences may help to understand bodily sensations. It is difficult to reconcile the results of the current experiment with respect to the three-domain disgust theory to clearly infer any clear differences between the three putative domains.

These preliminary data are an important contribution to understanding the subjective sensations of the proposed domains of disgust.

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Chapter 6: General Discussion

General Discussion

The emotion we call disgust has received considerable attention over the last four decades. One current theory, the three-domain disgust theory, proposes three sub-types of disgust: pathogen, moral and sexual (Tybur, Lieberman, Kurzban, & DeScioli, 2013). The core idea of the theory rests on an evolutionary account that moral and sexual disgust have co-opted pathogen disgust mechanisms. Pathogen disgust guides behaviour that prevents contamination, disease and infection. This is driven by mechanisms of rejection, such as nausea and vomiting, as well as avoidance behaviours such as withdrawal from potentially infectious agents. It has been argued that moral disgust has co-opted such mechanisms, which include withdrawal and punishing behaviour toward in-group members who violate social norms. Sexual disgust is said to have evolved by co-opting pathogen disgust mechanisms through the rejection of sexual advances from potentially unfit mates. The experiments conducted as part of this thesis do not support the three-domain disgust theory. The first three experiments (chapters 2, 3 and 4) revealed 'sexual' as a category is distinct from both pathogen and moral categories. Therefore, I tentatively propose that the sexual response be considered a separate basic emotion.

Regarding our choice of methodology, we used objective measures in chapters 2, 3 and 4 (lexical decision, emotional Stroop and fMRI study). Although subjective data can be intriguing (chapter 5), it is often hard to get a good sense of the reliability of the method as compared with the reliability of the experience. Objective measures act as an index of the cognitive processing underpinning the perception of word meanings, here, words relating to the designated disgust sub-types. This is advantageous because it is an advance on subjective reports.

In this final chapter, I will revise the main findings of the experimental chapters and discuss the implications of the results with respect to the three-domain disgust theory (Tybur et al., 2013). Additionally, I will discuss the proposal for the sexual response as a separate basic emotion. Finally, I will consider some of the limitations of the present experiments as well as future areas of research for the investigation of the sexual response as a separate basic emotion.

Overview of findings

In both the lexical decision task and the emotional Stroop task (Chapters 2 and 3), reaction times were slower in response to sexual stimuli relative to the pathogen and moral stimuli. Priming participants with sexual disgust prior to making a lexical decision slowed their reaction times compared with pathogen and moral primes. The time to identify the colours of sexual words was significantly slower relative to the pathogen and moral words. As basic emotion theory proposes that sub-types of a basic emotion show similar behavioural, physiological and neural profiles (Ekman, Levenson, & Friesen, 1983; Levenson, 1992; Vytal & Hamann, 2010), these results do not support the concept that the sexual condition is a sub-type of disgust. Instead, my results suggest that we could consider responses to sexual stimuli, the 'sexual response,' as different from responses to pathogen and moral categories.

The sexual condition in the fMRI experiment (Chapter 4) also revealed that neural responses to sexual stimuli are distinct from that of pathogen-related and moral-related stimuli. The sexual condition revealed much broader brain activity relative to the scrambled condition, particularly in the more primitive limbic regions of the brain, which did not happen in the moral and pathogen conditions. Thus, from an evolutionary perspective, it could be argued that a 'sexual' response may have preceded both pathogen and moral disgusts. I acknowledge

that this is purely speculative, however, that the sexual conditions in all three experiments were distinct from both pathogen and moral conditions suggests there is something different about 'sexual' as a category.

Sexual reproduction is a necessary function in the evolution of a species, presumably mate selection mechanisms adapted over time as a result of environmental pressures. Those pressures would have included access to mates and would have been influenced by the availability of resources (i.e., food, water and shelter). It is reasonable to suggest that 'sexual' as a category, may not show evolutionary roots in disgust, but rather in 'mate-choice' mechanisms (Buss, 1989; Trivers, 1972); that is, the choice to accept or reject a mate based on mate fitness, as well as the current availability of external resources. Therefore, mate-choice theories might better explain the results obtained in our experiments.

