Distinguishing moral disgust and anger using pupillometry and responses to economic behaviours

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Contents

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Abstract

A growing body of research suggests that our moral judgements are emotional and intuitive rather than carefully reasoned. Anger and disgust are two emotions that are thought to play key roles in driving these moral judgements. However, as both emotions are negative, reported in response to similar scenarios, and usually highly correlated it is often argued that they are not distinct emotional states. To address this, the present research uses two methods of distinguishing moral disgust from moral anger: pupillometry and an economic game. First, across two studies, we found that self-reported feelings of disgust, but not anger, predicted significant pupil dilation to emotionally engaging sounds and images. Second, we used this method to investigate emotional reactions to immoral vignettes, finding that a specific subtype of moral violation—purity violations—increased both disgust and pupil size. This distinguishes moral disgust and moral anger both physiologically and by the violation to which they respond. Finally, to address real examples of immorality which personally affect the participant, we use a novel economic game where the financial gains of participants were affected by the incompetence and potentially harmful financial choices of their teammates. Results indicate that, unlike the hypothetical moral judgements of the previous study, disgust responds to intentional financial harm inflicted on the participant whereas anger responds to incompetence. Additionally, in response to the same behaviours in a group the player was not a part of, there were different emotional responses: both anger and disgust were found in response to harm. Overall, the present research indicates that disgust and anger are usually distinguishable physiologically and by which behaviours they respond to, but they are elicited differently in hypothetical and non-hypothetical moral judgement.

Author Note

Chapter 4 of this thesis has been drafted in the form of an article as it has already been prepared to submit for publication. Thus, Chapter 4 will repeat in detail some similar theoretical content from other chapters in the thesis; however, the table and figure labels have been renumbered so as not to repeat.

Chapter 1: Introduction

The experience of emotion is ubiquitous to human life. Because of this familiarity, it may strike some as odd to even pose the question: what is the purpose of emotion? However, this universality, evidenced by cross-cultural similarities in emotional experiences (e.g., Ekman & Davidson, 1994; Elfenbein & Ambady, 2002), suggests that these discrete emotions likely evolved to serve adaptive purposes, selected for in our ancestors. One of the more interesting proposed purposes for our emotions is in moral behaviour. It is argued that morality does not rest first and foremost upon our rational judgements but on our emotions (Damasio, Everitt, & Bishop, 1996; Haidt, 2001; Koenigs et al., 2007). Two specific emotions have been identified as playing a core role in this process: anger and disgust. Most recognise that feelings of both anger and disgust are elicited by morally repugnant behaviour; moral disgust, for example, is widely and publicly referenced by politicians when expressing moral condemnation: “This was a disgusting, misogynistic attack” (@SadiqKhan, 2019). Yet, despite being a frequently communicated emotional experience, the validity and function of moral disgust—particularly as a separate emotional experience to moral anger—remains debated in the current literature.

Both moral disgust and moral anger are frequently reported in response to similar immoral behaviours. While anger is most often associated with acts that are considered intentionally harmful, unjust, and unfair (e.g., Graham et al., 2013; Izard, 1977; Rozin, Lowery, Imada, & Haidt, 1999; Russell & Giner-Sorolla, 2011a; Sell, Tooby, & Cosmides, 2009), these acts are also often considered disgusting. When we look at disgust elicitors spontaneously generated in qualitative research, we can see clear examples of

intentional harm, injustice, and unfairness, for example, animal cruelty, physical harm and abuse, verbal abuse, betrayal, and being 'ripped off' (Curtis & Biran, 2001). Because of this, some suggest that moral disgust is simply a synonym for moral anger rather than these being separate emotions with disparate adaptive functions (Herz & Hinds, 2013; Nabi, 2002). Two lines of research could assist our understanding of whether these emotions are, in fact, separate. First, we could aim to directly measure these emotions in a way that does not rely on self-report, such as via physiological measurements. Any psychophysiological correlates would provide evidence against the assertion that disgust and anger are only semantic equivalents. Second, we could attempt to separate these emotions based on their each having specific, adaptive roles in responding to different aspects of morality.

Consequently, our understanding of moral disgust and moral anger are necessarily affected by the wider disputes surrounding the difficulty categorizing and measuring discrete emotional states physiologically, as well as contradictory results found when discussing potentially different evolutionary roles for moral emotions. In this thesis, I aim to contribute to the current understanding of the moral emotions of disgust and anger using two novel avenues: measuring pupil size as a method of distinguishing disgust from anger and assessing disgust's and anger's potential social roles using methodology from behavioural economics.

Disgust and Anger as Discrete Emotions

First, underpinning our ability to distinguish between disgust and anger is the wider debate surrounding how emotions, in general, are produced and perceived.

Fundamentally, disagreements centre on whether each emotion is a discrete, universal entity measurable via its own physiology, feelings, and behaviour or a culturally dependent, descriptive category impossible to distinguish from emotions of the same valence based on measurements of any of these outputs. Whether we understand disgust and anger as natural, innate, universal emotions or as culturally dependent, descriptive categories necessarily impacts how we will approach the measurement of these emotions. In both cases describing something as eliciting disgust rather than anger may reflect a meaningful cultural and personal difference, but if it is purely a descriptive category the measurement of psychophysiological outputs would not allow us to determine this, and thus would be a less appropriate measurement than self-report. As such, before discussing disgust as an emotion with the potential to be investigated and separated from anger using pupillometry, it is important to explore the evidence for the appropriateness of this assumption.

Clearly, both within psychology and in the wider population, emotions are conceptualised as natural, separate, discrete states with distinct associated feelings and observable behaviours. Most would assert an ability to recognise and distinguish between, for example, sadness and fear in themselves and others. So, unsurprisingly, for over 100 years, understanding emotions as natural, universal, discrete entities has been the dominant view in Western science (Allport, 1922; Darwin, 1872; McDougall, 1909). More recently, this understanding has been key to basic emotion theory which asserts that in all humans the same basic emotions will be felt and expressed. The criteria for what would constitute a basic emotion, according to Ekman and Cordaro (2011) are, first, that emotions must be modular and distinguishable from each other and, second, that they have evolved through adaptation to our environment. In this way, an emotion should be

universally recognised across different cultures, have a distinct associated physiological response (such as increased heart rate in anger or widened eyes in fear), and a distinct subjective experience (Ekman & Cordaro, 2011). Based on these criteria, it has been argued there is currently sufficient evidence to define disgust as a basic emotion, alongside anger, fear, surprise, sadness, contempt, and happiness (Ekman & Cordaro, 2011).

The influence of basic emotion theory is clear; in a survey of emotion researchers, 74% of those surveyed used this discrete understanding of emotion to some extent in their research, and for these individuals, the five emotions that were considered to be empirically established were: sadness (by 80%), happiness (76%), fear (90%), anger (91%), and disgust (86%) (Ekman, 2016). However, despite the intuitive appeal, long history, and wide use of the basic emotion approach, there are critiques of this theory which should be addressed. First, rather than consistent behavioural outputs allowing for easy recognition of emotions in all cases, there is variation in appearance and behaviour of discrete emotions (Barrett, 2013; Lindquist, 2013; Stearns, Gendron, & Feldman Barrett, 2009). Depending on the situation, people can produce behaviours and expressions at odds with the predicted forms. For example, when feeling angry, you may scowl and argue, or you may politely force a smile (Barrett, 2013; Lindquist, 2013; Stearns et al., 2009). Specifically, for disgust, rather than consistently and exclusively finding the same response—that being the distinctive disgusted grimace and feelings of nausea or repulsion—there are studies that report finding concurrent, mixed emotions of amusement and disgust in response to disgusting stimuli (Hemenover & Schimmack, 2007). This introduces complexity to the ability to clearly and easily recognise emotions via behaviour and facial expression which, as mentioned above, has traditionally been

argued as key to understanding emotions as discrete (Ekman & Cordaro, 2011).

In addition to the recognition of emotions based on certain consistent associated behaviours, it is also thought that each basic emotion should be marked by distinct associated physiological responses, generally evidenced by psychophysiological measurements of the autonomic nervous system (Ekman & Cordaro, 2011). Psychophysiological evidence consists of measurements such as electrodermal activity, cardiovascular activity, muscular activity, and changes in pupil diameter. The parasympathetic and sympathetic divisions of the autonomic nervous systems have distinct functions which are reflected in these measures. Sympathetic activation is marked, for example, by pupil dilation, increases in heart rate, sweating, and decreased blood flow to the gastrointestinal system and the kidneys. Parasympathetic activity is marked by pupil constriction, decreased heart rate, increased salivary production, and increased blood flow to the gastrointestinal system (McCorry, 2007). The sympathetic system predominates as the body prepares for strenuous physical activity, such as during 'fight or flight' situations, whereas the parasympathetic system's purpose is to conserve energy and regulate basic bodily functions, such as digestion (McCorry, 2007).

Understanding the autonomic nervous system as an all-or-nothing system, it has been assumed that emotions would be associated with a suite of sympathetic or parasympathetic activation across effector organs. As an emotion related to aggression, including physical aggression, anger is theoretically associated with sympathetic activation and thus should be marked by high heart rate, low heart-rate variability (HRV; a measure of respiratory sinus arrhythmia and vagal tone), pupil dilation, decreased gastric activity, and galvanic skin response (GSR) showing activation of the sweat glands. Anger has been associated with GSR (increased skin conductance levels) however, this is

common for a range of negative and positive emotional responses including disgust (e.g., Christie & Friedman, 2004; Tsai, Chentsova-Dutton, Freire-Bebeau, & Przymus, 2002). Distinction from these other emotions can mostly be found using cardiovascular measures which associate anger with increased heart rate and low HRV (Foster & Webster, 2001; Rainville, Bechara, Naqvi, & Damasio, 2006; Vrana, 1993); this separates anger from other negative emotions marked by high heart rate but with concurrent high HRV: fear and sadness (Rainville et al., 2006).

In contrast, it has been suggested that, theoretically, disgust should activate the parasympathetic nervous system (Rozin, Haidt, & McCauley, 2008) and thus should be marked by low heart rate, high HRV, pupil constriction, increased gastric activity, and no GSR. In support of this, high HRV has been found in response to bodily fluids (de Jong, van Overveld, & Peters, 2011; Ottaviani, Mancini, Petrocchi, Medea, & Couyoumdjian, 2013; Rohrmann & Hopp, 2008) and mutilation (Shenhav & Mendes, 2014) and lowered heart rate during self-reported moral disgust (Konishi, Himichi, & Ohtsubo, 2019) and mutilation (Christie & Friedman, 2004; Codispoti, Surcinelli, & Baldaro, 2008; Rohrmann & Hopp, 2008; Shenhav & Mendes, 2014). These results indicate disgust is marked by parasympathetic cardiovascular responses.

However, as with behavioural outputs, variation can be found when investigating distinct psychophysiological markers for disgust. Sympathetic activation is also common in studies of disgust's psychophysiological correlates. Whilst lowered heart rate has been found in response to disgusting injuries and self-reported moral disgust towards scenarios, increased heart rate has been found in response to depictions of incest (Ottaviani et al., 2013) and bodily waste (Shenhav & Mendes, 2014). Further evidence of sympathetic activation is reflected by decreased gastric activity in response to depictions of bodily

waste (Shenhav & Mendes, 2014). Finally, as mentioned above, disgust has been associated with GSR, but this measure is associated generally with emotional reactivity (Christie & Friedman, 2004; Codispoti et al., 2008; de Jong et al., 2011; Rohrmann & Hopp, 2008; Tsai et al., 2002). To further complicate this pattern of results; there are also studies finding no difference in autonomic response when compared to control stimuli. For example, there was no difference in heart rate during control films compared to films of people vomiting (Ottaviani et al., 2013; Rohrmann & Hopp, 2008) or of a man gagging and digging through faeces (Horberg, Oveis, Keltner, & Cohen, 2009). Similarly, there is no significant difference in HRV to depictions of bodily waste compared to controls (Shenhav & Mendes, 2014). Based on this it would be difficult to say that disgust engenders an entirely parasympathetic or sympathetic response across effector organs or stimuli.

Psychological Constructivism

One offered solution to the variability seen in emotional responses and psychophysiological measures is to deny that separate emotions, such as disgust and anger, exist as discrete entities at all. This is the basis for dimensional theories of emotion which suggest that physiological measures only indicate the feeling's valence (positive or negative), arousal (activated or deactivated), and whether the person intends to approach or avoid. More specifically, one such theory, *psychological constructivism*, argues that emotions are descriptive, cognitive categories stemming from an individual's culture and personal experiences, with each category—such as disgust— containing a variety of unique instances of feelings and expressions. Experience of a supposedly discrete emotion emerges when one combines external information (e.g., visual, auditory, tactile)

with internal information (physiological arousal). As such, which emotion a person would say they are experiencing in response to external stimuli depends on categorisation based on two sources of information: *core affect* (i.e. basic physiology) and *conceptualisation* (i.e. contextual information) (Lindquist, 2013). It is argued that this process of conceptualisation uses prior experience, cultural information, and language to categorise a specific emotion (Lindquist, 2013).

The importance of culturally dependent information such as language to emotional experience is vital to the constructivist understanding of emotions. Researchers attempt to disrupt conceptualisation through *semantic satiation*—meaning repetition of a word until it becomes temporarily meaningless—of emotional words. This semantic satiation of an emotional word, such as anger, prevents participants from recognising the corresponding emotional expression, suggesting language is key to emotional recognition (Lindquist, Barrett, Bliss-Moreau, & Russell, 2006). Based on evidence such as this, it is suggested that an inability to label an emotion prevents experiencing that emotion. Extending this logic, Barrett (2017) argues different cultures will feel different emotions; language is specific to a culture with certain words, including emotional words, not having a direct translation (e.g., schadenfreude is specific to Germany without an exact English equivalent) and, for this reason, these emotions will be conceptualised in some cultures but not others. Similarly, even within a culture, a more limited emotional vocabulary disrupts conceptualisation. A lowered ability to make fine-grained distinctions between emotions, between anger and frustration, for instance, is associated with emotional dysregulation evidenced by excessive alcohol use and even mental illnesses such as Schizophrenia (Kashdan, Ferssizidis, Collins, & Muraven, 2010; Kring, Barrett, & Gard, 2003). Based on this, for emotional constructivism, the experience of an emotion and an

emotionally healthy existence is tied to the ability to label, and therefore conceptualise, emotions. This means that although, overall, psychological constructivism does not argue that discrete emotional categories are meaningless, emotions are culturally specific and cannot be categorised based on distinct, consistent, universal markers in outputs such as individuals' physiology, neurology, and expression.

Whilst the understanding of emotion offered by constructivism offers one solution to the variability previously demonstrated in physiological markers of disgust, a different approach would be to take a more complex view of the autonomic nervous system. In this way, rather than entirely rejecting the validity of measuring physiological outputs during the experience of emotion, we should perhaps not be entirely surprised by the complex pattern of results found in the measurement of this system. Rather than the autonomic nervous system being conceptualised as a simple, all-or-nothing system, there is evidence for independent and selective activation of sympathetic and parasympathetic systems in different effector organs, allowing for a quick and complex response pattern (Folkow, 2000). This is supported by evidence that there is some ability to separate disgust and anger using specific measures; in a review of 134 publications anger is associated with increased heart rate whereas decreased heart rate was associated specifically with mutilation disgust (Kreibig, 2010) a marker also associated with moral disgust in a more recent paper (Konishi et al., 2019). Additionally, the finding that contamination disgust was not associated with heart rate deceleration in this review is used to suggest that subtypes of disgust will be associated with different patterns of autonomic activity. Splitting disgust into subtypes, such as moral, sexual, and pathogen (Tybur, Lieberman, & Griskevicius, 2009) or core disgust, animal reminder disgust, and contamination disgust (Olatunji, Haidt, McKay, & David, 2008), is a common approach to this emotion and so

some physiological variation between categories would not be unexpected. Beyond this, these results suggest that parasympathetic cardiovascular responses can exist logically alongside sympathetic dermal and respiratory responses, and as such further avenues of investigation—such as pupillometry—may yield different results.

The Evolutionary Psychology of Emotion

The evidence suggesting emotions have somewhat consistent markers, albeit in a complex relationship with stimuli, requires a framework which addresses this complexity. While widely applied, neither the constructivist nor basic theories allow for the assumption that discrete emotions exist with a theoretical explanation for the evidenced variation in behaviour and physiology. However, a third theory which uses a modern evolutionary approach to the study of emotion exits which does so. In this approach emotions are hypothesised to be superordinate mechanisms, each representing a distinct 'mode' evolved to coordinate a suite of changes in, to name just a few processes, memory, attention, physiology, behaviour, motivational priorities, and energy allocation (Al-Shawaf, Conroy-Beam, Asao, & Buss, 2016; Cosmides & Tooby, 2000; Tooby & Cosmides, 2008). This explanation allows for a more complex understanding of emotions as flexible adaptations to address a range of problems, such as mate competition and retention, hierarchy negotiation, status management, punishment, and food acquisition. To address such a wide range of adaptive problems, this theory allows for variation in the behavioural and physiological markers based on proposed function and contextual requirements.

In this conception, not all emotions will be recognised by conspecifics and each instance of an emotion is not required to be identical. As with constructivism, each

occurrence of the same emotion may not activate the same suite of changes in memory, attention, physiology, behaviour, motivational priorities, and energy allocation. This allows for differences in, for example, motivational priorities whilst experiencing the same emotion; approach motivated fear could be experienced in one instance, such as a fight against a weaker opponent, compared to avoidant fear in another, such as escaping a dangerous predator. It is also asserted that it is not necessary for all emotions to be recognised, either at all or consistently, by conspecifics. Some emotions serve a communicative purpose (either consistently or based on situation) whereas others do not. So, important for this approach, is the difference between signals and cues: a signal, such as changes in body language or facial expression, is intentionally observable for conveying information or influencing others, whereas a cue such as sweating and other physiological changes are visible but not evolved to be communicative. As such, emotions may have universal cues but may not have a universal signal. Similarly, variation can be explained by context-specific outputs, such as communicating disgust to warn others or suppressing disgust out of politeness. Emotions, therefore, will be characterised by a coordinated profile of psychological, physiological, and behavioural activation and may have evolved a universal signal, no universal signal, or to give a context-dependent signal.

In this way evolutionary theory has reframed our understanding of emotions to address concerns raised about basic emotions, whilst still retaining that discrete, evolved, emotional categories are measurable and meaningful. So, based on evidence that there are differences reflected in cardiovascular autonomic measures for most subcategories of disgust and anger, in this thesis, we investigate pupil dilation as a physiological cue which the disgust 'mode' may coordinate. Additionally, as we use this evolutionary

understanding of emotion, we explore (using pupillometry as well as behavioural economics) the potential disparate adaptive functions of disgust and anger.

Disgust's Evolutionary Origin

As mentioned above, disgust is an emotion elicited by sources that are both social (e.g., immorality or disliked groups or individuals) as well physical (e.g., vomit, faeces, gory injuries, distasteful food). Consequently, evolutionary explanations of this emotion's adaptive function must cover this wide array of disgust elicitors. Generally speaking, those who study disgust agree that *physical* or *core disgust* originally developed as part of a system which helps humans to avoid illness and death by limiting our exposure to pathogens and/or other toxic substances (e.g. Curtis, de Barra, & Aunger, 2011; Haidt & Joseph, 2008; Schaller, 2011; Schaller & Park, 2011; Tybur, Lieberman, Kurzban, & DeScioli, 2013) whereas, *interpersonal* and *moral disgust* elicitors are argued either to be preadapted from this original function (e.g., Curtis, 2013; Haidt & Joseph, 2008) or evolved simultaneously to solve different adaptive problems (e.g., Tybur et al., 2009). However, before discussing interpersonal and moral disgust, it is important to understand that even explanations for the adaptive function of physical disgust differ; with disgust functioning either as an integral part of our bitter taste rejection system—discouraging consumption of toxic, inedible items—or as part of a pathogen avoidance system. The first conception relies on evidence that bitter tastes indicate the toxicity of a substance (Soranzo et al., 2005), the latter conception relies on evidence that common sources of disgust, such as faeces, are also pathogen-risks (e.g. Curtis, 2013).

The connection between physical disgust and food is as old as the English word

"disgust" itself; the etymology of "disgust" is the Middle French word for distaste: desgoust ('Disgust, n.', 1989). Many traditional, psychological conceptions have been based on this association, for example, by defining disgust as revulsion at the prospect of oral incorporation of an offensive substance (Angyal, 1941; Rozin & Fallon, 1987; Rozin, Millman, & Nemeroff, 1986). In this way, the mouth is conceptualised as the main port of entry of the outside world into the body and the final checkpoint where substances can be identified as food or toxin and rejected if necessary (Nemeroff & Rozin, 1989). However, this does not mean this theory limits disgust to the rejection of toxic, ingestible substances; it has been suggested that, through a process of cultural evolution, this system has been co-opted to encourage withdrawal from a wide range of elicitors, such as contaminating non-food items (such as bodily injuries), socially unacceptable behaviour and taboos, or certain members of social groups (Chapman & Anderson, 2013; Rozin, Haidt, & Fincher, 2009). In this way, some theorists maintain the focus on disgust's oral origins, albeit expanded to include evidence of disgust's role in pathogen avoidance (Chapman & Anderson, 2013; Rozin et al., 2009).

While distaste-based theories are founded on the protection of humans from the entry of disgusting substances and pathogens through the mouth, alternative conceptions frame it as a system that evolved to defend all animals from the entry of parasites and pathogens into any orifice; i.e. mouth, skin, airway, and genitals (Curtis, de Barra, & Aunger, 2011; Curtis, 2013; Schaller, 2006; Schaller & Park, 2011). In this way, the disgust reaction developed to aid avoidance of bodily contact with a variety of pathogen sources, such as faeces, blood, and nasal mucus. It is not coincidental that disgusting objects including these relate to dangerous diseases: faeces are the source of gastrointestinal infections such as cholera, exposure to nasal mucus can cause pneumonia

and tuberculosis, and pathogens carried in blood lead to AIDS, hepatitis, and syphilis (Curtis, 2013). It is clear, therefore, that avoiding these disgust elicitors would increase chances of survival and would thus be evolutionarily advantageous.

Distaste and Disgust Domains

It is recognised that a wide variety of objects, people, and behaviours can be labelled as disgusting, and, because of this, many authors attempt to categorise these elicitors into distinct domains with distinct evolved functions. However, there is a marked difference in how each theory categorises elicitors. This is even the case within the same theory as it develops to include new evidence. For instance, building on their earlier work, Rozin, Haidt, & McCauley (2008) argue that over our evolutionary history the range of disgust elicitors has expanded through a process of cultural evolution. In this conception disgust's origin is as part of a bitter taste rejection system, where distaste evolved early in our history to protect the body from poison. Then, in order, the following domains evolved from this original system: *core disgust* developed to protect from wider-ranging disease and infection (from food, animals, and body parts); *animal- reminder disgust* to respond to violations involving sex, death, body-envelope violations, and lack of hygiene; *interpersonal disgust* evolved to protect the individual from strangers and undesirable others; then finally *moral disgust* to further protect social order from certain moral offences. In this way, they argue, a process of preadaptation and cultural evolution has allowed the disgust emotion and associated physiology, behaviours, and expression to remain constant throughout our evolution, merely with expanding elicitors over time (Rozin et al., 2008).