An argument against 'sexual' as a sub-type of disgust

The type of sexual disgust Tybur and colleagues (2013) argue for is the rejection of sexual advances from mates of low genetic compatibility (kin) and low fitness value (health). This argument is more akin to mate-choice theory rather than a specific sexual disgust rejection mechanism. Mate-choice theory is a well-established research program that predicts that choices made to select a potential mate are distinct for the different sexes (Buss, 1989; Trivers, 1972). Trivers (1972) argues that the different investments made by males and females in sexual reproduction and offspring rearing, determines whether sexual activity ensues. Females bear the greatest investment by producing approximately 13 fertilisable eggs per year; once fertilised, their investment includes approximately 40 weeks of gestation and at the bare minimum, one year of child rearing. This limits female re-productivity to on average, one child per two-year period. On the other hand, males invest much less, producing

millions of sperm per day indicating the potential for males to sire an infinite number of offspring, depending on his access to females. Therefore females, who provide the greatest investment, are much more choosey when selecting a potential mate. Female mate-choice mechanisms thus better explain responses to sexual stimuli rather than the notion of 'sexual disgust.'

Many factors are in play for female mate-choice. A potential mate's 'profile' such as non-relatedness, good physical health, youth and attractiveness; are all cues signalling a potentially fit mate that would result in healthy offspring. It is difficult to argue that females are feeling 'sexually disgusted' by sexual advances from mates who do not fit this profile. This intuitive challenge is backed up by the findings of this thesis: that sexual items potentially described as sexually disgusting, nonetheless result in different patterns of behaviour than pathogen-disgust inducing items. A possible alternative is that females simply reject unfit mates when they have better alternatives.

From an evolutionary perspective, it is hard to evaluate what choices females have in whom they mate with and whether they indeed feel disgusted by certain sexual advances. As behaviour does not fossilise, an evolutionary perspective on the rejection mechanisms of sexual disgust as an expected sexual 'value' are tenuous. Some argue that disgust does play a role in mate-choice (Fleischman, 2014); however, to my knowledge, no one has directly tested this.

Another reason that we cannot consider sexual as a distinct form of disgust because of its notable confound with pathogen disgust. Pathogen disgust plays a role in modulating sexual outcomes. There is ample evidence that females tend to have higher pathogen disgust

sensitivity compared with males (Fleischman, 2014; Koukounas & McCabe, 1997; Tybur, Bryan, Lieberman, Hooper, & Merriman, 2011). This pathogen disgust sensitivity functions to modulate sexual arousal and thus, sexual encounters. The modulation of sexual encounters via pathogen disgust mechanisms does not make this interaction a specific sexual form of disgust.

Pathogen disgust generally motivates avoidance of bodily fluids which are potentially pathogenic, therefore, in sexual encounters, one must down-regulate pathogen disgust in order to copulate (Borg & de Jong, 2012). This has been shown in studies generating sexual arousal in participants and measuring their pathogen disgust ratings (Stevenson, Case, & Oaten, 2011). These pathogen disgust ratings tend to decrease as sexual arousal increases. However, these data are not consistent with the notion of a specific form of sexual disgust.

Tybur et al. (2013) argue that pathogen disgust is up-regulated in the event of a sexual advance from a sibling and that this constitutes sexual disgust. However, this argument is more consistent with mate-choice theory, which suggests humans have mechanisms to detect, and thus avoid, copulation with kin. This has been shown in studies investigating kin-recognition mechanisms in humans (Lieberman & Smith, 2012; Lieberman, Tooby, & Cosmides, 2007). It has been shown that sibling-copulations produce deleterious alleles in offspring, compromising the offspring's health (Bittles & Neel, 1994). Kin-recognition systems have also been investigated in other species and researchers relate this system with inbreeding avoidance (Brouwer, van de Pol, Atema, & Cockburn, 2011; Lebigre, Alatalo, & Siitari, 2010; Lihoreau, Zimmer, & Rivault, 2007; Nelson-Flower, Hockey, O'Ryan, & Ridley, 2012; Whitehorn, Tinsley, & Goulson, 2009).Thus, the avoidance of kin as potential

mates because of the risk to offspring survival, is better explained by kin-recognition mechanisms, not 'sexual' disgust.

Another argument proposed by Tybur et al. (2013) for 'sexual disgust,' are self-reports in response to incestuous acts. However, research in the moral disgust domain has highlighted that 'disgusted' responses to incest is considered morally wrong, regardless of the circumstances in which it occurs (Haidt, 2001). Many researchers have investigated 'disgusted' responses to incestuous acts (Antfolk, Karlsson, Backstrom, & Santtila, 2012; Antfolk, Lieberman, Albrecht, & Santtila, 2014; Fessler & Navarrete, 2004). More specifically, Antfolk et al. (2012) provided questionnaires to 434 male and female participants with various vignettes relating to different types of incestuous acts. Participants were asked to rate the vignettes according to how disgusted they felt. Overall, they found that women are more disgusted by incest than men and that parent child incest was more disgusting than sibling incest. While these results confirm that disgust is felt in response to incest, they do not implicate 'sexual disgust' *per se*.

Looking cross-culturally, Curtis and Biran (2001) interviewed people from global regions (India, Africa, the Netherlands and the UK) as well as at an international airport. They asked what sorts of objects and events cause disgust. A number of pathogenic items and immoral events were identified, however, the only references to sexual acts were from India (kissing in public), Africa (sexual relations before a child is weaned) and the Netherlands (dirty old men). Similarly, in a survey given to non-native English speakers conducted in the United States, Haidt, Rozin, McCauley, and Imada (1997) asked participants what situations produce disgust. They reported various pathogenic items and moral related acts, however, there was

little data on sexually based acts. These survey data are consistent with the notion that responses to sexual items do not constitute a form of disgust.

Finally, in a review of literature exploring the motives of young men and women who report why they avoided certain sexual encounters, there was no mention of 'sexual' disgust toward a potential suitor (Hatfield, Luckhurst, & Rapson, 2010). The predominant reasons for avoiding sexual encounters for both men and women were the risk of infection (pathogen disgust), and for women only, moral imperatives, such as reputation loss or violations of social expectation (moral disgust). Thus far, we do not have any firm support for the notion of sexual as a sub-type of disgust.

The sexual response as a basic emotion

In chapters 2, 3 and 4 of this thesis, responses to sexual stimuli were different to both pathogen and moral conditions. I therefore proposed that the 'sexual response' could be considered a distinct basic emotion. There is evidence in support of the notion that the sexual response could plausibly be identified as a separate basic emotion. I consider the sexual response to include sexual arousal, sexual drive, sexual motivation and sexual excitation based on previous literature. In one study, R. A. Stevenson et al. (2011) investigated whether the sexual response could be explained by basic emotion theories or dimensional emotion theories. They asked 1,099 participants to rate words and short phrases. Thirteen hundred and fifteen words/phrases were selected which incorporated sexual associations such as: romantic relations, sexual relations, sexual anatomy, sexually transmitted diseases and erotica to name just a few. Participants rated these words on 11 affective scales. Three were dimensional scales including valence, arousal and dominance measures; five were basic emotions (happiness, sad, fear, anger and disgust, e.g., 1 = not at all happy > 9 = extremely happy); and

the final three scales were sexual emotion scales (sexual arousal, sexual valence and sexual dominance). In regression analyses, the authors found that none of the basic emotions predicted responses to the sexual related words. The authors therefore, suggested that the sexual response be considered a separate basic emotion. In the current research, the sexual condition results were different from moral and pathogen disgust in each experiment (chapters 2, 3 and 4). This is consistent with the proposal that the sexual response should be considered a separate category, and perhaps a basic emotion.

Disgust, according to basic emotion theory, is purely an emotion that motivates avoidance (Ekman, 1992). Surprise on the other hand can elicit either approach or avoidant tendencies, depending on the stimulus. Research investigating responses to sexual stimuli such as actual experiences, visual images and mental imagery, demonstrated that participants showed either approach or avoidance behaviours (Borg & de Jong, 2012; Both, Laan, & Everaerd, 2011; Koukounas & McCabe, 1997). More specifically, sexual emotions can be either positive or negative (Everaerd, 2006). The sexual response as a basic emotion fits into an approach or avoidance tendency; for instance, *approaching* a sexual encounter due to feelings of sexual arousal, as opposed to *avoiding* a sexual encounter for lack of sexual arousal. Therefore, it is plausible to consider the sexual response within the basic emotion framework but not as a sub-category of disgust.