For this theoretical framework, the core disgust domain relies on an early

anthropological understanding of contamination known as sympathetic magic, which—albeit not explicitly—appears to describe a cross-cultural drive towards the avoidance of disease. This domain is based on a collection of cultural studies on religion and mythology by Frazer (1922). He argues that cultural ideas about magic are based on two laws, the law of similarity and the law of contact or contagion. According to the *law of contagion*, once two objects have been in contact they are always in contact, and according to the *law of similarity*, physical contact between objects transfers some (or all) of their physical properties. It is argued that belief in these two "magical" laws is what causes participants' unwillingness to drink apple juice which had previously contained a sterilised cockroach, to bite an apple or hamburger that had been bitten by someone you dislike, and to wear clothes worn by a disliked person (Rozin et al., 1986; Rozin, Nemeroff, Wane, & Sherrod, 1989). It seems logical that aversion to these behaviours reflects an evolutionary drive to avoid disease. Cockroaches, for example, have been found to harbour many bacterial pathogens, including those related to food poisoning such as Salmonella (Tachbele, Erku, Gebre-Michael, & Ashenafi, 2006), and as such, it would be evolutionarily advantageous to avoid consuming food that had come into contact with this creature (Elgderi, Ghenghesh, & Berbash, 2006; Menasria et al., 2014; Tilahun et al., 2012).

For the conception of animal-reminder disgust, the distaste theorists draw inspiration from terror management theory (Goldenberg, Pyszczynski, Greenberg, & Solomon, 2000; Greenberg, Pyszczynski, & Solomon, 1986). Terror management is underpinned by the idea that a variety of human behaviours are influenced by the knowledge of our mortality (Goldenberg et al., 2000). In the case of disgust, it is argued that any reminders of one's mortality will be considered repulsive, for example, disgust

elicitors such as body envelope violations (i.e. bones appearing through the skin) are considered disgusting as they are reminders of death. This is not limited to physical disgust; it is argued that social acts such as degrading, sexual behaviours invite comparisons to animals and as such give existential reminders of human's own animal nature and thus mortality. Animal-reminder disgust is fundamental to this theory of disgust, yet is quite open to criticism; notably, that terror management is not required to explain why the often-mentioned body envelope violations and dead bodies are disgusting. Terror management unnecessarily limits this disgust domain to humanity; it is unlikely that animals have existential fears about death and the soul (Tybur et al., 2013) yet animals display behaviours that suggest they too experience this specific type of aversion or revulsion. For example, it was suggested that humans avoid corpses because they are reminders of death, yet many animal species avoid dead bodies (Hussain et al., 2013; Moosa & Ud-Dean, 2010; Oliveira et al., 2014). As such, it seems more likely that humans and other animals avoid corpses because they aim to avoid whatever animal, event, or pathogen may have caused that death.

A second key problem with animal-reminder disgust is that it relies on the assumption that reminders of our animal nature are negative. However, Kollareth and Russell (2016) demonstrated that in both North America, North India, and South India there was no evidence that it is disgusting to be reminded of your animal nature. Rather than reminders of your animal nature being disgusting per se, it seemed that unpleasant, disgusting animal reminders containing pathogen risks—such as a tiger and a human both with facial tumours—elicit disgust. Harmless animal comparisons, such as images of humans or animals pictured sleeping, were not disgusting. Additionally, participants indicated it was the pleasant, not unpleasant animal comparisons that were the stronger

reminders of their animal nature but caused less disgust. The lack of consistency in animal-reminders eliciting disgust leads to conceptual issues with this theory which, at its core, substantially relies on the animal-reminder domain (Haidt, McCauley, & Rozin, 1994).

A further issue with this theory has been raised by Tybur, Lieberman, and Griskevicius (2009), who argue that the four disgust domains—core, animal-reminder, interpersonal, and moral—are not conceptually distinct. For example, although microbial infections are only mentioned in connection with core disgust, they are not exclusive to core-disgust elicitors (such as faeces and spoilt food) as, for example, there are also infection risks associated with sex (animal reminder disgust) and interactions with strangers (interpersonal disgust). Additionally, a core foundation of this theory may have been overstated: Curtis and Biran (2001) found no spontaneous mention of any bitter or sour foods in their aforementioned studies of disgust elicitors, which does not entirely fit with the evidence of disgust in response to bitter tastes in other studies (e.g. Eskine, Kacinik, & Prinz, 2011). Curtis (2013) argues that although bitter and sour flavours are distasteful, people do not consider them disgusting. This calls into serious question the oral incorporation gatekeeping mechanism as the foundational source of disgust (Rozin & Fallon, 1987; Rozin et al., 2009). At the very least, it suggests a lack of a strong cross-cultural presence compared with other disgust elicitors.

Despite the above issues, this four-domain (core, animal-reminder, interpersonal, moral) disgust theory has been influential to the study of disgust and remains widely used. This is partly due to the development of the Disgust Sensitivity Scale (DS; Haidt, McCauley, & Rozin, 1994) and, more recently, the Disgust Scale-Revised (DS-R; Olatunji et al., 2007) which are often used as a measure of disgust sensitivity. However,

this brings us to a final important criticism of this theory; that there are important differences between the DS-R and the original theory which underlies it. Instead of reflecting the four domains, the DS-R is made up of only three subscales: core disgust, animal reminder disgust, and contamination disgust. This reduces the importance of moral and interpersonal disgust to the theory, especially as independent domains. Even though sexual and moral items were initially, qualitatively produced during the development of the original Disgust Scale, they did not covary well with the other disgust elicitors, and so first moral items were omitted from the original scale, then sexual items were excluded from the final, revised scale (Haidt et al., 1994; Olatunji et al., 2008). As previously mentioned, both sexual and moral items are spontaneously generated as disgust elicitors (Curtis & Biran, 2001) so the omission of these items is theoretically difficult to justify.

The lack of sexual and moral items in the DS-R, as well as the focus on cultural rather than biological evolution, encouraged Tybur, Lieberman, and Griskevicius (2009) to develop an alternative, pathogen-based theory of disgust domains and their own measure of disgust sensitivity. Tybur et al. argue that there are three disgust domains which each evolved simultaneously to address specific selection pressures in our ancestral environments; *sexual disgust* elicited by biologically costly mates, *moral disgust* elicited by deviant group members, and *pathogen disgust* elicited by substances associated with disease (Tybur, Lieberman, & Griskevicius, 2009). As such, disgust functions across domains for disparate but related functions; although all require revulsion and the avoidance motivation it entails, they require it in different ways and to different extents—for example, it would be evolutionarily advantageous for sexual disgust to discourage incestuous behaviour with a relative, but it would not necessarily be advantageous to avoid that relative altogether, as you would faecal matter or rotten food. In support of

their model, Tybur et al. (2009) demonstrated that these three domains had a higher inter-item correlation and lower between-factor correlation than the three domains of the DS-R (Haidt et al., 1994; Olatunji et al., 2007). Tybur et al.'s scale is further supported by evidence that the three factors relate differentially to different traits: Psychopathy (Levenson, Kiehl, & Fitzpatrick, 1995) negatively correlated with moral and sexual disgust but was unrelated to pathogen disgust, whereas perceived vulnerability to disease (Duncan, Schaller, & Park, 2009) correlated with pathogen and sexual disgust but was unrelated to moral disgust.

The Behavioural Immune System and Pathogen Disgust

Communicable disease represents an important adaptive challenge to humanity, as it does to all animals. This remains the case even with the advantages offered by modern medicine; for example, the deadliest communicable diseases—lower respiratory tract infections—caused 3,000,000 deaths worldwide in 2016 (WHO, 2018). Further to the risk from existing pathogenic microorganisms, there is an ever-present risk of newly emerging pathogens, as 335 new infectious diseases have been reported since 1940 (Fumagalli et al., 2011; Taylor, Latham, & Woolhouse, 2001). These new pathogens overwhelmingly originate in other species (zoonotic), for example, HIV originates in chimpanzees and Ebola originates in bats (Sironi, Cagliani, Forni, & Clerici, 2015). The danger of pathogens, in general, is also increased by an evolutionary asymmetry; humans (and higher organisms, generally) have both far longer life spans and smaller populations than pathogens, meaning we evolve at a slower rate (Sironi et al., 2015). So, humans are faced with the threat of a wide variety of fast-evolving pathogens which emerge as new threats from different host species.

Unsurprisingly, species of pathogens and parasites are incredibly numerous, with a comprehensive literature review identifying 1415 species pathogenic to humans alone (Taylor et al., 2001). To live at the expense of nutrient-rich, warm, renewable hosts offers many advantages and, as such, the quantity of non-pathogenic bacteria far outnumber human cells within our bodies (Rohmer, Hocquet, & Miller, 2011). While non-pathogenic bacteria are tolerated by hosts, pathogenic organisms are exploitative and must overcome host defences, for example, by using toxic compounds, which can function defensively or offensively by manipulating or destroying rival microbes and host immune defences (Rohmer et al., 2011; Rudkin, McLoughlin, Preston, & Massey, 2017). However, many of these mechanisms cause damage to and risk killing the host, so, just as there are clear evolutionary advantages for pathogens to live at our expense, it is equally advantageous for animals to develop systems to defend against pathogens. This is the basis of the immune system as well as the behavioural immune system, and other similar theories of pathogen avoidance.

It is thought that the threat presented by pathogens is managed by both an internal, physiological, immune system and with a psychological, behavioural immune system. The physiological immune system uses two branches to defend against pathogens; the quicker but more evolutionarily primitive innate immune system relies on predetermined pattern recognition of abnormal, foreign bodies whereas the slower but more flexible adaptive immune system requires prior exposure and thus relies on specific recognition and immunological memory (Hilleman, 2004). Both systems are required for an effective response; emerging or unfamiliar pathogens must be dealt with quickly using the innate immune system which can expel or hold the pathogen at bay until the adaptive immune system can deploy the more sophisticated, targeted response. Despite the presence of this

physiological immune system, there is an evolutionary advantage for developing a psychological avoidance system which enhances our ability to avoid infection by recognising signs of disease. Aside from risking our immune system being bested by invaders, fighting off an infection is debilitating (even if just temporarily) and metabolically costly (Schaller, 2011). As such, a system which can recognise the presence and encourage avoidance of pathogens would increase our chances of survival.

There are multiple theories which include disgust as part of a pathogen avoidance system such as Tybur et al.'s (2009) *three-domain disgust* theory, *pathogen avoidance theory* (PAT; Curtis et al., 2011), and the *behavioural immune system* (Schaller, 2011). Theorists using these different frameworks, such as those who authored the three-domain (sexual, moral, pathogen) disgust theory, have argued that the behavioural immune system is functionally the same as their conceptions of pathogen disgust (e.g. Lieberman & Patrick, 2014); as such, we see no reason to make a distinction between the behavioural immune system and other similar theories in this section (Curtis et al., 2011; Schaller, 2011; Tybur et al., 2009).

The term ‘behavioural immune system’ was coined to capture the apparently unified functioning of specific behaviours and cognition that work to reduce the risk of infection (Schaller, 2011; Schaller & Park, 2011). It is proposed that disgust functions within this system by responding to various environmental cues, such as unpleasant odours, that tend to co-occur with pathogens (Chapman & Anderson, 2013; Curtis et al., 2011; Stern, 2002). This induces either withdrawal symptoms, such as nausea, or pathogen-removal behaviours, such as vomiting, washing, and spitting (Dalgleish & Power, 2000; Stern, 2002). It is important to note that just as the physiological immune system has costs (such as metabolic expense) as well as benefits, as does the behavioural

immune system. The avoidant responses of the behavioural immune system can stand in the way of other fitness-relevant goals, for example by encouraging avoidance of social or mating opportunities because of the possibility they carry some infection risk (Schaller, 2011). As such, the individual sensitivity of our behavioural immune system is an evolutionary trade-off to contend with.

The behavioural immune system offers an alternative explanation for the evidence presented by distaste theorists. For example, we can use the *smoke detector principle* (Haselton & Buss, 2000; Nesse, 2018), applied to disgust by Schaller and Park (2011), to explain disgust towards objects which do not contain pathogen risks as evidence of the necessity of over-sensitivity to the functioning of the behavioural immune system. Essentially, there is a cost trade-off. While the real threats may be less common than false positives, the false positives are a lot less costly to act on than the real threat is to ignore. Like a smoke detector, this system has the important responsibility of avoiding potentially fatal false-negative errors; mistaking a real fire for burnt toast for a smoke detector is similarly dangerous to mistaking a deadly infection for a harmless physical deformity. To avoid making these errors smoke detectors are oversensitive and triggered by false-positive errors, and our behavioural immune system seems similar: smoke detectors are set off by burnt toast and our behavioural immune system by harmless deformities treated as infectious disease. As evidence for this, signs of non-contagious but visible illness, such as acne, psoriasis, and eczema, cause the individuals with these illnesses to be avoided (Oaten, Stevenson, & Case, 2011). This is unrelated to declarative knowledge of the actual infection risk; participants will treat a visible birthmark with disgusted behaviours (such as washing) in the same way as an infectious disease, despite expressing their awareness that the person does not pose an infection risk (Ryan, Oaten, Stevenson,

& Case, 2012). We can use this evidence to reassess prior work, for example, it was argued by Rozin et al. (1986) that participants' refusal to eat fudge when it is shaped like dog faeces or put plastic imitation vomit in their mouths is due to sympathetic magic, however, the smoke detector principle offers an alternative explanation for this result—our behavioural immune system has made a false-positive error in treating the plastic vomit as if it is vomit.

Interpersonal Disgust

Pathogen disgust and the behavioural immune system also account for disgust elicitors which do not easily fit with a distaste-based conception of disgust, such as avoidance of unknown or disliked groups of people. Although humans are a hyper-social species, we are commonly averse to crowds (Curtis, Aunger, & Rabie, 2004), and to specific groups of people, such as those of a lower caste in India (Curtis & Biran, 2001) or individuals who are homosexual (Inbar, Pizarro, Knobe, & Bloom, 2009). Whilst interpersonal and outgroup disgust felt towards these groups could be explained by a process of cultural evolution, as with the sympathetic magic explanation, the behavioural immune system addresses the cross-cultural and (to a certain extent) cross-species universality: limiting our exposure to unknown humans limits our exposure to unknown pathogens (Huang, Sedlovskaya, Ackerman, & Bargh, 2011; Oaten, Stevenson, & Case, 2011). Pathogens (aside from zoonoses) tend to target specific host species, so the most likely sources of infection are members of one's species (Curtis, 2014). As such, solitary animals and social animals who limit their group size are less vulnerable to infection (Altizer et al., 2003; Cote & Poulinb, 1995).

In humans, actual and perceived infection vulnerability is linked to disgust

towards outgroups: pregnant women who are vulnerable to infection display increased ethnocentrism (Navarrete, Fessler, & Eng, 2007); university students display more behavioural disgust towards clothing worn by students from another university, suggesting the clothing is perceived as higher risk (Reicher, Templeton, Neville, Ferrari, & Drury, 2016); and those who feel at risk of infection, indicated by higher self-rated disgust sensitivity, show lower levels of extraversion, likely reducing contact with others (Hodson & Costello, 2007). A similar outcome can be produced by priming participants to feel at risk of infection; using an Implicit Association Test, Buckels and Trapnell (2013) found that disgust priming encourages dehumanisation of an arbitrary outgroup. Perceived vulnerability also works in the opposite direction, as vaccinated participants—who presumably feel less threatened by disease—display less racism (Huang et al., 2011).

Cultural differences in ingroup bias also appear to support the behavioural immune system. Pathogen risk varies across cultures, both historically and in the present day. When controlling for demography, selection pressures imposed by variation in pathogenic load explain much genetic variation between populations and thus has been argued to be the primary driver of local adaptation (Fumagalli et al., 2011). Aside from genetic variation, it has also been demonstrated that countries with a historically high disease burden are more likely to be collectivist (Fincher, Thornhill, Murray, & Schaller, 2008) which is hypothesised to be due to collectivist cultures having reduced intergroup contact due to a stronger ingroup-outgroup differentiation. Supporting this assertion, between 1950 and 2008 individualistic cultures were subjected to a higher number of infectious disease outbreaks than collectivist cultures (Morand & Walther, 2018). Suggesting historically high pathogen risk influences the psychology of specific cultures as well as providing some modern-day protection from infection.

Sexual Disgust

Sexual acts are often called disgusting, with some appearing to almost universally elicit disgust, such as incest, or elicit disgust dependent on culture or personal morality, such as promiscuity (Curtis & Biran, 2001; Haidt et al., 1994). Promiscuous mating strategies (even of individuals in otherwise monogamous groups) can easily be linked to pathogen risk, as they facilitate the spread of sexually transmitted diseases within a species (Altizer et al., 2003). Yet, there is a balance to reach as, even though all sexual behaviour carries some infection risk, it is clearly vital for the propagation of an individual's genes. As such, disgust towards all sexual behaviour would be incredibly maladaptive and without the associated disease risks promiscuity would be less costly. As such, a relatively low historic disease burden is reflected by a culture's increased tendency to seek multiple sexual partners (Schaller & Murray, 2008). This suggests that cultures which have been more at risk of disease have more sensitively calibrated behavioural immune systems, which then, in turn, affects the levels of pathogen risk they will take with their sexual behaviours. This can also be found specifically for women; women are more at risk from sexually transmitted pathogens than heterosexual men and accordingly exposing women to disgusting stimuli limits their subsequent sexual arousal (Fleischman, Hamilton, Fessler, & Meston, 2015).

Interestingly, there is a bidirectional relationship, such that sexual and moral disgust reactions can be lessened by sexual arousal in men. For example, male participants who were sexually aroused through self-stimulation (compared to those answering naturally) suggested they were more able to imagine wanting to be part of a range of sexual behaviours, including the following activities: having sex with someone that is extremely overweight, watching a woman urinate, and having sexual contact with

an animal (Ariely & Loewenstein, 2006). This also included morally disgusting behaviours; participants indicated they were more able to imagine the possibility of being attracted to a twelve-year-old girl, were more willing to pressure a woman into having sex and were more willing to commit date rape (Ariely & Loewenstein, 2006). Of 20 hypothetical questions, only sex with the light on and sex with a man were not significantly affected by arousal (Ariely & Loewenstein, 2006). Sexual arousal also mitigates disgust towards sexually and physically disgusting stimuli, such as putting your hand into a jar of unseen lubricated condoms, viewing an image of an injured naked woman, and listening to audio of fellatio (Stevenson, Case, & Oaten, 2011). Taken together this suggests adaptive flexibility in our disgust motivated avoidance of sexual behaviours, where the influence of the behavioural immune system is lessened by sexual arousal. With that being said, this appears to be limited to males, as the same was not found for women (Fleischman et al., 2015), although this is confounded by higher trait disgust sensitivity in women.

Although disgust is related to some sexual acts that have increased pathogen risk, such as promiscuity, clearly it also relates to sexual acts which do not entail an increased pathogen risk beyond the average sexual experience, such as incest. In explanation of this, for Tybur et al. (2009), sexual disgust is considered to have an evolved function separate from pathogen disgust. Specifically, these authors argue that there are valid evolutionary drives to feel disgust towards and avoid costly, inappropriate mates. Largely mates can be inappropriate across two dimensions: lack of intrinsic quality and low genetic compatibility. Intrinsic quality is reflected in a mate's attractiveness and resources, variation in which may motivate sexual attraction, sexual disinterest, or sexual disgust, whereas low genetic compatibility would be found in close relatives, where no matter the

intrinsic quality, mating has a high risk of producing low-quality offspring (Tybur et al., 2009). Importantly, sexual disgust should be motivationally distinct from pathogen disgust; there is a consistent, adaptive benefit to completely avoiding pathogen risks (such as faeces) but not individuals who are inappropriate mates. It would be maladaptive to avoid any interactions with inappropriate mates, such as kin, in the same way as you would avoid faeces or vomit; behaving in this way would prevent benefiting from social interactions other than mating (e.g. support from kin, friendship, group membership). Alternatively, incest is commonly considered an elicitor of moral disgust rather than sexual disgust (Graham et al., 2011; Haidt, 2001; Rozin et al., 1999) and as such, as with other immoral actions, would elicit disgust and avoidance of this behaviour due to social norms. In addition to incest, many sexual behaviours—such as rape and child abuse—are considered immoral (Ariely & Loewenstein, 2006) so, as with pathogen disgust, in certain cases, sexual and moral disgust are somewhat intertwined.

Anger's Evolutionary Origin

Like disgust, anger is a negative emotional response to aversive, harmful social actions or environmental stimuli. However, unlike disgust, anger is associated with hostility and verbal or physical aggression (Deffenbacher, Oetting, Lynch, & Morris, 1996) and, for many centuries (e.g., Aristotle, 325BC/2000), anger specifically has been thought of as an emotion in opposition to reason. Experiencing anger, arguably, prevents or limits critical thinking. This is supported by evidence linking anger to unreasonable blame of other individuals, especially when fault is ambiguous, as this emotion limits the consideration of alternative circumstantial influences on events (Keltner, Ellsworth, & Edwards, 1993; Lerner, Goldberg, & Tetlock, 1998). As such, anger has commonly

garnered a reputation as a noxious emotion, often discussed in relation to control and therapeutic treatment (e.g., Freud, 1924/2014), however, it is argued anger serves an adaptive social role in ensuring fairness. In support of this, anger motivates the blame of individuals and punitive judgements only when the participants believe the wrongdoer has not been appropriately punished (Goldberg, Lerner, & Tetlock, 1999). In this way, anger can be conceptualised as an emotion with an important social role.

Taking an evolutionary approach, it is thought anger's adaptive role is helping humans navigate social interactions, especially regulating harm and encouraging fairness. Great apes live incredibly complex social lives (Tomasello & Vaish, 2013) and display cooperative behaviour, fairness, and altruism towards known-others, strangers, and members of other species (Boesch, Bolé, Eckhardt, & Boesch, 2010; Tan & Hare, 2013; Warneken, Hare, Melis, Hanus, & Tomasello, 2007; Warneken & Tomasello, 2006). Although this shows a drive towards cooperation across species of ape, even when compared to our closest relatives, humans are considered a hyper-cooperative species. Human behaviours such as childcare of non-kin, communicating interests as well as instructions, and expectations that the behaviours of conspecifics should fit with agreed social norms are not found in closely related species (Burkart et al., 2014; Tomasello & Vaish, 2013).

Looking at anger's influence on human social lives, one theoretical model for anger's evolutionary role—the recalibrational theory of anger—suggests a potential social role would be to encourage others to appropriately consider your interests weighted against their own (Sell et al., 2009). This theory uses the concept of welfare tradeoff ratios (WTRs); that being, in a decision which could affect the welfare of either yourself or another person, how should you weight the welfare of the other person compared to

yourself? The recalibrational theory of anger suggests anger is elicited when you perceive someone has directed a lower than acceptable WTR towards you (by placing too much weight on their own welfare and too little on yours); the function of anger is, therefore, to recalibrate the decision-maker so they may choose to weigh the angry individual's (or close others) interests more highly (Sell et al., 2009). In this way, anger ensures your welfare is appropriately considered. In support of this Sell et al. (2009) found that stronger men felt they were entitled to better treatment and were more confident in their ability to resolve conflicts which in turn increased how frequently they felt anger and acted aggressively. The same was true for women (and men—albeit conflated with strength) who were more attractive. It is argued that stronger men, as a more formidable threat when aggressive, have a greater ability to ensure a higher WTR, and attractive people, as intrinsically more valuable coalitional and sexual partners, have a naturally higher WTR. In both cases lower than acceptable WTR would be more frequent and more aggressively responded to.

However, using a similar theoretical underpinning, it is argued that since anger is socially and physically risky it would not always be adaptive to express it if it would constitute a substantive social, economic, or physical cost. The propensity for anger, therefore, is argued to also vary substantially by culture. Male anger specifically has been argued to be higher: in societies where valuable resources are at risk of being appropriated by others, requiring anger to maintain economic resources; where social institutions offer less protection, requiring individual acts of self-defence; and in less cooperative societies where individuals do not depend as heavily on social relationships for social/political and economic gain, meaning the social risks of anger are less (Fessler, 2006). This does not, however, preclude individual differences in anger within these

cultures, for example, based on genetic variation (Cates, Houston, Vavak, Crawford, & Uttley, 1993) and personal experiences of trauma (Southwick et al., 1999). Overall, this theoretical approach suggests that anger is adaptively suited to increasing and maintaining one's own economic and social interests, with the important caveat of cultural and individual variation.

However, building on evidence such as this, it has been suggested that moral outrage—which is anger at violations of fairness and harm norms, regardless of relationship to the victim—does not exist (Batson, Chao, & Givens, 2009; Batson et al., 2007; O'Mara, Jackson, Batson, & Gaertner, 2011). Instead, it is argued, the goal of anger is to support our personal interests and the interests of those close to us, not uphold moral values. So, in this case, the moral framing would serve only to give rhetorical power and legitimacy to a selfish emotional response (Batson et al., 2007). As evidence of this assertion, Batson et al. (2007), demonstrate observing the unfair treatment of a third-party, known to be in a personally difficult situation outside of the experiment, only elicits anger after empathy is encouraged rather than objective assessment. However, this does not appear to entirely undermine the existence of moral anger. As mentioned above, objective assessment—i.e. reason—is in opposition to anger (e.g., Aristotle, 325BC/2000; Keltner et al., 1993; Lerner et al., 1998), so this seems to offer greater evidence that reason limits anger and empathy is important to emotional moral outrage. It, therefore, seems models such as this do not explain a great deal of available evidence since anger is often reported as fundamental to moral outrage. As such, we should also consider alternative explanations for moral anger's role.

Moral Disgust and Moral Anger

As an emotion which reacts to harm and unfairness anger is clearly at least an emotion which reacts to personal moral harm, if not all moral harm, depending on theoretical stance. On the other hand, the moral role of disgust—an emotion whose predominant function appears to be pathogen avoidance—requires more explanation. Although it is widely referred to as part of human experience, disgust towards immorality and violations of social norms feels far removed from disease-avoidance mechanisms, even when compared to other atypical disgust elicitors such as interpersonal or sexual disgust. As mentioned above (although not in all cases, such as incest) many cases of sexual and interpersonal disgust can be linked to pathogen avoidance: promiscuity, inappropriate sexual partners, and social contact with unknown individuals and groups introduce immediate disease risks. On the other hand, moral disgust can be found in response to acts which are not physically disgusting and contain no unusually high pathogen risks: Nazis, drunk drivers, hypocrites, and lawyers who chase ambulances were all generated as disgust elicitors during the conception of the Disgust Scale (Haidt et al., 1994) and politicians, insulting behaviour, betrayal, and rude people were generated in cross-cultural studies conducted by Curtis and Biran (2001).

It would be somewhat difficult to argue that these behaviours or individuals pose a particularly high pathogen risk compared to our average daily activities and social contacts. There are several responses to this; first, there are those that deny that disgust is elicited at all when there is no pathogen risk in an immoral scenario (Royzman, Atanasov, Landy, Parks, & Gepty, 2014) and second, there are those who acknowledge acts such as stealing can be called disgusting, but suggest that this descriptor is a rhetorical device expressing extreme moral anger (Herz & Hinds, 2013; Nabi, 2002). This argument can be

found for anger as well, as mentioned above, moral anger is also argued to be a rhetorical device, legitimising upset at being personally wronged (Batson et al., 2007). As such, both anger and disgust as moral emotions require some defence.

Despite the notable difference from other disgust elicitors, the understanding that emotions are integral to moral decision-making and that disgust is a moral emotion is common to many theories within moral psychology. First, emotions like disgust are considered essential to the modern conception of morality, which has advanced from the many rationalist theories of the 20th century (e.g. Kohlberg, 1971; for a review see Haidt, 2001). Rationalist approaches suggest moral judgements stem from reasoned deliberation taking into account issues such as harm caused to others (e.g. Turiel, Hildebrandt, & Wainryb, 1991). However, these approaches were found lacking in the face of evidence that moral decisions and values can defy rational defences. For more modern conceptions, such as Haidt's *social intuitionist model*, deliberation (if it occurs at all) occurs as a post hoc justification for a moral decision already made (Haidt, 2001). Haidt (2001) uses the scenario below to illustrate this phenomenon:

> *Julie and Mark are brother and sister. They are travelling together in France on summer vacation from college. One night they are staying alone in a cabin near the beach. They decide that it would be interesting and fun if they tried making love. At the very least it would be a new experience for each of them. Julie was already taking birth control pills, but Mark uses a condom too, just to be safe. They both enjoy making love, but they decide not to do it again. They keep that night as a special secret, which makes them feel even closer to each other. What do you think about that? Was it OK for them to make love?*

This scenario allows the usual objections to incest to be easily dismissed: the birth control

means there will be no offspring, the isolation and secrecy mean there would be no social rejection, and finally it is clear that no emotional or physical harm befalls either Julie or Mark. Yet, this scenario still feels morally unacceptable; as Haidt puts it, "one feels a quick flash of revulsion at the thought of incest, and one knows intuitively that something is wrong" (Haidt, 2001, p. 84). So, in this context, disgust at the thought of incest is causing condemnation of Julie and Mark without a rational defence for this feeling.

This emotional rather than rational basis of moral decision-making is supported by neurological evidence, specifically, by studies of individuals with damage to the ventromedial sector of the prefrontal cortex. Alongside difficulties with feeling emotions appropriately, these individuals have disrupted ability to adhere to social convention and difficulties making decisions about their own lives, despite retaining full abilities in learning, memory, language, and attention (Bechara, Damasio, & Damasio, 2000; Damasio et al., 1996). Importantly, in support of Haidt's intuitionist model, despite retaining declarative knowledge of social norms, individuals with this specific neurological damage have greatly altered moral and economic decision-making abilities. Compared to neurotypical controls, they display rigid adherence to extreme fairness in moral decisions and a maladaptively strong emotional reaction to unfair behaviours. As evidence for this, it has been demonstrated that they reject unfair offers in ultimatum games at an unusually high rate, due to limited regulatory control over emotions such as anger (Koenigs & Tranel, 2007) and endorse unusually utilitarian moral decisions, for example, they are more likely to endorse pushing an individual from a bridge or smothering one's own baby to save multiple adults (Koenigs et al., 2007). This connection between the inability to feel and regulate emotions appropriately with atypical moral and non-moral decision-making and behaviour offers clear support to the concept

that emotions are vital to the decision-making process, known as the *somatic marker hypothesis* (Damasio et al., 1996).

Given the evidence for the role of emotions in moral decision-making, much recent work in moral psychology has investigated the role of three emotions in particular: anger, contempt, and disgust. The relevance of these three emotions specifically stems from early work which proposes that they are the most clearly related to hostility and judgement of others (e.g. Haidt, 2003; Izard, 1977). The distinguishing roles of these emotions are often claimed to be either based on the type of violation to which each responds or by whom the violation affects, with a vast body of work specifically dedicated to disgust and anger.

Disgust and Purity: The CAD Hypothesis and Moral Foundations Theory

One approach to distinguishing moral emotions is to investigate which emotion would respond to a specific category of moral violation. Stemming from their work categorising disgust domains, Rozin, Lowery, Imada, and Haidt (1999) used this approach as the basis for the CAD Hypothesis (named for the shared letters of the violations and emotions). This theory suggests that *contempt* responds to violations of *community*, *anger* to violations of *autonomy*, and *disgust* to violations of *divinity*; it is argued these emotions are uniquely suited to respond to these violations. First, contempt is thought to be related to feelings of superiority, cold disapproval, and indifference (Ekman & Davidson, 1994; Izard, 1977) and, as such, would be elicited by violations such as an individual not fulfilling their societal role, behaving disloyally, or disrespecting authority (Miller, 1998). Anger, on the other hand, as a more aggressive response, is thought to be related to moral

violations directed at the self or close others, specifically violations of individual freedoms or rights (Rozin et al., 1999). Finally, moral disgust (drawing again on animal-reminder disgust and terror management) is elicited by divinity violations, which are described as impure, animalistic, degrading, and debasing. Examples of divinity violations are sexual deviancy (e.g., incest) and violations of food norms (e.g., cannibalism). In support of the CAD Hypothesis, Rozin, Lowery, et al. (1999) found that descriptions of these specific violations were matched with and elicited more facial expressions showing the hypothesised emotional response; contempt to community, anger to autonomy, and disgust to divinity.

The CAD Hypothesis is a precursor to *moral foundations theory* (MFT), which uses a similar approach of assigning specific emotions to specific moral actions. Although they admit there are potentially other domains, five *foundations* are outlined which they consider well-established categories of moral violations: *purity/degradation* (essentially, the divinity domain of the CAD Hypothesis), *care/harm*, *fairness/cheating*, *loyalty/betrayal*, and *authority/subversion* (Graham et al., 2013, 2011; Haidt & Joseph, 2004, 2008). This theory also mitigates the claims made by the CAD Hypothesis for unique associations between each foundation and a specific emotion. Graham et al. (2013, 2011) and Haidt and Joseph (2004, 2008) assert it is likely that mixed emotions will be felt for any foundation/violation, but the *characteristic* emotion differs dependent on the moral violation. MFT suggests the characteristic emotions of the five moral foundations are compassion for care/harm, gratitude/anger for fairness/cheating, pride and belongingness/rage (distinguished from anger by Haidt & Joseph, 2008) for loyalty/betrayal, respect/fear for authority/subversion, and disgust for purity/degradation (Haidt & Joseph, 2008).

Across conceptions of moral disgust in response to purity, although the title of the foundation/domain changes—usually being divinity, sanctity, or purity—their remains a consistent, albeit somewhat sweeping, definition of an impure act as "self- polluting, filthy, profane, carnal, hedonistic, unnatural, animal-like, or ungodly" (Horberg et al., 2009, p. 964) which "contaminate[s] the body or soul" (Giner-Sorolla & Chapman, 2017, p. 80). As such, many acts can exist under this umbrella, ranging from taboo ideas such as racism (Haidt & Joseph, 2004), deviant sexual practices such as incest, or food taboos such as cannibalism (Chapman & Anderson, 2014). With this in mind, vignettes specifically designed to tap into this concept are generally sexual (e.g. bestiality, incest, paraphilia/fetishism, necrophilia), food-related (e.g. cannibalism, eating food off of a dead body), or acts which span these two categories (e.g. sexual contact with food) (Clifford, Iyengar, Cabeza, & Sinnott-Armstrong, 2015).

Using this conception of purity, many researchers have found a distinct role for disgust in response to purity violations and, as such, are able to separate the roles of anger and disgust. For example, using a vignette which manipulated purity (cannibalism), direction of harm (whether the target in the scenario harmed themselves or other characters), and whether the act was intentional or accidental, when controlling for dual elicitation of anger and disgust, disgust was predicted by purity and anger by harm to others and intentionality (Russell & Giner-Sorolla, 2011a). Similarly, Horberg et al. (2009) demonstrated that participants who reported feeling disgust in response to purity violations also judge those violations more harshly. Even studies which somewhat undermine MFT display this distinction between anger and disgust; in a study which assessed the emotional reactions to the MFT vignettes, even though no other emotions fit clearly with their assigned moral foundation, disgust was still characteristic of the purity

foundation (Landmann & Hess, 2018). The distinction between anger and disgust also remained, as anger and rage were elicited by all moral foundations except for purity violations, which indicates that disgust should be related to purity violations, whereas all other violations should relate to anger.

In addition to disgust elicited by purity violations, there is also evidence that priming with physically disgusting stimuli and higher trait levels of disgust sensitivity increase the severity of moral condemnation of purity violations. For example, participants displayed harsher moral judgements towards purity violations after having their hands immersed in imitation vomit (Olatunji, Puncochar, & Cox, 2016), after viewing a disgusting clip (Horberg et al., 2009), and after listening to emetic audio recordings (Seidel & Prinz, 2013), whereas the ratings of other moral domains were harsher after immersion in ice water (Olatunji et al., 2016) and after listening to 'Japanese Noise Music' (Seidel & Prinz, 2013). The specificity of disgust's relation to purity has also been found for trait disgust sensitivity with these individuals displaying harsher judgements of purity violations (Wagemans, Brandt, & Zeelenberg, 2018a) and a stronger inclination to punish impure vices, such as untidiness and promiscuity, and reward pure virtues, such as refraining from drugs and alcohol (Horberg et al., 2009).

One offered explanation for why purity violations might be particularly disgusting is the inherent pathogen risks contained in many of these scenarios. Most widely used purity violations contain pathogen risks, for example, as discussed above, all sexual behaviours contain pathogen risks from STDs (Altizer et al., 2003; Schaller & Murray, 2008). As such, some have argued the elicited disgust is due to the pathogen risks inherent in these violations, evidenced by anger rather than disgust being predominant in response to pathogen-free purity violations, such as using a crucifix as a doorstop

(Royzman et al., 2014). Similarly, food violations such as cannibalism, which is widely used as a purity violation (Clifford et al., 2015; Liuzza, Olofsson, Cancino- Montecinos, & Lindholm, 2019; Russell & Giner-Sorolla, 2011a), also have inherent pathogen risks. The pathogens found in hosts of the same species generally evolved to target said species; as such, the eating of conspecifics that carry those pathogens, of course, carries many severe disease risks. Thus, cannibalism is uncommon even in high food stress situations for many species (Curtis, 2014). As an example of this risk, in one species with routinely cannibalistic individuals, the Tiger Salamander, cannibalism is associated with higher numbers of intestinal parasites, reflecting the dangers of this strategy (Pfennig, Loeb, & Collins, 1991).

Disgust and Other Foundations

Although the studies above support a distinct evolutionary role for disgust in response to purity violations, the evidence for this is not entirely conclusive. These results are undermined, or at least complicated, by any study which finds trait or state disgust as characteristic to domains other than purity. In one such study, highly disgust- sensitive participants (DS-R; Haidt et al., 1994, modified by Olatunji et al., 2007) rated straightforward, unambiguously immoral, autonomy violations, such as physical harm or theft, more harshly (Chapman & Anderson, 2013). This was the case even when controlling for feelings of anger and individual differences in tendencies to experience anger (state-trait anger expression inventory; Spielberger, 1988) suggesting it is unlikely that anger was underlying this result. This is further supported by electromyography studies that capture facial expressions, which demonstrate that disgusted expressions occur in response to both playing an unfair game and physically disgusting stimuli

(Chapman, Kim, Susskind, & Anderson, 2009) as well as in response to descriptions of someone cheating at a game (Cannon, Schnall, & White, 2011). Finally, despite self-reported disgust still being elicited by impurity, a recent study found that a specific type of disgust sensitivity—body odour disgust sensitivity—was related to general emotional reactivity and judgements of immorality rather than being specific to impurity (Liuzza et al., 2019). This suggests that disgust may be related to moral judgements more generally, rather than being exclusive to the purity domain.

Incidental disgust, for example through priming, can also be used to demonstrate disgust in response to other types of violation. Participants primed with vignettes about criminals (a con man, drug trafficker, fraudster, and burglars) displayed an increased likelihood of completing ambiguous word stems with disgusting words (e.g. REVOL_ING completed as REVOLTING) and taking a cleaning product as a gift (Jones & Fitness, 2008). It also seems disgust priming will affect the subsequent actions of participants in response to autonomy violations; Moretti and di Pellegrino (2010) demonstrated that primed participants (using disgusting images) rejected more unfair offers in an ultimatum economic game. Importantly, this appears to be related to moral judgement and resulting punishment, as the rejection of unfair offers was only found when the participants thought they were playing with another human, but not against a computer.

Even incidental disgust inductions used in works using the MFT and the CAD hypothesis as frameworks do not always display a clear distinction in disgust domains. For example, participants hypnotised to feel disgust in response to a neutral word judged vignettes from a variety of domains containing that word as more immoral and disgusting (Wheatley & Haidt, 2005); specifically, aside from an overall mean difference, they found

a significant increase in how harshly the participants judged both the incest (purity) and bribery (non-purity) scenarios. In another study, using the same vignettes, politically conservative participants' general moral judgements were harsher after priming with a bitter liquid (rated as disgusting), as opposed to a sweet or neutral liquid (Eskine et al., 2011). Finally, in four separate experiments, priming with a bad smell, an untidy room, a recollection of a disgusting experience, and a disgusting film clip increased the severity of moral judgements for participants who were highly attentive to their internal physical states (such as hunger and changes in heartbeat, assessed using the Private Body Consciousness Scale; Miller, Murphy, & Buss, 1981) with no distinction made between purity and non-purity vignettes (Schnall, Haidt, Clore, & Jordan, 2008). Based on the variation in these findings, although there is some convincing evidence for a distinct role for disgust in moral judgements of purity, this is not entirely consistent. As such, further investigations are required, such as what specifically is disgusting about impurity and the exact conditions required for moral violations outside the purity domain to elicit disgust.

Alternatives to MFT/CAD: Social Functionalism and the Stereotype Content Model

Findings that disgust responds to violations other than purity, as well as the apparently wide-ranging applicability of anger to all other foundations of MFT (e.g. Landmann & Hess, 2018), suggest the need for an alternative theoretical approach to understanding the disparate functions of the other-condemning moral emotions. One candidate theory is the Social Functionalist Model (SFM) of disgust, anger, and contempt (Hutcherson & Gross, 2011). SFM predicts different elicitation of anger and disgust to moral violations dependent on who is affected, rather than by the details of the act itself. SFM predicts that anger encourages approach whereas disgust and contempt encourage

avoidance. As, in this case, disgust and anger motivate different directional behaviours they are appropriate for different situations: anger responds to threats to the self and those we care about, whilst disgust and contempt are observer responses to threats to others.

The SFM understanding fits with the previously discussed evolutionary role of anger; encouraging high-risk, aggressive behaviour to gain and maintain personal social and economic status in a group (Fessler, 2006; Sell et al., 2009). In support of this, Lerner and Keltner (2001) demonstrated that dispositional and experimentally induced anger encouraged more optimistic, high risk, decisions. Also, as we have seen, anger and aggression have been associated with ensuring your personal interests are appropriately considered (Sell et al., 2009). Disgust, on the other hand, should motivate avoidance; most elicited disgust is found in response to pathogens and is behaviourally associated with distancing oneself and removing sources of disgust (e.g., Schaller, 2011). Furthermore, measures of dispositional disgust sensitivity have been associated with risk aversion (Sparks, Fessler, Chan, Ashokkumar, & Holbrook, 2018), in contrast to the risk-seeking found for dispositional anger (Lerner & Keltner, 2001).

Based on evidence such as this, SFM suggests disparate roles for three emotions: anger, disgust, and contempt. Anger would be appropriate for motivating risky behaviours, such as aggression, when an immoral action poses a personal risk to your social, physical, or economic wellbeing. On the other hand, disgust would limit risk-taking when it is currently unnecessary for your wellbeing; instead, encouraging distance from those whose past behaviour suggests it would be beneficial to avoid them. In addition to anger and disgust, SFM includes a third emotion—contempt—which is also included as part of the CAD Hypothesis (Rozin et al., 1999). Similar to disgust, contempt is thought to encourage some distancing, but unlike disgust, it is associated with feelings

of superiority, derision, and cold disapproval (Ekman & Davidson, 1994; Izard, 2007). This emotion is argued to motivate non-engagement, rather than passive-aggressive avoidance, with those who are not directly or intentionally harmful but waste resources through incompetence. Supporting this, it has been shown, using immorality vignettes that varied in the degree of self-relevance, that disgust was strongest when immoral actions were directed at others, less when directed at a friend, and least when directed at the self, whereas the opposite was found for anger (Hutcherson & Gross, 2011). This is supported by studies which evidence different punishment strategies for anger and disgust; specifically, approach-related punishments such as verbal aggression or violence for anger and avoidant strategies such as gossip or social exclusion for disgust (Molho, Tybur, Güler, Balliet, & Hofmann, 2017; Tybur et al., 2019).

A further alternative theoretical model, the *stereotype content model* (SCM), can also be used to generate hypotheses about the roles of anger, disgust, and contempt (Cuddy, Fiske, & Glick, 2007, 2008; Fiske, Cuddy, & Glick, 2007). Whilst SCM was developed to predict negative outgroup stereotypes, it has been suggested that all social cognition can be organised along the dimensions it uses: warmth and competence (Fiske et al., 2007). Warmth is defined by whether a person or group intends to help or harm, with low-warmth being disliked, while competence is decided by their ability to carry out their intentions, thus low-competence would be disrespected. These dimensions of personality—warmth and competence—have also been associated with differential elicitation of disgust, anger, and contempt (Cuddy et al., 2007; Harris & Fiske, 2006; Ufkes, Otten, van der Zee, Giebels, & Dovidio, 2012). Specifically, anger is associated with low-warmth regardless of competence, whereas disgust and contempt are associated with concurrent low-warmth and low-competence.