There are specific autonomic and visceral changes experienced in the body in response to sexual arousal and a lack of sexual arousal (Both et al., 2011). To my knowledge, physiological responses to sexual stimuli have not been compared with other basic emotions. On the basis of my research, however, I would predict that they are different from other basic emotion physiological responses. Consistent with this hypothesis, an arousing response in the

genitals that often accompanies sexual arousal is presumably specific to the sexual response (Everaerd, 2006). In the experiment on bodily sensations (Chapter 5), our participants coloured the genital regions only in response to the sexual words. This supports the idea that the sexual response is indeed specifically sexual and not indicative of bodily sensations of, for instance, anger, or pathogen disgust. Although I did not directly test physiological responses, the data on bodily sensations supports the idea that sexual sensations are at least reported to be associated with the genital region.

Limitations

There were some limitations in the present experiments. First, we were not able to completely control valence and arousal measures in the lexical decision task but those measures were highly controlled in the three subsequent experiments. Despite our failure to control for these measures in the lexical task, our stimuli were more highly controlled than other studies looking to disentangle sub-types of disgust. This provides a better basis for examining the potential similarities and differences between the proposed disgust sub-types. Second, in the lexical decision task (chapter 2), the fMRI study (chapter 4) and the bodily sensations (chapter 5) experiments, there was a lack of statistical power. However, this was overcome in the bodily sensations experiment by combining the words in each condition, which increased the statistical power by eliminating variance due to the individual words. This revealed a distinction between the conditions. Finally, it is possible that the distinction between sexual responses could overlap with the 'taboo' nature of our stimuli. We cannot be sure our results are specific to the 'sexual response' or 'taboo-ness,' therefore studies comparing sexual taboo words with non-sexual taboo words would help to elucidate this ambiguity.

Future directions

Based on the differences found in both the behavioural and neural data showing that the sexual condition was the outlier, other directions for research could investigate physiological responses. We have not directly investigated physiological responses to each of the domains of disgust, although, some studies demonstrated that physiological responses to each of the basic emotions are distinct (Ekman et al., 1983; Levenson, 1992). Therefore, the use of these measures in distinguishing other basic emotions could be useful for investigating the physiological markers in the sexual response.

The sexual response entails both positive and negative valence, therefore, it would be interesting to observe the difference between sexual words in the positive spectrum compared with those in the negative spectrum. Physiological measures, behavioural measures and neural data could help to disambiguate the types of differences and similarities that arise between positive and negative sexual responses. The recruitment of different brain regions and varying physiology could reveal more about the sexual response as a basic emotion. These studies would need to compare sexual responses against the basic emotions in order to clarify the distinction between the sexual response and those basic emotions.

Another interesting research avenue is to investigate 'sexual' facial expressions. Basic emotion theory also implies that facial expressions are a specific indicator of a basic emotion. Thus, there may be a universally recognised 'sexual' response facial expression. As previously mentioned, since the sexual response contains both positive and negative affective stimuli, it might be possible to find two distinct facial expressions that represent the two poles of the sexual response.

Conclusion

In sum, I have shown in Chapters 2, 3 and 4, that the sexual condition is distinct from both pathogen and moral conditions. In Chapter 5 it was revealed that reported bodily sensations were predominantly felt in the genital region in response to the sexual words, but not to words in the other domains. Due to the data showing this distinction of the sexual condition, I tentatively argue that 'sexual' cannot be considered a domain of disgust. These findings add to a growing literature that shows a lack of empirical support for the sexual response being a domain of disgust. I propose that instead, the sexual response is a candidate emotion within the basic emotion framework. Future research could focus on investigating physiological measures and facial expressions of the sexual response. This research is a good starting point to further investigate the sexual response as a basic emotion.

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Appendix

Appendix I: Disgust stimuli

Pathogen disgust primes	Related	Unrelated	Non-words
	Group 1	**Group 3**	**Group 2**
1)drinking your own urine	swallow	telephone	fulfilp
2)you touching pus on a pimple	appealing	rosebud	sangaurd
3)you drinking cow's blood	sweet	tricks	loids
4)you eating a cockroach	juicy	margins	vero
5)you handling human poo	caress	necklace	lugitive
6)you seeing maggots on meat	tasty	helmet	bowdy
7)you touching a human corpse	embrace	timer	watsif
	Group 2	**Group 1**	**Group 3**
8)you eating worms from the ground	nice	grammar	wede
9)you eating a friend's scab	delicious	instrument	preetish
10)finding a rat's tail in your soup	lovely	inlet	rowir
11)you seeing unflushed diarrhoea	fresh	pledge	mudge
12)you eating a preserved human eyeball	chew	vocal	vespol
13)you are accidentally sneezed on	inviting	brochure	noving
14)you seeing soiled underwear	touch	fork	fugua
	Group 3	**Group 2**	**Group 1**