Anger is argued to be exclusively related to the warmth dimension due to the appraisal that the group/individual is hostile (Cuddy et al., 2007). This again suggests that anger, as the emotion related to aggression, would be required to cope with a potential threat to yourself or your group. It was demonstrated that perceptions that members of an outgroup were warm and friendly negatively correlated with anger, but competence and capability did not correlate with anger (Cuddy et al., 2007). So, for this theory, an individual can be angry at someone they dislike, regardless of whether they respect them or not. This, again, fits with the conception of anger as an emotion which is elicited primarily by mistreatment, unfairness, and unfriendliness. However, unlike SFM, this allows for the existence of moral outrage—anger when you are not personally affected—as anger can be elicited by those perceived as having an unlikeable personality, even if you do not know them. This would offer an explanation for anger elicited by hypothetical, third party transgressions in previous studies (e.g., Goldberg et al., 1999; Konishi et al., 2019; Royzman et al., 2014; Rozin et al., 1999; Russell & Giner-Sorolla, 2011a).

Unlike anger, for SCM, disgust (Harris & Fiske, 2006) and/or contempt (Ufkes et al., 2012) would both be elicited when an individual is both low-warmth *and* low-competence. An individual who is low on both dimensions should be disliked, due to their harmful intentions, but also disrespected, as low competence limits their ability to carry out those intentions. As we have already seen, disgust is elicited by inanimate objects or specific animals as well as by humans (Curtis & Biran, 2001). As such, the lack of distinction between disgusting objects and humans who are thought of as disgusting is argued to lead to dehumanisation, explaining extreme animosity often displayed towards certain groups, such as the homeless and drug addicts. Disgust can explain examples of the most extreme prejudice because it allows humans to feel the same emotion towards

conspecifics as they would non-humans, such as vomit or rats. Neuroimaging studies have supported this hypothesis as similar patterns were displayed towards outgroups perceived as low-warmth and low-competence compared to disgusting objects (Harris & Fiske, 2006). Taken together, these results suggest, disgust would be elicited by people perceived as the worst of the worst (low-warmth and low- competence), whereas anger would be elicited by anyone, competent or incompetent, who is not warm or friendly.

Rather than organising morality by type of violation, these alternative theories organise by who is affected or by personality traits. SFM suggests different emotions are elicited when the target of the violation changes, which fits with the evolutionary view of anger as encouraging risk-taking and approach motivation compared to disgust which encourages risk aversion and avoidance. However, this theory is somewhat undermined by any evidence of anger towards violations which do not affect the angry individual. SCM, on the other hand, suggests emotions are elicited by personality traits. Emotions are considered to motivate like/dislike and respect/disrespect which in turn causes prejudicial behaviours towards the target group or individual. This allows emotions, such as anger, to be elicited by a wider range of actions, even without any personal harm. However, this does not offer as much of a clear-cut separation between these emotional responses compared to SFM or the CAD hypothesis and, in the case of anger especially, is not as clearly linked to a specific adaptive role for these emotions.

Summary and Current Work

There are several shortcomings in the literature on disgust that we have outlined above. First, we remain limited in our ability to directly measure discrete emotions such

as disgust, casting the existence of biologically-based emotional categories into doubt (e.g. Barrett, 2006, 2017; Barrett, Gendron, & Huang, 2009; Mauss & Robinson, 2009). Second, partly stemming from this difficulty in categorising and measuring any discrete emotional state, there is a specific challenge in distinguishing between anger and disgust, as two often conflated, highly correlated emotions of similar valence and arousal (e.g. Herz & Hinds, 2013; Nabi, 2002). Third, this, in turn, affects our ability to distinguish and offer clear adaptive roles for moral anger and moral disgust, specifically; whether they are differentially activated by types of moral violations such as impurity (Graham et al., 2013, 2011; Rozin et al., 1999); by who is affected by the immoral action—you, close others, or distant others (Hutcherson & Gross, 2011); or in response to indicators of personality traits such as warmth/competence (Cuddy et al., 2008; Fiske et al., 2007).

In the current work, we aim to address these difficulties in separating anger and disgust and investigate potential moral roles for these emotions. First, in Chapter 2, we utilise a physiological measure, pupillometry, as a method of directly measuring discrete emotional responses. Although pupillometry has been used to measure general positive and negative affect (e.g. Babiker, Faye, Prehn, & Malik, 2015; Bradley, Miccoli, Escrig, & Lang, 2008; Partala & Surakka, 2003; Widmann, Schröger, & Wetzel, 2018), to our knowledge this method has not previously been used as a method of distinguishing between discrete emotions. This offers a potential, non-invasive method of directly measuring parasympathetic and sympathetic activation during anger and disgust, potentially allowing for differentiation of these emotions. Second, in Chapter 3, based on our findings that anger and disgust can be discriminated using pupillometry, with disgust alone consistently marked by increases in pupil size, we then use pupillometry as a method of measuring emotional responses to purity violations compared to other

violations. This allows us to assess the explanations offered by the CAD hypothesis and MFT which propose disgust responds exclusively to impurity whereas anger responds to other moral foundations.

However, this method did not allow us to assess moral violations which directly affect the participant or to address the alternative discussed theories: SFM and SCM. So, third, in Chapter 4, we aim to explore other potential evolutionary roles for moral disgust, anger, and contempt in social cohesion using a novel economic game. This allows us to assess whether disgust and anger are elicited differently when the violation is not hypothetical and when the participant is directly affected.

Chapter 2: Pupil Dilation as a Measure of Disgust

The ability to measure physiological differences when people report being disgusted versus angry aids the investigation of moral disgust; it allows us to address whether these two emotions are just semantic equivalents as sometimes suggested (Herz & Hinds, 2013; Nabi, 2002) and, if they are not, allows for an alternative to self-report to investigate the specific scenarios which will elicit moral disgust rather than moral anger. However, despite a drive to discover distinguishable psychophysiological markers for different emotional states, research in this area has been somewhat inconsistent. To illustrate, using measures of cardiovascular and skin responses, different disgusting stimuli (such as vomit compared to a painful injury) activate different autonomic responses; some stimuli elicit parasympathetic activation (de Jong et al., 2011; Ottaviani et al., 2013; Rohrmann & Hopp, 2008; Shenhav & Mendes, 2014) whereas others elicit sympathetic activation (Codispoti et al., 2008; de Jong et al., 2011; Ottaviani et al., 2013; Rohrmann & Hopp, 2008; Shenhav & Mendes, 2014; Vrana, 1993). Results such as these are often taken as evidence that it is impossible to use psychophysiological measures to distinguish emotions (e.g. Barrett, 2006, 2013, 2017; Barrett et al., 2007; Mauss & Robinson, 2009). However, considering the autonomic nervous system allows for complex patterns of simultaneous parasympathetic and sympathetic activity (Folkow, 2000), there is a potential for different results to be found when measuring the output of different effector organs of the autonomic nervous system.

When looking at specific physiological measures, specific subtypes of emotion, or by measuring multiple outputs to observe overall patterns, emotions may become

distinguishable (Kreibig, 2010). Anger, for example, elicits sympathetic activation in the form of increased heart rate (Foster & Webster, 2001; Rainville et al., 2006; Vrana, 1993) without the significant concurrent changes in the parasympathetic marker HRV that mark other negative emotions such as fear and sadness (Rainville et al., 2006). HRV is also associated with disgust (e.g. Rohrmann & Hopp, 2008), albeit in association with heart rate deceleration. As such, based on a review of 134 psychophysiological papers, it was found that anger is associated with increased heart rate whereas decreased heart rate was associated specifically with mutilation-disgust (Kreibig, 2010) and, more recently, with moral-disgust, separating this emotion from moral-anger (Konishi et al., 2019). In this chapter, we aim to investigate whether pupillometry, a measure which was not included in the review by Kreibig (2010), could offer an alternative method of distinguishing between anger and disgust using a range of stimuli.

Pupil dilation reflects sympathetic activation of the iris dilator muscle and parasympathetic inhibition to relax the iris sphincter muscle (with vice versa for pupil constriction). Changes in pupil size impact vision: as pupils become smaller the image becomes sharper and the depth of field increases (allowing us to see sharply across a wide range of distances), whereas, increases in pupil size increase sensitivity and field of view. It is argued, therefore, that pupil constriction and the associated visual acuity is required when fine visual discrimination is required, such as when optimising current task performance. Pupil dilation and the associated visual sensitivity, on the other hand, is required when searching in a vigilant state, ready to detect important environmental stimuli (Campbell & Gregory, 1960; Mathôt & Van der Stigchel, 2015).

The use of pupillometry as a measure of emotional arousal is well established, with early research linking dilation to positive emotional valence (e.g. Hess, 1975),

however, many recent studies have shown that pupil dilation is found when experiencing both positive and negative valanced emotional reactions to sounds (Partala & Surakka, 2003) and greyscale images (Bradley et al., 2008). Furthermore, in opposition to early pupillary work, there is some evidence that negative emotions are related to greater increase and more sustained pupil dilation than positive emotions (Babiker et al., 2015). This emotional pupillary reaction is specifically related to sympathetic activation as it is a late pupillary response, present in low light, which reflects sympathetically driven activation of the iris dilator muscle (Widmann et al., 2018). However, whilst pupillometry has been used quite frequently to study emotional arousal and valence it has not been used widely to investigate discrete emotional responses. Despite this, there are indications that measurements of pupil size have potential to be a valid measure of disgust, as the chosen negative stimuli used in emotional pupillometry studies are often disgusting (*mutilation*; Bradley et al., 2008; *violent imagery*; Henderson, Bradley, & Lang, 2014).

Although there are no studies specifically linking participant changes in pupil diameter to anger and disgust discretely, looking at studies of the communicative role of pupil size there is evidence for some discrete activation. Unlike other measures such as heart rate and despite the subtlety of pupillary changes, it has been demonstrated that differences in pupil size are noticed and reacted to by conspecifics (Brambilla, Biella, & Kret, 2019; Hess, 1975; Kret, 2017). Consequently, pupillary changes exist in an interesting intersection as a noticeable emotional output but also an indicator of genuine physiological arousal. This fits with an evolutionary model of emotion which suggests that there are certain visible emotional cues, such as sweating, which are more consistent and ‘honest’ due to lack of conscious control when compared to the variation seen in controllable emotional signals such as facial expressions (Al-Shawaf et al., 2016). This

cue also affects the judgement of facial expressions; although happy faces, in general, are judged as more trustworthy than angry faces, angry faces with small pupils are even less trustworthy (Kret & De Dreu, 2019).

As pupil dilation is a cue noticed by conspecifics, self-reports linking larger pupils to specific emotions could tell us about the possibility of distinguishing these emotions through measurement of pupil diameter. If we assume that pupil sizes are both honest reflections of physiological responses and noticed by others, our opinions of emotional pupillary reactions should reflect actual pupil size displayed during those emotional experiences. In one early study (Hess, 1975) which was recently replicated (Kret, 2017), it was demonstrated that participants will draw smaller pupil sizes on angry faces and larger pupil sizes on happy faces (Hess, 1975), with participants drawing increasingly small pupils on angry faces as they age, suggesting learning from repeated exposure (Kret, 2017). As such, specific negative emotions, such as anger, could be related to smaller pupil sizes, and the negatively valenced pupil dilation response found in previous studies may be driven by other emotions (Bradley et al., 2008; Partala & Surakka, 2003; Widmann et al., 2018).

In the following two studies, we build on work outlined above which suggests that pupil dilation is related to emotional arousal (Babiker et al., 2015; Bradley et al., 2008; Partala & Surakka, 2003; Widmann et al., 2018) by conducting an exploratory investigation into whether anger or disgust drive pupil dilation or constriction in a way that would allow separation of these emotions. Prior work using cardiovascular measures has suggested that disgust would be marked with parasympathetic activation, and as such could be marked by decreases in pupil size, whereas anger is generally sympathetic and so could be marked by pupil dilation (Konishi et al., 2019; Kreibig, 2010). However, as it

has been demonstrated that differences in pupil sizes are recognised in others (Brambilla et al., 2019; Hess, 1975; Kret, 2017) and that participants generally assume angry faces should have smaller pupils (Hess, 1975; Kret, 2017), it is also fair to hypothesise that anger will be marked by smaller pupil sizes than other negative emotions such as disgust.

To investigate this, we conducted two studies designed to examine the relationship between anger and disgust with pupil size. However, in addition to measuring these two emotional responses, we included two other emotions of similar valence (sadness and fear) and a positive emotion (happiness) for comparison. Since prior work used positive and negative valence, and since mixed emotions are commonly reported, we include a variety of emotions to control for any potential influence of these other emotions. This should allow us to associate pupillary changes with anger or disgust rather than a different discrete emotion or by general valence. In Study 1, we measured pupil size during exposure to affective sounds and images widely used in psychological research. In Study 2 we replicated Study 1's design using a different set of audio stimuli.

Study 1: Pupil Dilation in Response to Images and Sounds

We assessed changes in pupil size in response to the two emotions of interest, anger and disgust, as well as the other three discrete comparison emotions: fear, sadness, and happiness. This covers a range of high- and low-arousal negative emotions, as well as a positive emotion. These five were specifically chosen as they have been argued to be empirically well-established candidates for discrete emotions; in a recent survey of emotion researchers, the existence of sadness was considered empirically established by

80% of researchers, happiness by 76%, fear by 90%, anger by 91%, and disgust by 86% (Ekman, 2016). Participants rated each stimulus for these five emotions.

Part i: Stimuli Choice

Before collecting pupillary responses, stimuli were selected to elicit the chosen discrete emotions whilst avoiding stimuli that will elicit multiple emotions indistinguishably, introducing multicollinearity to our main experiment. To this end, we conducted a survey with participants rating a broad range of stimuli from the International Affective Picture System (IAPS) and International Affective Digitized Sounds (IADS) databases (Bradley & Lang, 1999; Lang, Bradley, & Cuthbert, 1999), both intended to provide standardised stimuli useful for eliciting emotions. Although the IAPS and IADS are widely used in emotional research, collecting ratings of these stimuli for disgust, anger, fear, sadness, and happiness is a necessary step for the current research as the IADS and IAPS datasets are only pre-rated for general emotional valence and arousal rather than specific discrete emotions.

Methods

The survey was administered to a convenience sample of 109 participants recruited using Amazon's Mechanical Turk and via personal social networks. We did not collect demographic data as this was a pilot study designed to assist in choosing stimuli for the main experiment and we did not expect any influence of age or gender on emotional reactions to the stimuli. Twenty-eight participants did not fully complete the survey leaving 81 complete surveys for analysis. We selected the stimuli to be rated using

pre-existing valence ratings in the IAPS and IADS databases to choose negative (ratings of below 3) stimuli and neutral (ratings between 3 and 6) stimuli. Each stimulus was rated for the five emotions on a 9-point Likert scale ranging from 0 (not at all) to 8 (very).

There were 750 items, 650 images and 100 sounds. The stimuli were split into blocks of neutral, slightly negative, and very negative based on the original IAPS/IADS ratings. Due to the distressing nature of some of the content, such as images of mutilation, we sought to limit participants' exposure. Each participant rated 10% of the stimuli within each block, randomly selected (for example, being exposed to 15 out of 150 very negative images; rating 65 images and 10 sounds in total). All stimuli were rated eight to 11 times.

Results and Discussion

Stimuli were considered to have elicited a meaningful emotional response when the mean rating was 3.5 or above. Using this criterion, we were able to select 12 images and 12 sounds to be used in the main study. However, many of the highest-rated stimuli elicited multiple emotions. As such, we conducted further analyses to ensure stimuli that did not have high correlations between the emotions. That is, we sought to identify stimuli that participants tended to rate strongly as one emotion or another, for example, having either disgust or anger elicited by an image rather than equal ratings for both.

The results of these further analyses for images can be seen in Table 1. This shows us that in most cases there were no significant correlations between emotions that were above the 3.5 threshold. And in cases where there were (specifically IAPS 9810, 9560, and 9428) there were no significant correlations between all of the elicited emotions. This suggests there was enough variation between participant responses as to allow differentiation between all investigated emotions.

Table 1

Pearson Correlation Matrix of Emotional Reactions to all Chosen Image Stimuli

Stimuli	Variable	M	SD	1	2	3	4
	1 Fear	0.89	1.54	1			
Dirty Toilet	2 Anger	1.00	1.41	0.40	1		
(9300)	3 Disgust	6.89	1.36	-0.72*	-0.13	1	
N=9	4 Happiness	0.33	1.00	0.76	0.27	-0.79**	1
	5 Sadness	1.67	2.00	0.27	0.22	-0.34	0.25
	1 Fear	0.70	2.21	1			
Vomit	2 Anger	1.30	2.83	0.46	1		
(9322)	3 Disgust	7.60	0.97	0.15	0.21	1	
N=10	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	1.20	1.62	0.61	0.69*	0.34	-
	1 Fear	5.56	2.19	1			
Snake	2 Anger	0.11	0.33	0.08	1		
(1110)	3 Disgust	0.67	1.00	0.04	0.5	1	
N=9	4 Happiness	0.78	1.56	-0.33	0.77**	0.27	1
	5 Sadness	1.78	2.28	0.43	0.20	0.51	-0.02
	1 Fear	5.75	2.55	1			
Tarantula	2 Anger	0.63	1.19	0.20	1		
(1200)	3 Disgust	2.88	3.31	0.45	0.31	1	
N=8	4 Happiness	0.13	0.35	0.04	0.47	-0.23	1
	5 Sadness	1.00	2.14	0.00	0.39	-0.26	0.94***
	1 Fear	3.14	3.24	1			
Mutilated face	2 Anger	3.86	3.85	0.50	1		
(3000)	3 Disgust	6.71	2.98	-0.17	0.40	1	
N=7	4 Happiness	0.14	0.38	0.39	0.36	0.04	1
	5 Sadness	7.43	0.98	0.03	0.06	-0.18	-0.65

Stimuli	Variable	M	SD	1	2	3	4
Abused, injured dog (9183) N=9	1 Fear	1.33	1.94	1			
	2 Anger	7.00	1.32	-0.20	1		
	3 Disgust	6.11	2.62	0.19	0.40	1	
	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	7.11	1.05	-0.33	0.63	0.31	-
Baby with facial tumour (3170) N=8	1 Fear	4.50	2.88	1			
	2 Anger	2.63	2.83	0.40	1		
	3 Disgust	4.25	3.24	0.02	0.32	1	
	4 Happiness	0.13	0.35	0.35	0.77*	0.47	1
	5 Sadness	7.13	0.99	0.43	-0.29	0.34	-0.05
Beaten, naked woman (3191) N=9	1 Fear	2.22	3.11	1			
	2 Anger	5.78	2.39	0.18	1		
	3 Disgust	4.56	2.55	0.56	0.02	1	
	4 Happiness	0.11	0.33	0.58	0.03	0.36	1
	5 Sadness	4.22	2.54	-0.09	0.03	-0.37	-0.18
Slit throat (3071) N=10	1 Fear	4.00	2.98	1			
	2 Anger	3.70	3.20	0.54	1		
	3 Disgust	6.40	2.41	0.54	0.52	1	
	4 Happiness	0.50	1.58	0.12	0.03	-0.06	1
	5 Sadness	5.70	2.63	0.58	0.54	0.04	-0.23
KKK (9810) N=10	1 Fear	4.80	3.39	1			
	2 Anger	6.10	2.18	-0.31	1		
	3 Disgust	5.80	2.97	0.25	0.65*	1	
	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	4.20	3.19	0.32	0.54	0.56	-

Stimuli	Variable	M	SD	1	2	3	4
	1 Fear	2.33	3.08	1			
Bird in oil	2 Anger	6.11	1.96	0.36	1		
(9560)	3 Disgust	5.56	1.81	0.93***	0.51	1	
N=9	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	5.89	1.69	0.25	0.79**	0.27	-
	1 Fear	6.63	1.51	1			
Man thrown into a fire	2 Anger	5.75	2.66	0.58	1		
(9428)	3 Disgust	4.75	3.24	0.71*	0.87**	1	
N=8	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	5.13	1.89	0.32	0.75*	0.71*	-

Note. *p <.05, ** p <.01, ***p <.001. Bold indicates a mean rating above our threshold for this study. The IAPS identifying numbers in brackets are below description of stimuli.

The correlations between the emotional responses to sounds can be seen in Table 2. Unlike the images, in most cases we were able to find sounds which elicited only one emotion above the threshold, however, even in cases of clear mixed emotions (IADS 282, 290, and 278), there were no significant correlations between all of the elicited emotions. Again, this should allow enough variation between participant responses as to allow differentiation between the emotional responses.

Table 2

Pearson Correlation Matrix of Emotional Reactions to all Chosen Sound Stimuli

Stimuli	Variable	M	SD	1	2	3	4
	1 Fear	0.00	0.00	1			
Belch	2 Anger	2.11	2.42	-	1		
(702)	3 Disgust	4.67	3.39	-	0.05	1	
N=9	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	0.89	2.03	-	0.44	0.34	-
	1 Fear	0.71	1.89	1			
Blowing nose	2 Anger	0.43	1.13	-0.17	1		
(251)	3 Disgust	4.29	2.50	0.30	0.48	1	
N=7	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	0.00	0.00	-	-	-	-
	1 Fear	2.50	3.07	1			
Woman Coughing	2 Anger	0.88	2.47	0.33	1		
(242)	3 Disgust	4.13	2.36	0.44	0.15	1	
N=8	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	0.63	0.92	0.03	0.61	-0.37	-
	1 Fear	0.90	1.45	1			
Vomit	2 Anger	0.90	1.73	0.57	1		
(255)	3 Disgust	5.80	2.86	0.40	0.42	1	
N=10	4 Happiness	0.20	0.63	-0.22	-0.18	-0.47	1
	5 Sadness	0.80	1.48	0.98***	0.56	0.36	-0.19
	1 Fear	5.11	3.06	1			
Bees	2 Anger	0.33	1.00	0.23	1		
(115)	3 Disgust	2.78	3.53	0.59	-0.08	1	
N=9	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	0.89	1.17	0.49	0.04	0.6	-

Stimuli	Variable	M	SD	1	2	3	4
Scream (275) N=7	1 Fear	6.43	1.51	1			
	2 Anger	1.14	1.95	-0.19	1		
	3 Disgust	1.14	1.86	0.33	0.13	1	
	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	0.71	1.50	0.51	-0.10	0.91***	-
Baby crying (261) N=8	1 Fear	2.13	2.47	1			
	2 Anger	1.00	1.77	0.36	1		
	3 Disgust	1.25	2.82	0.67	0	1	
	4 Happiness	0.75	2.12	0.63	-0.23	0.97***	1
	5 Sadness	4.63	3.07	0.40	-0.34	0.33	0.44
Shooting and the 'Last Post' (611) N=8	1 Fear	2.38	3.34	1			
	2 Anger	2.00	2.83	1.00***	1		
	3 Disgust	1.50	2.51	0.85**	0.85**	1	
	4 Happiness	1.13	2.80	-0.25	-0.25	-0.21	1
	5 Sadness	4.50	3.78	0.54	0.53	0.53	-0.45
Car Horns (420) N=6	1 Fear	0.33	0.52	1			
	2 Anger	4.17	2.32	0.11	1		
	3 Disgust	1.17	1.60	0.89*	0.37	1	
	4 Happiness	0.83	2.04	-0.32	-0.88*	-0.36	1
	5 Sadness	1.17	2.04	0.89*	0.29	0.97**	-0.28
Women arguing (282) N=6	1 Fear	2.33	2.34	1			
	2 Anger	4.33	2.42	0.40	1		
	3 Disgust	3.83	2.40	0.40	0.56	1	
	4 Happiness	0.83	2.04	0.56	-0.07	0.44	1
	5 Sadness	2.83	1.60	0.82*	0.79	0.56	0.36

Stimuli	Variable	M	SD	1	2	3	4
Woman being beaten by man (290) N=8	1 Fear	7.00	1.41	1			
	2 Anger	6.38	1.19	0.68	1		
	3 Disgust	5.00	2.88	-0.14	-0.33	1	
	4 Happiness	0.13	0.35	-0.86**	-0.47	0.14	1
	5 Sadness	4.63	2.77	0.51	0.79*	-0.14	-0.09
Baby being hit by man (278) N=9	1 Fear	3.22	3.35	1			
	2 Anger	5.67	2.78	0.20	1		
	3 Disgust	5.44	3.36	0.00	0.85**	1	
	4 Happiness	0.78	2.33	-0.36	0.04	0.29	1
	5 Sadness	5.56	2.83	0.54	0.41	0.39	0.06

Note. *p <.05, ** p <.01, ***p <.001. Bold indicates a mean rating above our threshold for this study. The IADS identifying numbers in brackets are below description of stimuli.