15)you seeing exposed intestines	great	ringer	dexed
16)you licking someone's sweat	smell	write	gliping
17)you licking a dirty toilet seat	tempting	ripped	gork
18)you drinking from a bed pan	yummy	acorn	tachelors
19)your hair is filled with lice	pleasing	royalty	gexes
20)you seeing a glob of mucous	lunch	wherein	thordplay
21)you smelling vomit in your hair	inhale	swing	coters

Moral disgust primes	**Related**	**Unrelated**	**Non-words**
	Group 1	**Group 3**	**Group 2**
22)you punching a woman	tender	statewide	buffle
23)you stealing from a charity	endorse	presenter	turies
24)you expressing racist slander	helpful	wooden	slere
25)you telling a malicious lie	loyal	outline	stipods
26)you slapping a child	delightful	turtle	sloever
27)you being cruel to animals	brilliant	revolve	plished
28)you committing a violent assault	decent	mobile	blerved

	Group 2	**Group 1**	**Group 3**
29)you exploiting the poor	promising	drive	cleatment
30)you committing a violent crime	considerate	whistle	slansient
31)you banning civil liberties	pure	training	voil
32)cheating on your partner	ideal	lions	brins
33)you supporting violent dictatorships	peace	stove	fligs

34)you humiliating a friend	healthy	trips	gleorem
35)you denigrating refugees	kind	lakes	dort

	Group 3	**Group 2**	**Group 1**
36)stealing from your mother	reward	high	lurnip
37)verbally abusing your father	polite	block	rugget
38)physically abusing your partner	success	suitcase	brying
39)you torturing a cat	welcome	sunlight	clansfer
40)bullying others to get your way	giving	stool	muin
41)you witnessing someone's murder	grand	bottle	hadly
42)sleeping with your best friend's partner	valuable	symposium	vamerio

Sexual disgust primes	**Related**	**Unrelated**	**Non-words**
	Group 1	**Group 3**	**Group 2**
43)you swallowing semen	feast	vehicle	glims
44)you fooling around with a young boy	dignified	sweeping	gacklog
45)you watching child pornography	cute	cable	gormwood
46)you making love with a very old man	desire	gravity	snisky
47)being sexually intimate with your granddad	natural	toaster	sorkhorse
48)you having paedophile sex	rational	green	funvy
49)you are a peeping tom	darling	marker	snereof

	Group 2	**Group 1**	**Group 3**
50)exposing your genitals in public	charming	prescribe	plereon
51)being sexually intimate with your grandma	habit	poster	fulla
52)having sex with your brother	passion	folder	backpard
53) going to bed with your father	fondle	portray	grolly
54) you rubbing a stranger's thigh	precious	accord	fuging
55)going to bed with your mother	devour	accent	torker
56)mother approaching you for intimacy	exciting	symmetric	toyal

	Group 3	**Group 2**	**Group 1**
57)oral sex with your sister	affection	during	tudeness
58)father approaching you for intimacy	opportune	steering	wheegbaso
59)you fooling around with a young girl	brother	lightest	phrarting
60)you making love with a very old woman	stimulate	migrated	porldwide
61)you having an orgy with ten others	normal	mining	prinnied
62)foreplay with your first cousin	tasteful	hedges	dumigate
63)you having anal intercourse with an animal	ordinary	marching	nowed

Appendix II: Control stimuli

Control pathogen	Related	Unrelated	Non-words
	Group 3	**Group 2**	**Group 1**
drinking from your water bottle	swallow	telephone	fulfilp
you touching jelly in a bowl	appealing	rosebud	sangaurd
you drinking fresh lemonade	sweet	tricks	loids
you eating a mandarin	juicy	margins	vero
you handling clean laundry	caress	necklace	lugitive
you seeing sauce on meat	tasty	helmet	bowdy
you touching a computer mouse	embrace	timer	watsif
	Group 1	**Group 3**	**Group 2**
you eating chips from a packet	nice	grammar	wede
you eating an orange	delicious	instrument	preetish
finding tomatoes in your soup	lovely	inlet	rowir
you seeing unflushed water	fresh	lactose	mudge
you eating preserved strawberry jam	chew	vocal	vespol
you are accidentally bumped	inviting	brochure	noving
you seeing clean underwear	touch	fork	fugua
	Group 2	**Group 1**	**Group 3**
you seeing exposed feet	great	ringer	dexed
you licking an ice cream	smell	write	gliping
you licking chocolate on a choctop	tempting	ripped	gork

you drinking from a bubbler	yummy	acorn	tachelors
your hair is filled with conditioner	pleasing	royalty	gexes
you seeing a glob of gel	lunch	wherein	thordplay
you smelling flowers in a shop	inhale	swing	coters