As a result of the above procedure, we chose 12 sounds and 12 images which elicited a range of negative emotions. For the images, 10 of the 12 chosen elicited disgust, seven elicited anger, six elicited fear, and eight elicited sadness. For the sounds, seven of the 12 chosen elicited disgust, four elicited anger, four elicited sadness, and three elicited fear. As such, each negative emotion was elicited by multiple items in this data set but not by every item.

In addition, we chose three neutral sounds (radio tuning: IADS identifier 723, chickens: IADS identifier 132, yawn: IADS identifier 262) and three neutral images (pole: IAPS identifier 7161, filing cabinet: IAPS identifier 7705, empty plate: IAPS identifier 7006) all of which had means and standard deviations below 1 for all emotions in the survey. Finally, we chose three positive sounds (rock music: IADS identifier 815,

crown laughing: IADS identifier 226, and baby laughing: IADS identifier 110) and three positive images (puppies: IAPS identifier 1710, bunnies: IAPS identifier 1750, and beach: IAPS identifier 5833) using the original IAPS and IADS valence scores (ratings of above 7), we did not conduct a survey for the positive emotional stimuli as we did not plan to measure positive emotions other than happiness in this study. These chosen stimuli should elicit the range of emotions that we sought to examine using pupillometry, with sufficient variation to avoid multicollinearity.

Part ii: Pupillometry

To investigate whether increases in disgust, anger, sadness, fear, and happiness were significantly related to increases or decreases in pupil size, we measured pupillary responses and collected emotional reactions to the 18 sounds and 18 images pre-rated above. We hypothesised that these stimuli should elicit a range of emotional responses some of which will be associated with pupil dilation.

Methods

Participants. A power analysis for multiple regression with five predictors was conducted in G*Power to determine a sufficient sample size using an alpha of 0.05, a power of 0.80, and a medium effect size ($f2 = 0.15$) (Faul, Erdfelder, Buchner, & Lang, 2013). Based on the aforementioned assumptions, the desired sample size is 94, to meet this sample size we collected data from a convenience sample of 98 participants recruited via the University of Essex's participant pool. Of these participants, 65 identified as female and 33 as male. All individuals were aged between 18 and 46 years (M=23.09,

SD=4.75).

Stimulus Preparation. For images, low-level stimulus properties such as luminance (e.g. Watson & Yellott, 2012), contrast, or the colours of the image (e.g. Barbur, Harlow, & Sahraie, 1992; Kimura & Young, 1995) can affect pupil diameter. As such, using MATLAB (*MATLAB*, 2010), all images were edited to have the same mean intensity and the same root mean squared (RMS) contrast. RMS contrast is the mean pixel intensity divided by the standard deviation; as such it is not affected by angular frequency distribution or spatial distribution of the image (Bex & Makous, 2002). As a further precaution, we created Fourier-phase scrambled versions of each image that maintained the frequency spectrum and the colours of the original image but obscured the content, the pupillary reactions to these images were to be used as a control for the model assessing reactions to the images.

Procedure. Visual stimuli were presented on a monitor (screen resolution 1280x1024 pixels) while auditory stimuli were presented through speakers with volume kept at a constant level across participants. We displayed each image and sound for 9 seconds. Participants' head motion was limited using an SR Research head support, which ensured a fixed distance to the screen and the eye-tracking camera. SR Research's Eyelink 1000 eye-tracking hardware and associated software were used to record the participant's eye movements and pupil diameter.

Each participant saw all 18 sounds and 36 images (18 original and 18 Fourier transformed) but sounds and images were grouped for presentation by stimulus type: whether participants saw sounds or images first was counterbalanced. Within blocks, all stimuli were randomised for order, but all scrambled images were presented prior to non-scrambled to prevent unscrambled images enhancing content recognition in the scrambled

images based on low-level properties such as colour. Before each stimulus was presented, participants fixated on a cross for two seconds to create a baseline period and, for the sounds, this cross remained on screen throughout stimulus presentation. After each stimulus presentation, using a number pad, participants were asked to rate the stimuli on how strongly it elicited the five emotional dimensions (how happy, sad, angry, fearful, and disgusted they felt), presented in a random order, on a 1-9 scale (1 being not at all, 9 being very much).

Data Preparation. All pupil data were recorded using the Eyelink units; typical pupil area is 100-10000 units, with a precision of one unit. All analyses will be conducted using these units as the conversion to standard measurements (such as mm) involves the creation of an imitation pupil for comparison and could increase the chance of measurement error. The data were cleaned as follows: the data were split into pre-stimulus baseline periods and stimulus presentation periods; all pupil outliers caused by blinking (indicated by a sudden drop in pupil size towards 0) were removed, these were taken to be pupil sizes that dropped below Tukey's lower fence (1.5 IQR) for the range of pupil sizes in that period (including pupil sizes which were recorded as 0); participants with less than 5400 samples (5.4 seconds of data, 60% of 9 seconds) for the trial period and less than 200 samples (0.2 seconds of data, 10% of two seconds) in the baseline period were removed, finally the data were baseline corrected by taking the median pupil size from the baseline period subtracting it from each sample in the trial period, as is common practice in pupillometry (Hupé, Lamirel, & Lorenceau, 2009; Laeng & Sulutvedt, 2014; Partala & Surakka, 2003). The baseline-corrected pupil data was then aggregated giving a baseline-corrected mean pupil size for each trial. As such, these pupil sizes indicate the mean difference from the participant's pupil size before stimulus onset.

This procedure left 72 participants for analysis.

Results and Discussion

Descriptive Statistics. We computed correlations between the independent and dependent variables for sounds and images separately. For both images and sounds, these correlations indicate a small but significant positive relationship between increases in pupil size from baseline and all negative emotions (not with happiness). The strongest significant correlation with pupil dilation for images was for sadness, the weakest significant correlation was for anger. The strongest correlation for sounds was anger, the weakest was disgust. As expected, all negative emotions were significantly positively correlated, and negatively correlated with happiness. The mean emotional ratings suggest that disgust was elicited more strongly than the other emotions in response to both stimuli, the second highest was sadness for images and anger for sounds. Overall, images seemed to elicit higher mean ratings for emotional responses, but lower mean pupil sizes.

Table 3

Pearson Correlation Matrix for Variables in Models

Stimuli	Variable	M	SD	1	2	3	4	5
Images	1 Pupil Size	269.40	291.56	1				
	2 Disgust	4.31	3.29	.12***	1			
	3 Anger	3.35	3.02	.09**	.65***	1		
	4 Fear	3.29	2.89	.11***	.56***	.53***	1	
	5 Happy	2.32	2.52	-.03	-.47***	-.36***	-.33***	1
	6 Sad	3.89	3.21	.14***	.65***	.76***	.52***	-.41***

Stimuli	Variable	M	SD	1	2	3	4	5
Sounds	1 Pupil Size	546.04	303.60	1				
	2 Disgust	3.07	2.67	.09***	1			
	3 Anger	2.93	2.52	.13***	.56***	1		
	4 Fear	2.46	2.36	.10***	.33***	.45***	1	
	5 Happy	2.35	2.34	-.02	-.31***	-.31***	-.23***	1
	6 Sad	2.69	2.41	.12***	.45***	.66***	.52***	-.27***

*p <.05, ** p <.01, ***p <.001. n=1296 images, n=1296 sounds

Mixed Effects Models. The data were modelled using linear mixed-effects models, fitted with the lme4 R package (Bates & Sarkar, 2007). Significance was evaluated using p-values produced using Satterthwaite approximations and 95% Wald confidence intervals (lmerTest package; Kuznetsova, Brockhoff, & Christensen, 2017). As sounds and images will have different low-level properties which may differently affect pupil size, we analysed these stimuli separately.

For both models, fixed effects were mean centred. Each model includes two crossed random intercepts: one for each participant, which allowed us to account for natural variation in pupil size and emotional responses between participants, and another for each stimulus (sound or image), allowing us to account for differences in stimulus properties. To test for multicollinearity, we examined the Variance Inflation Factors (VIF edited for use with lmer; Frank, 2019) of individual predictors in linear models, which did not indicate any issues for any model (all VIF < 2).

Model 1: Images. For the first model, we analysed pupillary reactions to the image stimuli. Ratings for fear, happiness, anger, sadness, and disgust were regressed

onto baseline-corrected mean pupil size for each trial, controlling for the pupil size in reaction to the same image when it was scrambled. Disgust significantly predicted a significant pupil size increase from baseline (p =.004), indicating sympathetic activation. It should be noted that although the control variable—Fourier pupil size— does also significantly (if unsurprisingly) predict larger pupils (p <.001), suggesting some co-variation, but the inclusion or removal of this control variable does not qualitatively alter results. Full results of this model can be found in Table 4.

Table 4

Linear Mixed Model for Images, DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
Intercept	261.300	29.050	76.840	8.995	<.001	204.381	318.269
Fear	1.723	2.817	1135.000	0.612	.541	-3.797	7.244
Anger	5.644	3.216	1185.000	1.755	.079	-0.659	11.947
Happiness	6.001	3.795	306.600	1.581	.115	-1.436	13.438
Sadness	1.585	3.318	892.000	0.478	.633	-4.918	8.087
Disgust	**8.602**	**2.962**	**865.300**	**2.904**	**.004**	**2.796**	**14.408**
Fourier Pupil	**0.107**	**0.031**	**1284.000**	**3.504**	**<.001**	**0.047**	**0.167**

Note. Significance indicated in bold

Model 2: Sounds. For the second model, we analysed pupillary reactions to the audio stimuli. Ratings for fear, happiness, anger, sadness, and disgust were regressed onto baseline-corrected mean pupil size for each trial. When controlling for the other emotions, as in Model 1, only disgust significantly predicted increases in pupil size from baseline (p =.023). Full results of this model can be found in Table 5.

Table 5

Linear Mixed Model for Sounds, DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
Intercept	554.361	33.036	83.961	16.781	<.001	489.612	619.109
Fear	3.668	2.848	1002.241	1.288	.198	-1.915	9.250
Anger	-1.467	3.075	1091.418	-0.477	.634	-7.493	4.560
Happiness	2.177	3.010	63.445	0.723	.470	-3.723	8.078
Sadness	5.366	3.105	1107.891	1.728	.084	-0.719	11.451
Disgust	**6.360**	**2.786**	**718.937**	**2.283**	**.023**	**0.900**	**11.820**

Note. Significance indicated in bold

Overall, the results from the current study indicate that disgust is the emotion most consistently linked to pupil dilation. And, importantly for our purposes, anger was not a significant predictor of pupil dilation which indicates this can be a useful method for distinguishing between these two emotional responses.

Study 2: Pupil Dilation in Response to Sounds

We chose to conduct a second study to ensure we would replicate the results of Study 1 when using different stimuli. We decided to exclusively use sounds for several reasons: first, due to the complexity associated with low-level properties of images which affect pupil sizes (such as luminosity and contrast); second, the results from the Study 1 were not different for images or sounds; and third, the influence of eye-movements on pupil size is a lesser concern as participants only be presented with cross in the centre of the screen to draw visual attention. Based on the results of Study 1, we hypothesise that disgust will be related to pupil dilation and that anger will not.

Part i: Stimuli Choice

Before collecting any pupillary responses, as before, it was important to select stimuli which had the potential to elicit the chosen discrete emotions whilst avoiding stimuli that will elicit all/multiple negative emotions concurrently and indistinguishably. To this end, we conducted a survey assessing opinions of emotionally engaging stimuli.

Methods

We selected 39 emotionally engaging sounds, collected from YouTube, intending to select sounds which would elicit a variety of emotions at least somewhat discretely. As before, we are aware that mixed emotions are often felt so we aimed to limit the collinearity this may introduce. These sounds included scenes from TV shows such as The Fresh Prince of Bel-Air, arguments from reality TV shows, films such as Good Will Hunting, and realistic sounds such as alarm clocks.

Each participant rated a random subset of 13 of these sounds (so as not to overwhelm individual raters) on a 9-point scale ranging from 0 (not at all) to 8 (very) on the five relevant emotions (happiness, fear, anger, sadness, and disgust). The survey was completed by 40 participants recruited through the University of Essex's volunteer mailing list and via social networks. This gave each sound 12-14 ratings.

Results and Discussion

In the previous study, stimuli were considered to elicit a meaningful emotional response when the mean rating was 3.5 or above. Using this criterion, we were able to select 14 emotional sounds: four sounds for disgust, three for happiness, four for sadness, two for fear, and one for anger. Although this does mean at least one sound elicited each desired emotion meaningfully, to increase the number of sounds in each emotional category, we lowered the boundary for an emotional response to mean ratings of 2 and above. Based on this lowered boundary, we were able to select an additional seven emotional sounds (two happy, two anger, two fear, one fear and anger) and consider the existing stimuli to elicit mixed emotional responses.

We again assessed the correlations between the emotional responses to ensure emotions did not extensively covary, these results can be seen in Table 6. Overall, we were able to identify 24 sounds which elicited a range of emotions, including three that elicited no emotion. Based on our final criteria, of the 24 sounds, five sounds elicited happiness (all not positively correlated), five sadness (four low-correlated, one significantly correlated), five disgust (two low-correlated, three correlated), nine anger (four low-correlated, five correlated), and seven fear (five low-correlated, two correlated).

Table 6

Pearson Correlation Matrix of Emotional Reactions to all Chosen Sound Stimuli

Stimuli	Variable	M	SD	1	2	3	4
Purring N=13	1 Fear	1.23	2.01	1			
	2 Anger	0.38	0.96	0.17	1		
	3 Disgust	0.00	0.00	-	-	1	
	4 Happiness	1.00	1.87	-0.29	-0.09	-	1
	5 Sadness	0.00	0.00	-	-	-	-
Ticking clock N=13	1 Fear	1.69	2.25	1			
	2 Anger	0.62	1.19	0.45	1		
	3 Disgust	0.08	0.28	0.17	0.10	1	
	4 Happiness	0.08	0.28	0.17	0.10	1.00***	1
	5 Sadness	0.77	1.36	0.33	0.15	0.05	0.05
White noise N=14	1 Fear	0.86	2.21	1			
	2 Anger	0.14	0.36	-0.07	1		
	3 Disgust	0.14	0.53	0.02	0.68*	1	
	4 Happiness	0.93	1.86	-0.19	-0.10	0.01	1
	5 Sadness	0.21	0.58	-0.09	0.21	0.39	0.16
Crickets N=14	1 Fear	0.36	0.74	1			
	2 Anger	0.07	0.27	0.25	1		
	3 Disgust	0.07	0.27	0.25	1.00***	1	
	4 Happiness	2.00	3.35	0.12	0.52	0.52	1
	5 Sadness	0.29	0.83	-0.05	0.25	0.25	0.67**
Baby laughing N=14	1 Fear	0.93	2.43	1			
	2 Anger	0.14	0.53	0.84***	1		
	3 Disgust	0.07	0.27	0.84***	1.00***	1	
	4 Happiness	5.86	3.25	-0.74***	-0.52	-0.52	1
	5 Sadness	0.29	1.07	0.84***	1.00***	1.00***	-0.52

Stimuli	Variable	M	SD	1	2	3	4
Kitten meow N=12	1 Fear	0.17	0.58	1			
	2 Anger	0.00	0.00	-	1		
	3 Disgust	0.00	0.00	-	-	1	
	4 Happiness	3.17	2.82	-0.13	-	-	1
	5 Sadness	1.17	1.70	-0.22	-	-	-0.44
Laughter N=14	1 Fear	0.00	0.00	1			
	2 Anger	0.43	1.34	-	1		
	3 Disgust	0.14	0.53	-	0.98***	1	
	4 Happiness	5.43	3.16	-	-0.57	-0.50	1
	5 Sadness	0.07	0.27	-	-0.09	-0.08	0.14
Sea sounds N=12	1 Fear	0.17	0.58	1			
	2 Anger	0.00	0.00	-	1		
	3 Disgust	0.00	0.00	-	-	1	
	4 Happiness	5.33	2.46	-0.04	-	-	1
	5 Sadness	0.08	0.29	-0.09	-	-	0.34
‘Good Will Hunting’ N=13	1 Fear	1.62	2.81	1			
	2 Anger	0.92	1.61	0.71	1		
	3 Disgust	0.46	1.20	0.85	0.89	1	
	4 Happiness	0.46	1.20	-0.24	-0.24	-0.16	1
	5 Sadness	4.00	2.38	0.40	0.37	0.53	-0.12
‘The Fresh Prince of Bel-Air’ N=12	1 Fear	1.33	2.46	1			
	2 Anger	1.67	2.23	0.52	1		
	3 Disgust	0.42	1.00	0.79*	0.07	1	
	4 Happiness	0.08	0.29	-0.17	-0.09	-0.13	1
	5 Sadness	4.17	2.89	0.25	0.33	0.07	0.42

Stimuli	Variable	M	SD	1	2	3	4
Puppy whining N=13	1 Fear	2.15	2.23	1			
	2 Anger	2.15	1.91	0.11	1		
	3 Disgust	0.85	1.72	0.27	0.67*	1	
	4 Happiness	0.77	1.96	0.18	-0.15	-0.16	1
	5 Sadness	4.69	2.93	0.52	0.49	0.40	-0.39
Woman crying N=14	1 Fear	2.14	1.92	1			
	2 Anger	2.07	2.70	0.40	1		
	3 Disgust	1.07	1.69	0.28	0.39	1	
	4 Happiness	0.14	0.36	0.52	0.30	0.23	1
	5 Sadness	4.93	2.62	0.48	0.49	-0.14	0.25
Diarrhoea N=14	1 Fear	0.07	0.27	1			
	2 Anger	1.00	1.52	0.00	1		
	3 Disgust	5.86	2.32	0.27	0.07	1	
	4 Happiness	0.43	0.94	0.18	-0.11	-0.01	1
	5 Sadness	0.64	1.28	0.08	0.63*	-0.28	-0.18
Vomit N=14	1 Fear	0.75	1.48	1			
	2 Anger	0.58	1.16	0.30	1		
	3 Disgust	6.08	1.78	0.35	0.46	1	
	4 Happiness	0.00	0.00	-	-	-	1
	5 Sadness	0.75	1.22	0.62*	0.05	-0.12	-
Woman eating N=14	1 Fear	0.64	1.39	1			
	2 Anger	2.29	1.73	0.27	1		
	3 Disgust	5.57	2.38	0.23	0.78***	1	
	4 Happiness	0.71	2.13	-0.14	-0.33	-0.62*	1
	5 Sadness	0.36	0.84	-0.15	0.24	0.20	-0.07

Stimuli	Variable	M	SD	1	2	3	4
Whoopee cushion N=13	1 Fear	0.15	0.38	1			
	2 Anger	1.23	2.49	-0.13	1		
	3 Disgust	5.15	3.41	-0.28	0.38	1	
	4 Happiness	1.85	2.34	0.60*	-0.37	-0.79**	1
	5 Sadness	0.38	0.87	0.06	0.38	0.17	-0.17
Argument N=13	1 Fear	1.00	1.68	1			
	2 Anger	3.69	2.43	0.35	1		
	3 Disgust	2.85	3.16	0.36	0.35	1	
	4 Happiness	0.08	0.28	0.54	0.53	0.49	1
	5 Sadness	1.38	2.75	0.45	0.70*	0.49	0.61*
Car alarm N=13	1 Fear	2.23	2.45	1			
	2 Anger	2.54	2.60	0.31	1		
	3 Disgust	0.54	1.13	-0.08	-0.11	1	
	4 Happiness	0.15	0.38	0.41	0.08	0.18	1
	5 Sadness	0.85	1.34	0.77**	0.24	-0.05	0.55
Mosquito N=14	1 Fear	1.07	2.02	1			
	2 Anger	2.64	3.27	0.07	1		
	3 Disgust	1.79	2.78	0.76*	0.38	1	
	4 Happiness	0.50	1.61	-0.08	-0.15	-0.11	1
	5 Sadness	0.43	1.09	0.37	0.63	0.52	0.04
Electric alarm clock N=13	1 Fear	0.38	0.87	1			
	2 Anger	2.54	2.93	0.21	1		
	3 Disgust	0.08	0.28	0.21	-0.16	1	
	4 Happiness	0.38	1.12	-0.08	-0.30	0.16	1
	5 Sadness	1.15	1.52	0.46	0.04	-0.03	0.55

Stimuli	Variable	M	SD	1	2	3	4
'R.E.C. 1' N=14	1 Fear	4.71	2.79	1			
	2 Anger	2.79	3.04	0.48	1		
	3 Disgust	1.29	2.43	0.17	0.68*	1	
	4 Happiness	0.07	0.27	0.34	0.30	0.32	1
	5 Sadness	1.57	1.79	0.38	0.05	0.14	0.23
'Paranormal Activity 1' N=14	1 Fear	6.36	2.65	1			
	2 Anger	2.64	2.79	0.33	1		
	3 Disgust	1.93	2.50	0.26	0.94***	1	
	4 Happiness	0.14	0.36	0.26	0.28	0.35	1
	5 Sadness	2.71	2.58	0.16	0.75*	0.66*	0.13
Dog barking N=13	1 Fear	3.38	1.98	1			
	2 Anger	0.62	1.12	0.11	1		
	3 Disgust	0.23	0.44	0.37	0.37	1	
	4 Happiness	0.08	0.28	0.40	0.10	0.53	1
	5 Sadness	0.69	1.18	0.41	0.03	0.79**	0.59*
Tiger N=14	1 Fear	2.36	2.21	1			
	2 Anger	0.07	0.27	-0.05	1		
	3 Disgust	0.07	0.27	-0.05	1.00***	1	
	4 Happiness	0.93	2.30	-0.28	0.38	0.38	1
	5 Sadness	0.86	1.35	0.61*	0.03	0.03	-0.18

Note. *p <.05, ** p <.01, ***p <.001. Bold indicates a mean rating above our threshold for this study.

The results of this survey suggest the emotions did not extensively co-vary, limiting multicollinearity in the main experiment, and that they should elicit the range of emotional responses investigated, albeit perhaps not as strongly as Study 1.

Part ii: Pupillometry

To confirm the findings of Study 1, which found that self-reported disgust is related to increases in pupil size, we measured pupillary responses and collected emotional reactions to the 24 selected sounds.

Methods

Participants. Data were collected from 102 participants who were recruited via the University of Essex's participant pool, of these 75 identified as female, 26 as male, and one preferred not to specify. All individuals were aged between 18 and 29 years (one participant preferred not to specify their exact age, M=20.13, SD=2.15).

Procedure. Stimuli were presented using headphones with volume kept at a constant level whilst looking at a fixation cross presented on a screen in front of them (screen resolution 1280x1024 pixels). Participants' head motion was limited using an SR Research head support, ensuring a fixed distance to the screen and eye-tracking camera. SR Research's Eyelink 1000 eye-tracking hardware and associated software were used to record the participant's eye movements and pupil diameter.

Each participant heard the 24 sounds presented in a fully randomised order. Participants were directed to focus visually on a fixation cross, present during each trial, located in the centre of the screen. Before each stimulus was presented, there were two seconds of silence to create a baseline period. After each stimulus was presented, participants were asked to rate the stimulus for the five target emotions, presented in a random order, on a 1-9 scale using a numeric keypad.

Data Preparation. All pupil data were recorded using the Eyelink units (typical pupil size between 100-1000 units). The data were cleaned in the same way as Study 1 (those with more than 60% missing trial data removed, samples taken during blinking—indicated by pupil sizes below Tukey's lower fence—were removed, the median pupil size from the pre-stimulus baseline period was subtracted from all trial pupil size samples, and finally pupil sizes were averaged per trial), leaving 84 participants for analysis (63 female, 21 male, age M=19.93, SD=1.94 including one who did not specify their age).

Results and Discussion

Descriptive Statistics. Before modelling the results, we computed correlations between the independent and dependent variables. The results of these correlations can be seen in Table 7. They indicated a positive relationship only between disgust and increases in pupil size from baseline. All negative emotions were significantly positively correlated, and negatively correlated with happiness. The mean emotional ratings suggested that disgust and sadness were elicited very slightly more than the other emotional responses, but in this study, all emotional ratings are very similar. It should also be noted that the mean ratings are, overall, quite low, which fits with the survey pre-rating these sounds as less emotionally arousing than the IAPS and IADS stimuli.

Table 7

Pearson Correlation Matrix for Variables in Models

Variable	M	SD	1	2	3	4	5
1 Pupil Size	252.14	286.67	1				
2 Disgust	2.80	2.69	.13***	1			
3 Anger	2.57	2.25	-.01	.45***	1		
4 Fear	2.68	2.38	-.03	.07**	.29***	1	
5 Happy	2.17	2.22	.01	-.25***	-.28***	-.25***	1
6 Sad	2.80	2.49	-.01	.17***	.38***	.28***	-.26***

*p <.05, ** p <.01, ***p <.001. n= 2016

Mixed Effects Model. Again, the data were modelled using linear mixed-effects models, fitted with the lme4 R package (Bates & Sarkar, 2007) with p-values produced using Satterthwaite approximations (lmerTest R package, Kuznetsova, Brockhoff, & Christensen, 2017). Ratings for fear, happiness, anger, sadness, and disgust were regressed onto baseline-corrected mean pupil size. All fixed effects were mean centred. The model includes random intercepts for each participant, allowing us to account for natural variation in pupil size between participants, and random intercepts for stimuli, allowing us to account for differences in stimulus properties. To test for issues of multicollinearity we used the Variance Inflation Factors (VIF for lmer; Frank, 2019) which did not indicate any issues with multicollinearity (all VIF < 2).

Full results of this model can be found in Table 8. The results of this model indicate that, when controlling for other emotions, fear (p =.019), happiness (p <.001), and disgust (p <.001) significantly predicted pupil increases from baseline. As such, again, disgust was found to be related to pupil dilation; however, in this case, fear and

happiness also predicted pupil size increases. Despite the changes in other emotional pupillary responses, importantly anger did not appear to have a significant relationship with pupil size in either study.

Table 8

Linear Mixed Model for Study 2 Sounds, DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
(Intercept)	252.141	24.923	92.866	1.117	<.001	203.293	30.990
Anger	0.037	2.837	1644.731	0.013	.990	-5.524	5.598
Fear	**6.455**	**2.746**	**883.672**	**2.351**	**.019**	**1.073**	**11.837**
Disgust	**12.255**	**2.814**	**373.977**	**4.356**	**<.001**	**6.740**	**17.769**
Happiness	**13.374**	**2.828**	**1361.127**	**4.729**	**<.001**	**7.830**	**18.917**
Sadness	3.729	2.763	712.047	1.350	.178	-1.686	9.145

Note. Significance indicated in bold

Discussion

Across two studies, using different sets of stimuli, self-reported disgust consistently predicted pupil dilation. This can be seen in Figure 1**,** where the results of the standardised betas and confidence intervals for all models in this chapter are plotted

(using the sjstats package; Lüdecke, 2018). This shows us a small but consistent increase in pupil size from baseline exclusively for disgust, with fear and happiness only rarely showing this effect in specific models, and anger never significantly predicting increases or decreases in pupil size. As mentioned above, smaller pupil sizes are associated with increased visual acuity, improving fine visual discrimination with decreased field of view of but increased depth of field, whereas pupil dilation is associated with increased visual sensitivity and increased field of view, improving visual search (Campbell & Gregory, 1960; Mathôt & Van der Stigchel, 2015). So, this suggests that disgust increases visual sensitivity and attentional vigilance, whilst anger does not.

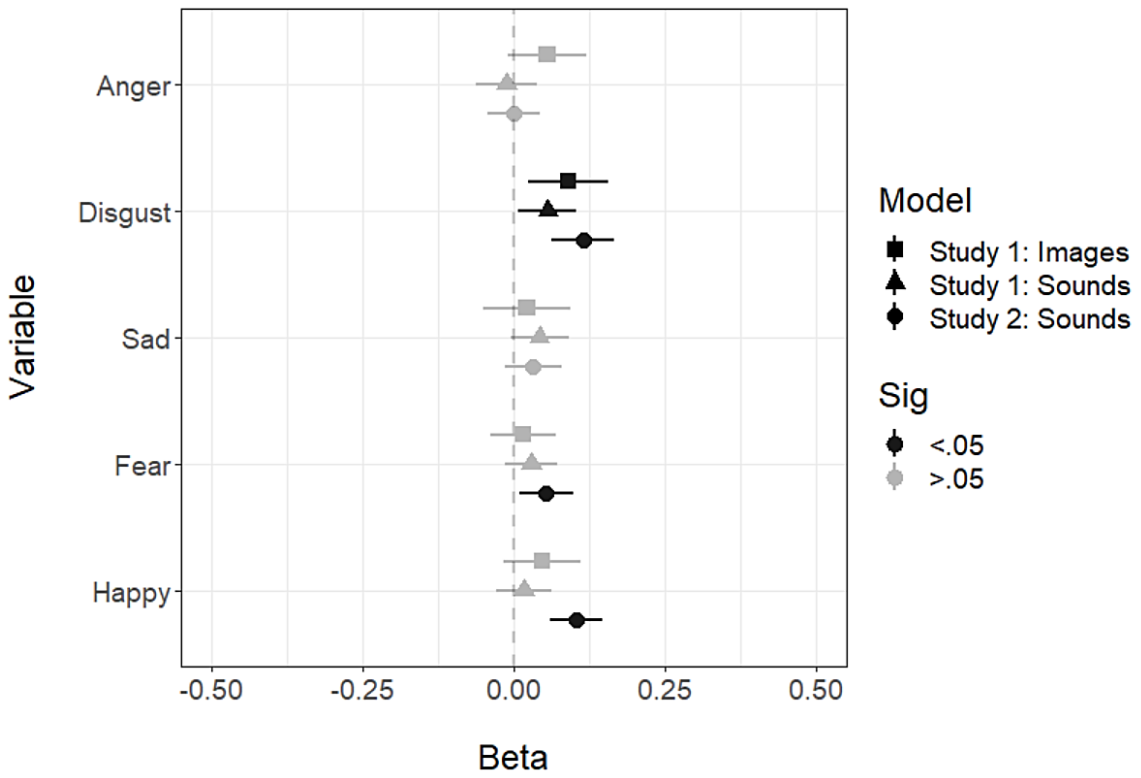

Figure 1. Graph of standardised Beta estimates and confidence intervals from all models in the chapter.

Based on these results, this study provides evidence that pupil dilation would be a useful method of distinguishing disgust from anger. This contributes most importantly to the literature (and to this thesis) as evidence that self-reported experiences of disgust and anger are not reflected by identical physiological, pupillary responses—suggesting they are noticeably separate experiences. This points to a physiological difference as, based on the means and standard deviations of each emotion, all emotions were elicited to similar extents (albeit overall not as strongly in Study 2) yet not all were related to pupillary changes. As such, there was a bodily difference when reporting feeling disgusted compared to angry. This allows us the opportunity to support self-report with physiological measures when investigating disgust.

Our findings also fit logically with prior research. For example, it has been found that participants associate smaller pupil sizes with angry faces than happy faces (Hess, 1975; Kret, 2017), this is supported by our findings that anger was unrelated to increases in pupil size. Additionally, these studies provide further evidence that disgust engenders a mix of sympathetic (e.g., galvanic skin response) and parasympathetic (e.g., heart rate deceleration) responses in different effector organs (Kreibig, 2010). This also suggests that there is a value to differentiating discrete emotions in studies of the psychophysiology of emotion, where the influence of disgust may have been missed by focusing on general negative arousal rather than discrete states (e.g. Bradley et al., 2008; Partala & Surakka, 2003; Widmann et al., 2018). With that being said, these results also somewhat support this prior work as, in addition to disgust, fear and happiness were—at different points—associated with pupil dilation, albeit not as consistently (Bradley et al., 2008; Partala & Surakka, 2003; Widmann et al., 2018).

Limitations

There are several limitations to these studies. First, our initial power calculations suggested a sample size of 94 participants would be required and, as such, 98 participants were tested for the first study and 102 for the second. However, after those with excessive missing data were removed (which can be explained by excessive blinking, moving during stimulus presentation, or extended eye closures) only 72 participants were analysed for the first study and 84 in the second, meaning both were somewhat underpowered. Clearer instructions, including scheduled breaks to encourage participants to rest their eyes more often, and shortening the length of experimental sessions could improve the quality of the data collected in future. However, even without the excluded participants, the sample size is larger than other experimental studies of this kind (e.g. Bradley et al., 2008; Partala & Surakka, 2003; Widmann et al., 2018).

A further limitation is the difficulty finding stimuli which elicit emotions strongly. In both studies the mean ratings for each emotion were below the mid-point of the scale, highlighting this difficulty. This was especially relevant for Study 2 where we also had to lower our criteria for our stimuli choices meaning at the offset some were not as strong as we would have preferred. It would be ideal to find stimuli which elicit a stronger emotional reaction if possible. However, this does not appear to have affected the ability to elicit a physiological response as in Study 2 there were more emotions found to significantly predict pupil dilation.

Another limitation of these studies is that they can only provide evidence for physiological emotional reactions in a lab environment in response to specific types of stimuli. Because the stimuli used depict negative events or environmental stimuli which cannot personally affect the participant, this may limit the emotional responses,

particularly for anger. Anger is often argued to be primarily elicited by personally harmful events—with some going as far as to argue this is the only possible way of eliciting actual anger, with all other uses of the word being rhetorical (Batson et al., 2007; O'Mara et al., 2011; Sell et al., 2009). Disgust, on the other hand, is theoretically associated with the behavioural immune system (Schaller, 2011). The behavioural immune system is argued to be overly sensitive and commonly makes false-positive errors: mistaking harmless stimuli for actual disease threats (e.g., Ryan et al., 2012). This means that, theoretically, you should be able to elicit a physiological disgust reaction using stimuli such as audio and images, despite their distance and lack of actual threat.

Future Directions

This study opens several avenues for further investigations. First, it would be interesting to see these results further replicated using different stimuli such as tactile or olfactory stimuli. It has been found that there are differences in autonomic responses such as skin conductance and systolic blood pressure depending on whether a disgusting stimulus is visual, auditory, haptic, or olfactory (Croy, Laqua, Süß, Joraschky, Ziemssen, & Hummel, 2013). As such, for a more thorough investigation of pupillary responses to disgust, haptic and olfactory stimuli could be used. Second, although this was not the focus of our studies, further research could investigate the inconsistency in happiness and fear's association with pupil dilation as well as include additional unmeasured emotions, such as surprise. Third, measurements of pupil diameter could be included alongside other physiological measures, such as heart rate. This could reveal a pattern of sympathetic and parasympathetic activation in different effector organs. Finally, as we will see in Chapter 3, these results could be used to investigate anger and disgust's moral, social roles, by allowing differentiation of these often-conflated responses.

Chapter 3: Pupil Dilation as a Measure of Moral Disgust to Impurity

The Oxford English Dictionary defines the word 'judgement' as "the ability to make considered decisions or to arrive at reasonable conclusions or opinions on the basis of the available information" ('Judgement | judgment, n.', 2019). Yet evidence suggests, rather than being an entirely rational process based on reasonable consideration of external information, moral judgement is inextricably linked to emotion over reason. This is at odds with the rationalist approaches to morality, predominant in the 20th century, which suggest moral judgements stem from careful consideration of issues such as harm caused to others (e.g. Turiel, Hildebrandt, & Wainryb, 1991). For more modern conceptions, emotion is vital to judgement and decision-making as a whole, including moral judgement (Bechara et al., 2000; Damasio et al., 1996; Koenigs & Tranel, 2007; Koenigs et al., 2007). It is argued, therefore, that moral judgements are intuitively, emotionally made and only justified post hoc (Haidt, 2001). As we have seen, two emotions linked to moral judgement are disgust and anger, with both being found in response to immorality (e.g., Hutcherson & Gross, 2011; Molho et al., 2017; Rozin et al., 1999; Russell & Giner-Sorolla, 2011a).

Distinguishing Moral Disgust from Moral Anger

The high correlation between moral disgust and moral anger, as well as the evidence linking disgust primarily to pathogen avoidance, has called into question whether they are separate emotional responses or even genuine reactions to immorality (e.g., Kayyal, Pochedly, McCarthy, & Russell, 2015). The use of the descriptors 'anger'

and ‘disgust’ as reflections of actual emotional responses during moral judgements is doubted. For example, using the word ‘anger’ has been argued to simply give legitimacy to a moral judgement, rather than describe the actual experience of this emotion (Batson et al., 2007) while, entirely contradictorily, the word ‘disgust’ is argued to be just a synonym for moral anger (Herz & Hinds, 2013; Nabi, 2002). In this way, a commonly used argument against the legitimacy of applying specific emotions to morality is often that participants are using these words as rhetorical devices. Thus, to attempt to disentangle these emotions from each other and from rhetoric, alternatives to self-report are required.

As we have established in Chapter 2, one such alternative is the use of psychophysiological measurements reflecting genuine emotional reactions to stimuli. The experience of emotion is reflected by increases in pupil diameter (Babiker et al., 2015; Bradley et al., 2008; Partala & Surakka, 2003; Widmann et al., 2018) and, as we have seen in Chapter 2, is consistently related to self-reports of disgust but not self- reports of anger. This fits with prior work suggesting angry facial expressions are assumed to be related to smaller pupil sizes (Kret, 2017). By measuring pupil size alongside self-reported disgust and anger towards moral violations, we can directly measure which aspects of immorality are reacted to with disgust and the associated psychophysiological arousal. This should allow us to parse genuine disgust from anger as well as ‘disgust’ used rhetorically, neither of which would be associated with pupil dilation. So, by measuring disgust physiologically we can ascertain whether there is a unique role for genuine moral disgust which is clearly separate from anger.

Impurity Is Disgusting

One unique role for disgust often demonstrated in the literature is as a response to one specific category of moral violation: purity violations (also called divinity or sanctity violations). An impure act is defined as "self-polluting, filthy, profane, carnal, hedonistic, unnatural, animal-like, or ungodly" (Horberg et al., 2009, p. 964) and "contaminate[s] the body or soul" (Giner-Sorolla & Chapman, 2017, p. 80). This moral foundation is usually investigated via vignettes which are sexual violations such as bestiality, incest, paraphilia/fetishism, necrophilia; food violations such as cannibalism, eating food off of a dead body; or acts spanning both of those categories, such as sexual contact with food (Clifford et al., 2015). Purity violations have been linked to disgust by two related theories, already discussed: the CAD hypothesis and moral foundations theory (MFT). To review, the CAD hypothesis suggests contempt's role is to respond to violations of the community ethic, anger to autonomy violations, and disgust to divinity (i.e. purity) violations (Rozin et al., 1999). Building on this, for MFT, different emotions are characteristic of five foundations: compassion for care/harm, gratitude/anger for fairness/cheating, pride and belongingness/rage for loyalty/betrayal, respect/fear for authority/subversion, and disgust for purity/degradation (Haidt & Joseph, 2008). The common ground between these two theories is that disgust is the characteristic, or exclusive, response to impurity.

This is supported by studies which generally find disgust in response to impurity whereas they find anger more generally in response to other types of immorality. Specifically, anger appears to be related to harm – a moral foundation related to those who cause physical and/or emotional pain. For example, in a vignette study which manipulated harm, intentionality, and impurity, disgust was found to be elicited by an

impurity (specifically, cannibalism) whereas anger responded to harm (whether the incident upset others) and intentionality (Russell & Giner-Sorolla, 2011a). Another study investigating emotional reactions to MFT found disgust was characteristic of impurity whereas all other foundations were reacted to with anger (Landmann & Hess, 2018). Additionally, disgust priming (using tactile, visual, and auditory disgust stimuli) amplifies moral judgements specifically towards purity violations (Horberg et al., 2009; Olatunji et al., 2016; Seidel & Prinz, 2013), as does trait levels of disgust sensitivity (Wagemans et al., 2018a). As such, evidence suggests that, rather than being semantic equivalents, moral disgust and moral anger have distinct roles in responding to different violated moral rules.

Impurity Is Not Disgusting

However, some have suggested that this disgust reaction to impurity is not evidence of a moral role for disgust. Instead, they argue, that these scenarios are simply a greater disease risk (Royzman et al., 2014). Most widely used purity violations contain inherent pathogen risks; for example, sexually deviant behaviours contain the same pathogen risks as other sexual behaviours (Altizer et al., 2003; Schaller & Murray, 2008) as well as potentially disgust inducing fitness costs, for example, in the case of incest, from deleterious recessives (Bittles & Neel, 1994; Tybur et al., 2009). Similarly, a food violation, such as cannibalism, is a high pathogen risk, as evidenced by routinely cannibalistic members of a species being infected with more pathogens (Pfennig et al., 1991). So, as evidence that the elicited disgust is due to the pathogen risks inherent in these violations, it has been demonstrated that anger—rather than disgust—is the predominant response to pathogen-free purity violations, such as using a crucifix as a doorstop (Royzman et al., 2014).

There are also further challenges from those who suggest that whilst moral disgust may be genuine, it can also be found in response to non-purity scenarios, which should be reacted to with anger. First, we have seen qualitatively non-purity violations, such as rudeness and betrayal, have been generated by participants as disgust elicitors (Curtis & Biran, 2001). Additionally, experimentally, disgust has been related to autonomy violations – such as unfairness and harm – which should induce anger, for example, disgust sensitivity increases the severity of judgements towards autonomy violations such as physical harm or theft (Chapman & Anderson, 2014); disgusted facial expressions have been found in response to unfairness as well as physically disgusting stimuli (Cannon et al., 2011; Chapman et al., 2009); and disgust priming increases the likelihood of rejecting unfair offers in an economic game (Moretti & di Pellegrino, 2010). This, again, increases the difficulty in parsing disgust and anger if, in fact, they do respond to the same immoral scenarios.

So, overall, any study of the disgust-purity connection should also ascertain whether this connection is in fact due to feelings of anger, judgements of impurity, judgements of harm (which should elicit anger), or the presence of disease risks. However, this remains difficult when relying on self-report where any elicitation of disgust or distinction from anger can be argued to be rhetorical. By introducing pupillometry as a psychophysiological measure, based on the results of Chapter 2, we can open several avenues of investigation. First, we can demonstrate whether moral disgust is reflected by pupil dilation in the same way as general disgust in Chapter 2, differentiating this emotion from anger. Second, we can investigate whether any disgust-induced pupil dilation is exclusive to purity violations, to physically disgusting scenarios, and/or also found in response to other moral violations which are generally associated with anger.

Third, we can determine whether any disgust-pupillary reaction to purity violations can be linked to self-reported judgements of impurity or whether this response is driven by other aspects of the scenario, such as the disease risk to the character or how physically or emotionally harmful the scenario is perceived to be.

Current Research

To investigate the use of pupil dilation as a measure of moral disgust to impurity we measure pupil diameter in response to audio recordings of moral vignettes. Based on prior research, using the theoretical model of MFT and the CAD hypothesis, we expect that purity violations and physically disgusting scenarios will be reacted to with disgust, and this will be reflected by increases in pupil diameter. We predict anger in response to non-purity violations but predict that, as in Chapter 2, this will not be associated with changes in pupil size. We will test the following three hypotheses in this study:

H1: We hypothesise that higher self-rated feelings of disgust will predict larger pupil sizes and that anger will not predict any significant change in pupil size.

H2: We hypothesise that when the participants judge scenarios to be more immoral this will be reflected by an increase in pupil size only with concurrent self-reported disgust.

H3: We hypothesise that disgust will be higher and pupil size will be larger when the act described is a purity violation or a physically disgusting act but not for other moral violations.

Methods

Participants. A power analysis for a multiple regression analysis with five predictors was conducted in G*Power to determine a sufficient sample size using an alpha of 0.05, a power of 0.80, and a medium effect size ($f2 = 0.15$) (Faul et al., 2013). Based on these assumptions, the necessary sample size is 94. To meet this sample size, while allowing for participants who fall within the exclusion criteria for missing data to be removed during data cleaning, we collected data from 104 participants, ten above the necessary sample size. These participants were recruited via the University of Essex's participant pool; 81 identified as female and 22 as male. All individuals were aged between 18 and 47 years ($M = 20.87$, $SD = 4.08$).