Control moral	**Related**	**Unrelated**	**Non-words**
	Group 3	**Group 2**	**Group 1**
you helping a woman	tender	statewide	buffle
you giving to charity	endorse	presenter	turies
you expressing racial concern	honesty	wooden	slere
you telling the truth	loyal	outline	stipods
you hugging a child	delightful	turtle	sloever
you caring for animals	brilliant	revolve	plished
you stopping a violent assault	decent	mobile	blerved

	Group 1	**Group 3**	**Group 2**
you giving to the poor	promising	drive	cleatment
you stopping a violent crime	considerate	whistle	slansient
you promoting civil liberties	pure	training	voil
loving your partner	ideal	lions	brins
you opposing violent dictatorships	peace	stove	fligs
you phoning a friend	healthy	trips	gleorem
you supporting refugees	kind	lakes	dort

	Group 2	Group 1	Group 3
sharing with your mother	reward	high	lurnip
consulting your father	polite	block	rugget
giving your partner a massage	success	suitcase	brying
you petting a cat	welcome	sunlight	clansfer
aiding others to help your cause	giving	stool	muin
you witnessing someone's reward	grand	bottle	hadly
chatting with your best friend's partner	valuable	symposium	vamerio

Control sexual	Related	Unrelated	Non-words
	Group 3	Group 2	Group 1
you swallowing juice	feast	vehicle	glims
you playing marbles with a young boy	dignified	sweeping	gacklog
you watching children's cartoons	cute	cable	gormwood
you making love with a nice man	desire	gravity	snisky
playing chess with your grandfather	natural	toaster	sorkhorse
you having consensual sex	rational	green	funvy
you are a bystander	darling	marker	snereof

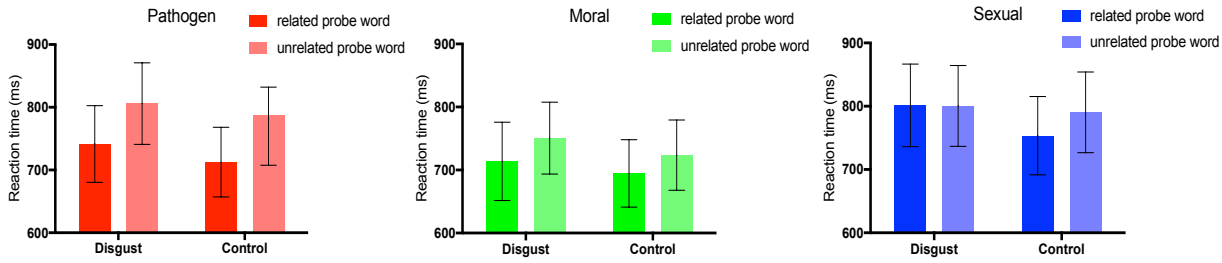
	Group 1	Group 3	Group 2
buying groceries with your sister	affection	during	tudeness

gardening with your grandmother	habit	poster	fulla
having breakfast with your brother	passion	folder	backpard
you sitting next to a stranger	precious	accord	fuging
going to work with your father	fondle	portray	grolly
going to work with your mother	devour	accent	torker
mother approaching you for help	exciting	symmetric	toyal

	Group 2	**Group 1**	**Group 3**
exposing your hands in public	charming	prescribe	plereon
father approaching you for help	opportune	steering	wheegbaso
you playing marbles with a young girl	brother	lightest	phrarting
you making love with a nice woman	stimulate	migrated	porldwide
you playing cards with ten others	normal	mining	prinnied
hanging out with your first cousin	tasteful	hedges	dumigate
you watching animals in a zoo	ordinary	marching	nowed

Appendix III: Raw reaction time data in the lexical decision task

A 3-way repeated measures ANOVA (3 x 2 x 2) on the raw RT data from the word conditions with factors: Category (pathogen, moral, sexual), Emotion Content (disgust, control) and Probe Type (related, unrelated). All three factors revealed main effects: Category ($F_{2,120} = 16.458$, $p < 0.001$), Emotion Content ($F_{1,60} = 7.084$, $p = 0.01$) and Probe Type ($F_{1,60} = 20.88$, $p < 0.001$). The only interaction that was significant was between Category and Probe type ($F_{2,120} = 5.109$, $p = 0.007$), such that participants took as long to identify related probes as they did unrelated probes in the sexual category, which did not happen in the pathogen and moral categories. No three-way interaction was observed.