Stimuli. The stimuli used for this experiment were audio recordings of nine vignettes. These were recorded in the default text-to-speech Microsoft male US voice, to ensure consistency in tone and emphasis across scenarios. We allocated the scenarios into three categories: immoral purity violations, non-purity moral violations, and physically disgusting scenarios. This separation is based on the divisions in the original studies and the definition of purity as animalistic violations of food and sexual norms. There were three vignettes in each category. All purity and non-purity scenarios were used in prior research (Horberg et al., 2009; Rozin et al., 1999; Schnall et al., 2008; Wheatley & Haidt, 2005), whereas only one of the three physically disgusting scenarios was used in prior research (Rozin et al., 1999); we created the other two (due to a lack of suitable prior versions). We edited all scenarios to be similar in style and length, including using only male characters for consistency across scenarios, as can be seen in Table 9.

Table 9

Categories and sources for scenarios used for Study 1

Category	Scenario	Adapted from
Purity Moral	Mark and his sister wait for a time when nobody is around, and then they find a secret hiding place. Once they are hidden, Mark and his sister kiss each other on the mouth passionately.	Horberg, Oveis, Keltner, and Cohen (2009)
	Jason's plane crashes in the Himalayas. The only other survivor is a young boy. After a few days, the young boy dies of his injuries. So, to survive, Jason eats the boy.	Schnall, Haidt, Clore and Jordan (2008)
	Frank's pet dog was killed by a car in front of his house. Frank had heard that some people occasionally eat dog meat, and he was curious what it tasted like. So, he cuts up the body, cooks it and eats it for dinner.	Schnall, Haidt, Clore and Jordan (2008)
Non-purity Moral	Tom is driving a train. He realises if he does nothing, and the train remains on its current course it will kill five workmen. So, Tom chooses to change tracks, intentionally killing one workman instead of five.	Schnall, Haidt, Clore and Jordan (2008)
	Arnold is a congressman who frequently gives speeches condemning corruption. But Arnold is just trying to cover up the fact that he himself will take bribes from the tobacco lobby to promote their legislation.	Wheatley and Haidt (2005)
	Jack sees a woman with a guide dog sit down and place her handbag next to her. He realises she is blind and decides to steal her handbag. Jack quietly takes the handbag and leaves without the woman noticing.	Rozin, Lowery, Imada, and Haidt, (1999).

Physical Disgust	Greg bites into an apple which has a worm in it. Greg does not realise there is a worm in the apple until after he has swallowed.	Rozin, Lowery, Imada, and Haidt, (1999)
	David goes out for a walk. On his walk, he accidentally steps in dog excrement. When David gets home and cleans his shoes, he gets some of the dog faeces on his hands.	Original
	Andrew goes on a night out with his friend. Afterwards, when she is drunk, he offers to hold her hair back while she vomits. However, because of this, some vomit lands on Andrew's arm.	Original

Procedure. The experiment was programmed and run using MATLAB experimental software (*MATLAB*, 2010), using the Psychtoolbox and Eyelink toolbox experimental packages (Cornelissen, Peters, & Palmer, 2002; Kleiner, 2007). SR Research's Eyelink 1000 eye-tracking hardware was used to record the participant's eye movements and pupil diameter. Stimuli were presented using headphones. The volume was kept at a constant level for each participant but was changed between participants, as it was important to hear the scenarios clearly and comfortably. While scenarios were playing, participants were asked to focus on a fixation cross presented on a screen in front of them (screen resolution 1980x1080 pixels). Participants' motion was limited using an SR Research head support, ensuring a fixed distance to the screen and eye-tracking camera.

After two practice vignettes and questions, each participant heard all nine scenarios presented in a fully randomised order. Before each stimulus was presented, there were two seconds of silence to create a baseline period. During the baseline and trial

period, a fixation cross was displayed to participants. After each stimulus was presented, using a number pad, participants answered questions about the scenario. Fourteen questions were used to assess emotional reactions. Participants were asked how disgusted, grossed out, repulsed, angry, annoyed, sad, happy, and fearful they felt on a 1-9 scale (where 1 is neutral and 9 is very). They were also asked to rate how well happy, sad, angry, fearful, happy and neutral facial expressions fit their emotional experiences (1 not at all well, 9 very well). Finally, six questions were used to assess opinions about the scenario itself; how immoral the scenario was, how animalistic and degrading (as a measure of impurity), how sinful it was (also as a measure of purity), how likely the character is to catch an illness or disease because of their behaviour (as a measure of disease-relevance), how emotionally or physically harmful the behaviour was, and how exemplary of bad character the scenario was (1 not at all, 9 very).

Data Preparation. All pupil data were measured in Eyelink 1000 units (typical pupil size between 100-1000 units). The data were cleaned in the same way as described in Chapter 2 (participants missing more than 60% trial data were removed entirely, pupil sizes below Tukey's lower fence indicating blinking period were removed, median pupil size from baseline period subtracted from trial pupil sizes, then averaged per trial), leaving 92 participants for analysis.

As we intended to use multiple measures of emotions (facial expressions and multiple words), we conducted a Confirmatory Factor Analysis (CFA; Rosseel, 2012) to determine whether our hypothesised factor structure was supported by the data. The model fits the data well (Root Mean Square Error of Approximation = 0.093, 90% CI [0.85, 0.10], p <.001), with an improved fit compared to the baseline model (Comparative fit index = .93, Tucker-Lewis Index = .90). The results indicate that all measured

variables displayed significant positive factor loadings onto the specified latent variables (*ps* <.001) with standardised coefficients ranging from .65 to .93, for full results, see Figure 2.

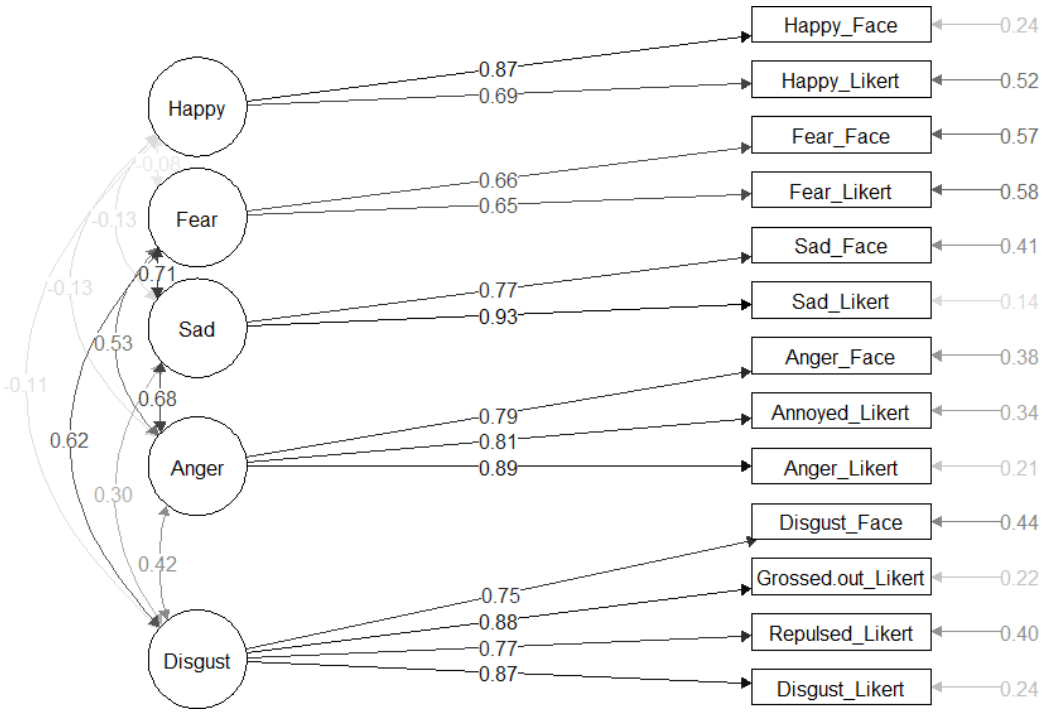

Figure 2. Standardised coefficients (β) from Confirmatory Factor Analysis of emotional variables. Latent variables found in circular nodes, measured variables in square nodes. The strength of the relationship is indicated by the shade of grey, with lighter being weaker. Error variance for each variable found on the right of the figure, covariation between latent variables found to the left.

Based on the results above, we reduced the data as planned. So, in the analyses below, happiness, sadness, and fear were averages of the endorsement of facial expressions and the associated emotional words (for example, the average of how well the

happy facial expression matched the participants' emotional response averaged with how well the word “happiness” described their emotional response). The variables anger and disgust were averages of multiple emotional words/phrases— “grossed out”, “repulsed”, and “disgusted” for disgust, “annoyed” and “angry” for anger—as well as the accompanying facial expressions.

Results

We conducted preregistered analyses (https://osf.io/6b739) and exploratory analyses so, to reflect this, the results below are split accordingly. Any deviations from preregistration are noted. The data were modelled using linear mixed-effects models and significance was assessed through both Satterthwaite approximated p-values and Wald confidence intervals (lme4, Bates & Sarkar, 2007; lmerTest R package, Kuznetsova, Brockhoff, & Christensen, 2017). Each model includes random intercepts for each participant, allowing us to account for natural variation in pupil size, and each stimulus they were presented with, allowing us to account for differences in stimulus properties. For all models, to test for issues of multicollinearity we used the Variance Inflation Factors (VIF for lmer; Frank, 2019) of individual predictors in all linear models, which did not indicate any issues with multicollinearity for any model (all VIF < 4).

Descriptive Statistics

Disgust had the highest average rating of the emotions measured, while, based on their mean ratings, anger, fear, and sadness also appeared to have been elicited by the scenarios. All emotions were significantly correlated with each other; the highest correlations were sadness with anger and sadness with fear. Happiness was, as expected,

not elicited highly and negatively correlated with all other emotional responses, albeit not significantly for fear. Full results of these analyses can be found in Table 10.

Table 10

Pearson Correlation Matrix for Emotions and Pupil Size

Variable	M	SD	1	2	3	4	5
1. Pupil size	152.16	206.82					
2. Disgust	5.33	2.53	.03				
3. Anger	4.12	2.65	-.01	.40***			
4. Fear	3.57	2.33	-.04	.47***	.39***		
5. Sadness	4.04	2.76	-.03	.26***	.57***	.52***	
6. Happiness	1.20	0.81	.01	-.09**	-.10**	-.04	-.09**

*p <.05, ** p <.01, ***p <.001. n=828

Figure 3 shows the differences in pupil sizes, disgust ratings (averaged from disgusted, repulsed, grossed out, and the disgust facial expression), and anger ratings (averaged from anger, annoyed, and the anger facial expression) per category of violation. The category that received the highest mean anger ratings is the non-purity immoral scenarios (M = 5.27, SD = 2.55) and lowest to physically disgusting scenarios (M = 2.44, SD = 1.86). The category that received the highest disgust ratings is the impure immoral scenarios (M = 6.78, SD = 2.11) and lowest to the non-purity immoral scenarios (M = 3.72, SD = 2.21). Additionally, the differences in pupil sizes between the categories mirrors the ratings for disgust; with the largest pupil sizes for impurity (M = 164.32, SD = 212.88), then physical disgust (M = 152.17, SD = 202.83), then finally non-purity immoral scenarios (M = 139.99, SD = 204.67).

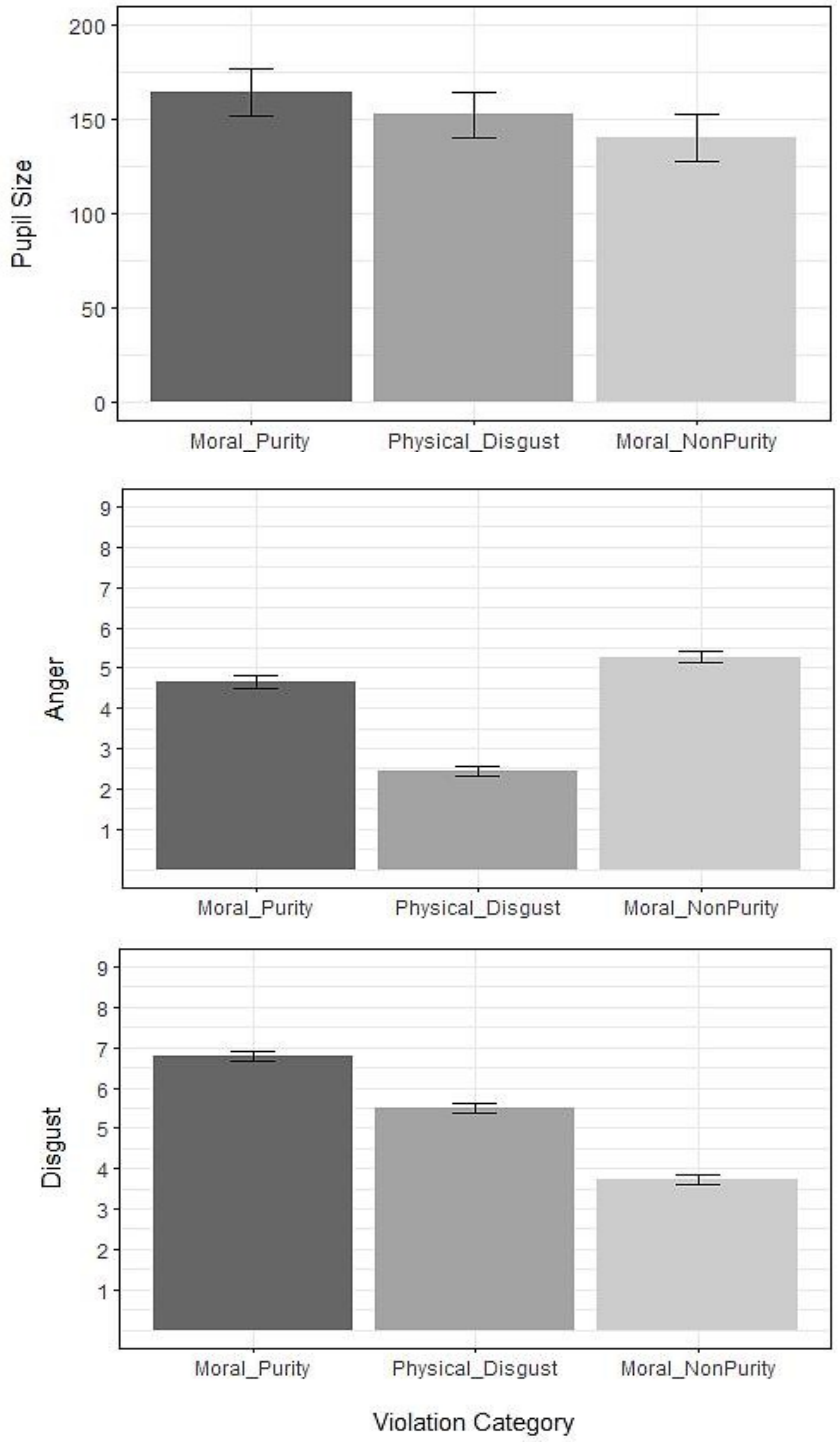

Figure 3. Bar charts showing means and standard errors of pupil size, anger, and disgust for each category of vignette. Anger is the average of the ratings for anger, annoyed, and endorsement of the anger facial expression. Disgust is the average of disgusted, repulsed, grossed out, and the endorsement of the disgust facial expression.

Figure 4 shows the differences in immorality and purity (how animalistic and degrading the scenario was) for each category of violation. As we would expect, both purity violations (M = 6.20, SD = 2.71) and non-purity violations (M = 6.30, SD = 2.82) have higher mean ratings for immorality than the physically disgusting stimuli. Additionally, for purity violations, there was a higher mean rating for impurity (M = 6.51, SD = 2.62) than is found for the non-purity violations (M = 4.82, SD = 2.83).

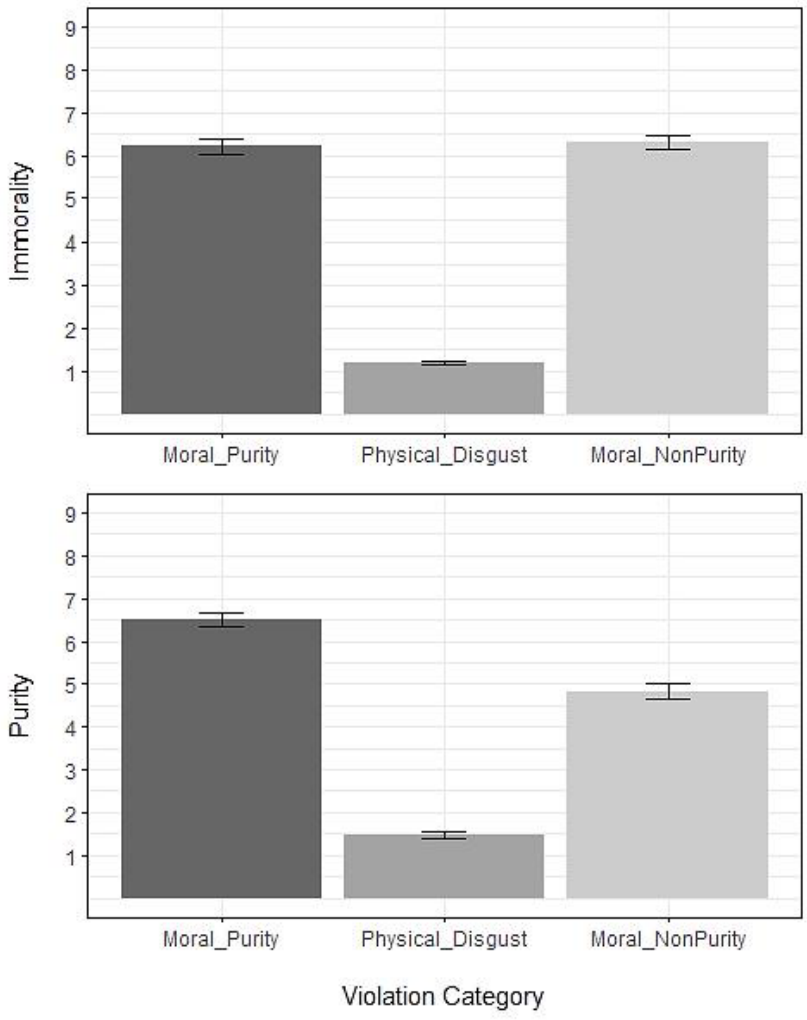

Figure 4. Bar charts showing means and standard errors of immorality and purity for each category of vignette. Purity is how animalistic and degrading the act described is judged to be.

Exploratory Analyses: Self-Report Only

Before analysing the pupil diameter data, we conducted exploratory analyses using only the self-report data which, as they were secondary to the main analyses, were not preregistered. The aim of these analyses was to investigate whether prior work would be replicated in our study; specifically, those studies which connect self-reported purity to disgust and anger to harm. We expected that if these connections are still found with self-report then we should then have good reason to expect these distinctions in moral foundations to be reflected with differences in pupil dilation in our subsequent analyses. Therefore, we initially investigated which of the self-report judgements commonly used in prior research (harm, impurity, sin, bad character, and disease risk) best predicted anger and disgust without the inclusion of the pupil dilation data. We also investigated which categories of violation elicited higher disgust and anger.

Prior research has indicated that feelings of disgust are related to purity (Graham et al., 2011; Horberg et al., 2009), disease (Biran & Curtis, 2001; Royzman et al., 2014; Schaller, 2011; Tybur et al., 2009), and bad character (Giner-Sorolla & Chapman, 2017). In contrast, anger has been found to be elicited by harm (Rozin et al., 1999). Additionally, although it is also argued to be part of purity (Horberg et al., 2009), some studies have found anger in relation to sin (Royzman et al., 2014). So, we hypothesise that higher ratings of disgust will be predicted by impurity, disease risk, and bad character, whereas anger will be predicted by harm and sin.

To investigate this, using a mixed-effects linear model, we regressed the ratings for impurity, sin, immorality, harm, bad character, and disease risk onto ratings of anger and disgust (in two separate models), when controlling mixed emotions of anger and disgust. The results of these models suggested that, as hypothesised, impurity predicted

higher disgust (B = 0.62, β = .24, p <.001) but not higher anger. Similarly, increases in perceived disease risk predicted higher disgust (B = 0.41, β = .16, p <.001) but lower anger (B = -0.17, β = -.06, p =.039). Also, fitting with prior work, anger but not disgust was predicted by higher judgements of sin (B = 0.33, β = .12, p =.016) and harm (B = 0.25, β= .09, p =.004). However, in contrast to previous findings, judgements of bad character predicted higher anger (B = 1.00, β = .38, p <.001) rather than disgust, interestingly also being the strongest predictor of this emotional response. So, in summation, we found that disgust was increased by judgements of impurity and disease risk, whereas anger was higher when the scenario is judged to be harmful, sinful, and indicative of bad character.

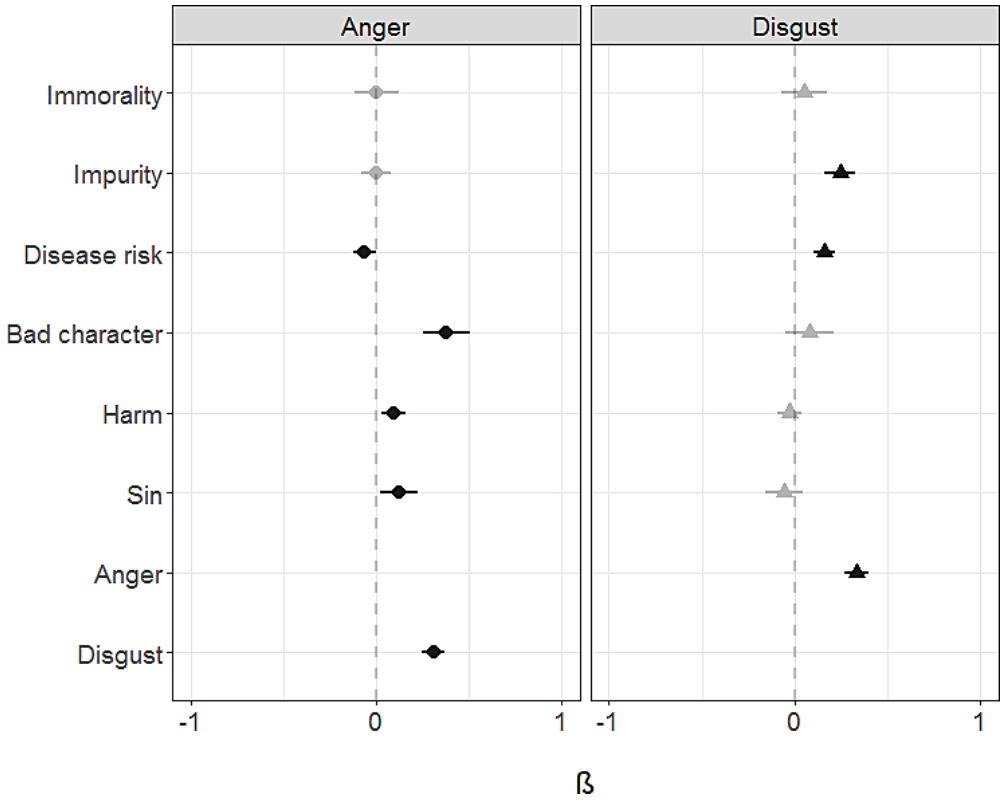

Figure 5. Plots of standardised estimates and 95% confidence intervals from 2 Linear Mixed-Effects Models, one with anger as a DV the other with disgust as a DV. Variable names can be found to the left of the graph. Estimates with confidence intervals excluding 0 highlighted in black.