Appendix IV: fMRI word stimuli

Pathogen	***Moral***	***Sexual***	***Matched***
allergy	arrogant	AIDS	addicted
carcass	blackmail	anal	alone
cockroach	blasphemy	bisexual	avalanche
corpse	contempt	bondage	bereavement
decompose	controlling	brothel	bored
dirty	corrupt	carnal	burdened
fever	criminal	fanny	confused
foul	deceit	fornicate	cyclone
fungus	discouraged	gigolo	derelict
gangrene	fraud	grope	dreadful
germs	gossip	herpes	fatigued
hospital	greed	hooker	flood
measles	guilty	infidelity	frustrated
medicine	immoral	lesbian	guillotine
mildew	lie	mistress	haphazard
morbid	malice	monogamy	horror
mucus	moral	nymphomaniac	hurricane
muddy	neglect	penis	ignorance
pungent	nuisance	pervert	lazy
pus	obnoxious	phallic	messy
rancid	offend	pimp	moody
rat	regretful	prostitute	nasty
disease	ridicule	rape	nervous
sickness	robber	sadomasochism	nonsense
slime	scandal	scrotum	noose
smallpox	scapegoat	sleazy	obesity
sour	scorn	syphilis	penalty
urine	sin	taboo	shark
toxic	sinful	testicle	solemn
tumor	snob	transsexual	thorn
vomiting	prejudice	whore	clumsy
rotten	extortion	vaginal	ferocious

Appendix V: emBODY software instructions

Instructions: For MTurk participants using the emBODY software.

'READ THESE INSTRUCTIONS VERY CAREFULLY

In this experiment we study whereabouts in their bodies people feel different emotions in response to disgusting sentences. You will be presented with a disgusting sentence (such as "handling dog poop" or "physically hurting your mother"), and pictures of two blank human bodies.

Think about what you feel in your body in response to the sentence. Your task is to colour the bodily regions whose activity you feel changing during the emotions you feel in response to the sentence. For example, the sentence "handling dog poop" might induce increased activity around the hands, mouth or stomach, whereas the sentence "physically hurting your mother" might induce decreased activity around your hands and arms. However, your particular response may differ from these examples. Try not to think too much about the sentences, use your intuition to guide you.

For the left hand-side body (red), colour the regions whose activity you feel increasing or getting stronger when you feel emotions in response to the sentence. For the right hand-side body (blue), colour the regions whose activity you feel decreasing or getting weaker when feeling those emotions in response to the sentence. You can colour any region of the bodies you feel appropriate, from the head to the toes. It is ok if you colour slightly outside the lines of the body, but try and colour mostly within the body. When you have completed colouring the bodies, click the button at the bottom right of the screen to proceed to next page. And remember, try not to think too much about the sentences, rather, use your intuition to guide you.'

Appendix VI: Ethics approval

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(Research)

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MACQUARIE
University

28 July 2016

Dear Prof Williams

Reference No: 5201400104

Title: *The neural correlates of physical disgust and moral aversion using biographical memory*

I am pleased to advise that ethical approval has been granted for the amendment dated 26 July 2016.

The HREC (Medical Sciences) Terms of Reference and Standard Operating Procedures are available from the Research Office website at:

http://www.research.mq.edu.au/for/researchers/how_to_obtain_ethics_approval/human_research_ethics

Please do not hesitate to contact the Ethics Secretariat should you have any questions regarding your ethics application.

The HREC (Medical Sciences) wishes you every success in your research.

Yours sincerely

Professor Tony Eyers
Chair, Macquarie University Human Research Ethics Committee (Medical Sciences)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) *National Statement on Ethical Conduct in Human Research* (2007) and the *CPMP/ICH Note for Guidance on Good Clinical Practice*.