We ran two additional mixed-effects models where we regressed the dummy coded categories of violation onto ratings of anger and disgust (in two separate models) when controlling mixed emotions of anger and disgust. The results of this model suggest that, as we would expect, disgust is higher towards the impurity category (B = 3.33, β = .62, p <.001) and physical disgust category (B = 3.02, β = .56, p <.001) compared to the non-purity immoral scenarios. The opposite is found for anger; both impurity (B = -2.25, β = -.40, p= .009) and physical disgust (B = -3.77, β = -.67, p <.001) elicit significantly lower anger.

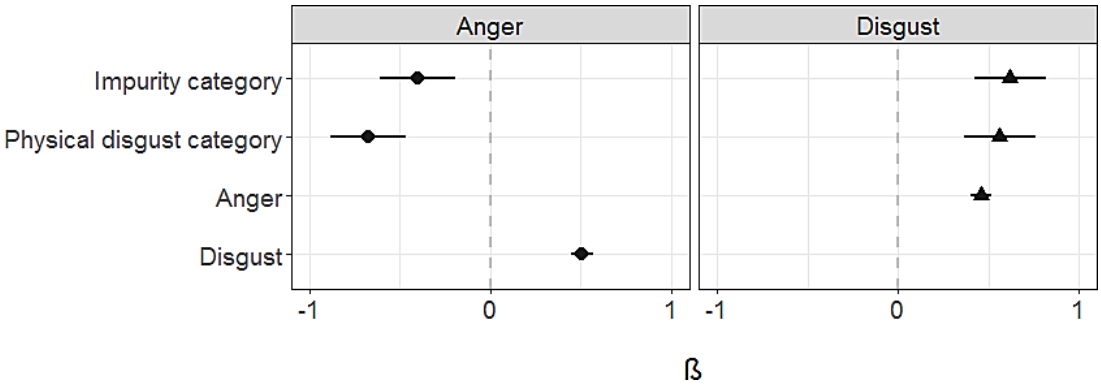

Figure 6. Plots of standardised estimates and 95% confidence intervals from 2 Linear Mixed-Effects Models, one with anger as a DV the other with disgust as a DV. Anger is the average ratings of angry, annoyed, and the angry facial expression, disgust is the average of disgusted, repulsed, grossed out, and the endorsement of the disgusted facial expression. Variable names can be found to the left of the graph. Estimates with confidence intervals excluding 0 highlighted in black.

Planned Analyses: Pupil Dilation

Hypothesis 1: Disgust will predict larger pupil sizes. For our pre-registered analyses, first, we hypothesized that higher self-rated feelings of disgust would predict

larger pupil sizes and that anger would not predict any significant change in pupil size. To test this, as with the previous experiments from Chapter 2, we used a mixed-effects model where the variables fear, happiness, anger, sadness, and disgust were regressed onto baseline-corrected mean pupil size. However, unlike previous results, this model suggested that no emotion was significantly related to increases or decreases in pupil size. As such, in this case, disgust did not predict larger pupil sizes overall. Full results of this model can be found in Table 11.

Table 11

Linear Mixed Model for Emotional Ratings DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
(Intercept)	152.160	16.857	39.757	9.026	<.001	119.121	185.199
Anger	-3.141	9.215	187.636	-0.341	.734	-21.202	14.921
Disgust	12.557	8.915	138.355	1.409	.161	-4.916	30.029
Fear	-17.135	9.166	638.489	-1.870	.062	-35.099	0.829
Happiness	4.371	6.603	796.802	0.662	.508	-8.570	17.312
Sadness	1.787	9.400	291.046	0.190	.849	-16.636	20.209

Hypothesis 2: Immorality will predict larger pupil sizes only with concurrent disgust. To test our second hypothesis, in a slight deviation from the originally planned three-way interaction – to increase simplicity and ease of interpretability – we constructed

a linear model with two two-way interactions between ratings of disgust and immorality and with anger and immorality, regressed onto baseline-corrected mean pupil size. No predictors or their interactions significantly predicted pupil dilation, as such immorality and concurrent disgust does not predict larger pupil sizes. Full results can be seen in Table 12.

Table 12

Linear Mixed Model for Emotional Ratings, DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
(Intercept)	151.748	17.040	53.818	8.905	<.001	118.350	185.145
Anger	-11.552	9.808	629.758	-1.178	.239	-30.776	7.672
Disgust	7.060	8.284	79.987	0.852	.397	-9.176	23.297
Immorality	8.776	9.766	78.367	0.899	.372	-10.364	27.917
Anger* Immorality	-3.298	8.405	402.475	-0.392	.695	-19.772	13.176
Disgust* Immorality	11.145	7.375	215.029	1.511	.132	-3.310	25.599

Hypothesis 3: Disgust will be higher and pupil size larger towards purity violations. For our third hypothesis, we constructed two linear models. First, investigated whether the pre-categorised purity violation vignettes were responded to with greater disgust and pupil dilation. Second, we investigated whether the participants' self-rated judgements of impurity (that being, how animalistic and degrading the act is) predicted

disgust-induced pupil dilation.

Model 1: Violation Categories. First, we constructed a linear model with disgust, violation category, and their interaction regressed onto baseline-corrected mean pupil size. Full results of this model can be found in Table 13. There was a significant interaction between violation category and disgust, as can be seen in Figure 7; such that increases in disgust predict increases in pupil dilation exclusively towards purity violations ($B = 43.09$, $\beta = .21$, $p = .02$). This supports our hypothesised association between disgust and purity violations and replicates that disgust is reflected by pupil dilation, albeit for a subset of predictors in this case.

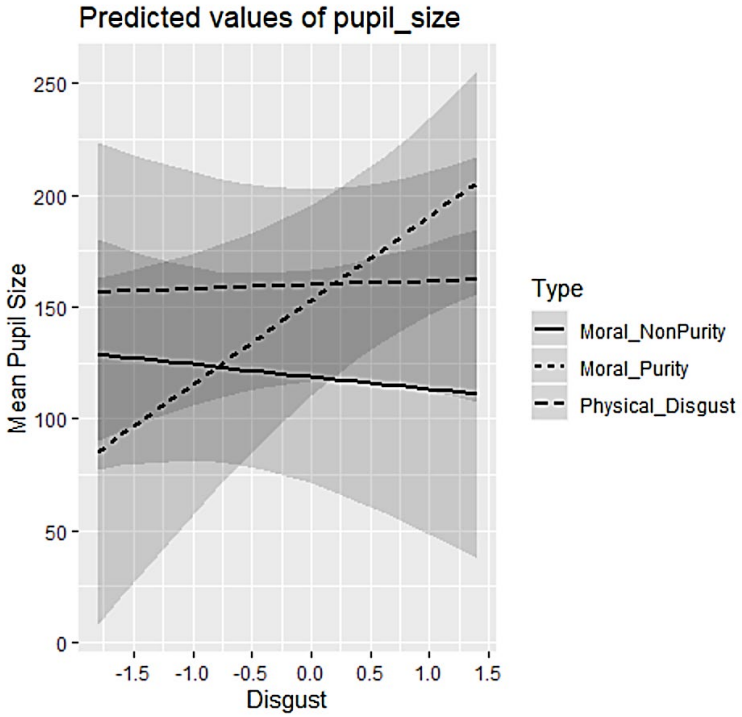

Figure 7. Plot of predicted values from the model assessing the interaction between type of scenario and disgust in relation to pupil size.

Although purity violations were related to disgust induced pupil dilation,

importantly, this effect was only found when controlling for disease risk. For disease risk there was an opposite effect on pupil size: as the perception of disease risk increased, pupil size decreased (B = -21.61, β= -.10, p =.01). Rather than showing that disgust towards purity is driven by disease risk, moral disgust only predicted pupil dilation when disease risk was held constant. Judgements that the scenario was emotionally or physically harmful and anger, on the other hand, did not influence pupil size in either direction.

Table 13

Linear Mixed Model for Pre-categorised Stimuli, DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
(Intercept)	118.806	24.381	33.205	4.873	< .001	71.021	166.591
Impurity	34.089	27.890	14.864	1.222	0.241	-20.575	88.753
Physical disgust	40.937	29.883	19.884	1.370	0.186	-17.632	99.506
Disgust	-5.529	14.162	647.590	-0.390	0.696	-33.287	22.229
Disgust*Impurity	**43.091**	**17.914**	**647.505**	**2.405**	**0.016**	**7.980**	**78.202**
Disgust* Physical disgust	7.191	17.767	495.265	0.405	0.686	-27.632	42.014
Anger	-13.774	9.664	639.166	-1.425	0.155	-32.715	5.168
Harm	17.041	8.904	761.576	1.914	0.056	-0.411	34.493
Disease Risk	**-21.613**	**8.610**	**262.640**	**-2.510**	**0.013**	**-38.488**	**-4.739**

Note. Significance indicated in bold

Model 2: Impurity Self-report. For the second model, we aimed to investigate whether self-rated purity had the same interaction with disgust as the purity category. We hypothesised that as ratings of impurity and disgust increased so would pupil size. To this aim, we constructed a linear model with an interaction between ratings of disgust and ratings of purity regressed onto baseline-corrected mean pupil size. As before, we entered perceived disease risk, anger, and harm as control variables. In this case, no variable significantly predicted changes in pupil size. Unlike the previous model, this did not support our hypothesised association between disgust, impurity, and pupil size: self-reported ratings of impurity did not interact with disgust to cause pupil dilation. Full results found in Table 14.

Table 14

Linear Mixed Model for Self-reported Purity, DV Baseline Corrected Mean Pupil Size

						95% Confidence Interval	
	Estimate	SE	df	t	p	Lower Bound	Upper Bound
(Intercept)	148.857	16.115	49.981	9.237	<.001	117.272	180.442
Impurity	-0.197	10.110	158.869	-0.020	0.984	-20.012	19.617
Disgust	15.659	9.155	171.341	1.710	0.089	-2.285	33.603
Disgust* Impurity	8.077	6.829	419.291	1.183	0.238	-5.308	21.461
Anger	-16.931	9.351	420.059	-1.811	0.071	-35.258	1.397
Harm	14.313	8.908	524.177	1.607	0.109	-3.146	31.773
Disease Risk	-15.978	8.093	149.897	-1.974	0.050	-31.840	-0.116

Discussion

Prior research using MFT and the CAD hypothesis as a framework suggest that, in the moral realm, disgust is exclusively elicited by purity violations. In the current study, this is what was found using the self-report data alone: only judgements that the scenario was degrading and animalistic (impure) or posed a disease risk increased disgust ratings. Other moral judgements that the scenario was sinful, indicative of bad character, and harmful increased anger but not disgust. Similarly, as expected, disgust was highest towards the physically disgusting and impure scenarios, whereas anger was higher towards the non-purity moral violations. However, when introducing pupillometry the results are more complicated, but nevertheless, provide interesting insights into the disgust-purity connection which could not have been gleaned from self-report alone.

The addition of pupil dilation data, to a certain extent, also supports the findings from prior research and our self-report analyses: that disgust is elicited by purity. We found disgust-induced increases in pupil size exclusively towards the pre-categorised purity violations, albeit only when disease risk is held constant. Additionally, as mentioned above, we found anger to a greater extent in response to the non-purity violations and, as expected, this was not associated with pupil dilation, instead of being associated with a non-significant decrease in pupil size. This fits with the results of Chapter 2 which demonstrated disgust is related to increases in pupil size, but anger is not. As this provides evidence that moral disgust and moral anger are distinguishable physiologically, our results do not suggest that moral disgust is a synonym for anger as suggested by some authors (Herz & Hinds, 2013; Nabi, 2002). Our analyses of both self-report and physiology support the understanding that participants report higher levels of disgust in response to purity violations and that this is reflected by differences in

associated physiology.

Additionally, our results also do not support the theory that disgust is only elicited by the disease risk found in purity violations, a claim which undermines the existence of purely moral disgust rather than exclusively general physical disgust. Instead, we found a clear—if unexpected—association between disease risk and decreases in pupil size, distinguishing this from the pupil dilation found in moral disgust. As such, the results of this study suggest that it is particularly important to parse these two types of disgust. Moral disgust only appeared to increase pupil size when controlling for the judgement of disease risk. The finding that disease risk had the opposite effect on pupils suggests that disgust towards disease risk and moral disgust may represent two separate pathways, or separate emotions entirely, with different physiological markers. This would fit with prior results finding moral (Konishi et al., 2019) and mutilation disgust are marked by heart rate deceleration, but contamination disgust is not (Kreibig, 2010). Taken together our results indicate that moral disgust is distinguishable via physiology not only from moral anger but also from disease- elicited disgust.

However, this study also introduces uncertainty about what exactly is disgusting about purity scenarios. Whilst higher self-reported disgust and the associated pupil dilation were found in response to what we determined were purity violations based on theory, the participant's own self-reported judgements of impurity and concurrent disgust did not predict larger pupil sizes. So, even though the self-report data alone would suggest higher ratings of impurity (degrading/animalistic) predicted higher levels of disgust, the lack of associated physiological response suggests that there may be a different or additional aspect of these scenarios that drive the physiological disgust response. Other options for what could underlie this response—immorality, anger, harm, or (as discussed

above) the disease risk of the purity scenarios—either did not significantly predict changes in pupil size or predicted smaller pupil sizes, suggesting none of these judgements drive this effect either. So, although judgements that a scenario is animalistic and degrading did increase disgust ratings, this alone is not strong enough to drive a physiological reaction.

Consequently, it may be that another aspect of impure scenarios is a stronger predictor of disgust, rather than how animalistic or degrading they are alone. There are other suggestions for what is disgusting about purity violations which were not assessed in this study; for example, how weird, counter-normative, inexplicable, or unusual the scenarios are. Some have argued that purity scenarios suffer from sampling bias, as they are both weirder and less severe than harm scenarios (Gray & Keeney, 2015). In support of this, it has been demonstrated that the weirdness of the items in the Disgust Sensitivity scale correlates with severity of moral judgements exclusively for purity violations (not harm) (Wagemans, Brandt, & Zeelenberg, 2018b). However, when weird items are removed disgust sensitivity is still related to harsher judgements of purity violations, suggesting weirdness is likely not to be the only driver for this association (Wagemans et al., 2018b). Thus, further research is required to investigate whether weirdness and other similar judgements, increase disgust towards purity violations

Limitations

The first limitation of this study, as with any vignette study, is that it only provides evidence for emotional reactions to patently hypothetical, third party scenarios. The emotional reactions and judgements of real-life immorality, or immoral behaviour which has involved the participant or someone they care about may be reacted to differently.

Additionally, as mentioned above, it has been argued that the purity scenarios commonly used within the literature suffer from sampling bias which could underlie the consistent disgust reactions towards them (Gray & Keeney, 2015). It is therefore conceivable that a different set of moral vignettes may elicit different emotional responses and a different associated physiological reaction. That being said, it has been highlighted that the inclusion of a random effect for stimuli, as in our analyses, should increase the generalisability of results (Yarkoni, 2019).

A further limitation of this study is that the emotional predictors by themselves did not show the same pattern as the pupillometry studies from Chapter 2; disgust did not significantly predict pupil dilation overall. These results, therefore, highlight an important difference in physiological reaction to recordings of scenarios compared to emotional sounds and images used in previous work. This is especially surprising as the emotional ratings were stronger for this study than both of the pupillometry studies in Chapter 2, suggesting the strength of the self-reported emotional reaction is not reflected by the strength of physiological response. Again, this could fit with previous work finding that the form of stimuli has an important impact, as differences have been found in other autonomic responses depending on whether a disgusting stimulus is visual, auditory, haptic, or olfactory (Croy, Laqua, Süß, Joraschky, Ziemssen, & Hummel, 2013). This suggests further research would be required to better understand the impact of stimuli type on physiological reactions.

Future Directions

The results of this study open several potential avenues for further investigation. It would be interesting to include additional physiological measures such as heart rate, as

heart rate has recently been used to distinguish moral anger and moral disgust successfully (Konishi et al., 2019) and it has been suggested that multiple measures may increase the ability to distinguish between emotions (Kreibig, 2010). Second, as we have seen, this study brings into question what exactly is disgusting about purity scenarios. There may be more than just the judgement that the scenario is animalistic and degrading underlying the physiological disgust reaction to purity scenarios. This could be explored using qualitative investigations of participant's specific thoughts and emotions in response to these scenarios. This would allow a more in-depth exploration of their reactions. Finally, it would be of interest to see the difference in emotional reactions to immorality which has personally affected the participant, perhaps via recall or (as in the following chapter) using less severe violations. This would allow the psychophysiological correlates of emotional reactions to personally relevant immoral behaviours to be compared to those in response to hypothetical judgements seen in this study.

Chapter 4: Disgust, Anger, and Contempt in Response to Harm and Incompetence[1]

When other people transgress moral rules and norms, we are intuitively and emotionally driven to react appropriately. Recent work suggests that specific emotions such as anger, disgust, and contempt play key roles in driving our moral judgements. Whilst rationalist traditions of moral psychology argue that whether an individual will consider a behaviour immoral stems from careful, reasoned deliberation of how we "ought to relate to each other" (Turiel, 1983, p. 3), taking into account issues such as harm caused to others (Kohlberg, 1971; Turiel, Hildebrandt, & Wainryb, 1991), more recent moral theory tends to disagree with this stance. Instead, it is suggested that emotions are vital to moral decisions and judgements (Damasio, Everitt, & Bishop, 1996) and, in some cases, that all moral rationality demonstrated is likely to be post hoc justification (e.g. Haidt, 2001). Neurological evidence supports this view; individuals with damage to the ventromedial prefrontal cortex demonstrate the importance of emotions in judgements and decision-making (Bechara et al., 2000; Damasio et al., 1996). Alongside difficulties with feeling emotions appropriately, these individuals have difficulties making decisions, despite retaining full abilities in learning, memory, language and attention (Bechara et al., 2000; Damasio et al., 1996). This has interesting consequences for morality, as these individuals endorse extremely utilitarian moral decisions (compared to healthy controls), such as pushing an individual from a bridge or smothering one's own baby to save multiple adults (Koenigs et al., 2007). They also

[1] NB: This chapter is drafted as an article. See Authors Note.

differ behaviourally as, compared to controls, they reject unequal offers in ultimatum games at an unusually high rate, arguably due to limited regulatory control over emotions such as anger (Koenigs & Tranel, 2007). As such, emotions play an important role in shaping which behaviours we will endorse as morally appropriate and how we will react when it is perceived that we have been personally wronged.

Moral Emotions: The Hostile Triad

Early work in moral psychology proposed anger, contempt, and disgust as the emotions most clearly related to hostility and judgement of others (e.g. Haidt, 2003; Izard, 1977). However, although anger and contempt's relationship with immoral behaviour is rarely doubted, there is greater controversy regarding disgust. Largely, there is a consensus that disgust has a hypothesised evolved function outside of the moral domain, being first and foremost associated with physical repulsion towards potential sources of disease (e.g., Curtis, de Barra, & Aunger, 2011; Schaller & Park, 2011). Given this distinct purpose for disgust, its role in morality seems less obvious; some have argued that it is only used as a synonym for anger (Herz & Hinds, 2013; Nabi, 2002) or a reaction to the pathogenic content of many immoral scenarios, such as cannibalism and incest (Royzman et al., 2014), rather than a specific reaction to immorality itself. We next review key relevant theories on moral emotions that make predictions about the roles of the hostile triad in morality.

Moral Foundations Theory (MFT)

One method of distinguishing between moral emotions is based on the type of moral violation. MFT identifies five domains of moral violations: care/harm,

fairness/cheating, loyalty/betrayal, authority/subversion, and purity/degradation (Graham et al., 2013, 2011). MFT predicts that these moral domains will each elicit a different predominant emotion (although this does not necessarily mean that mixed emotions will not be felt). These emotions are *compassion* for care/harm, *gratitude*/*anger* for fairness/cheating, *pride* and *belongingness*/*rage* (distinguished from anger by Haidt & Joseph, 2008) for loyalty/betrayal, *respect*/*fear* for authority/subversion, and *disgust* for purity or degradation (Haidt & Joseph, 2008). Purity violations (also known as divinity violations) tend to be immoral behaviours which violate decency, are hedonistic, degrading, impure, or violate religious norms. Similarly, a widely cited precursor to MFT, the CAD Hypothesis (Rozin et al., 1999), also suggests that disgust is related to purity violations, with the difference being anger's exclusive role to react to violations of an individual's freedoms or rights (autonomy violations) and contempt to individuals behaving disloyally or disrespecting authority (community violations). This theory remains widely used in the emotions literature as it presents a clearer distinction between anger and disgust than MFT, and because it also incorporates the third other-condemning emotion that is widely used alongside anger and disgust—contempt. The common ground between CAD and MFT for disgust and anger is that both predict that disgust is exclusively related to purity violations, whereas anger is related to violations such as harm and unfairness.

A number of empirical studies appear to demonstrate that disgust is exclusively related to purity violations. For example, disgust predicted harsher judgements of purity violations whereas anger was related to justice violations (Horberg et al., 2009), those with higher disgust sensitivity have been found to be more sensitive to purity violations than violations of the other four domains of MFT (Wagemans et al., 2018b), and

participants were disgusted by impurity and angered by intentional harm (specifically upset caused to others; Russell & Giner-Sorolla, 2011). Even in a study which otherwise undermines MFT (Landmann & Hess, 2018), anger and rage (but not other emotions) were characteristic of all moral foundations except for purity violations which elicited disgust.

However, there is also evidence that disgust and anger may not be functionally distinct in their moral roles. For example, disgust has been found related to violations outside of the purity domain: Participants displayed the same distinctive disgust facial expression in response to bad tastes, photographs of contaminants, and unfair treatment in an economic game (Chapman, Kim, Susskind, & Anderson, 2009), while Moretti and di Pellegrino (2010) found that priming with disgusting images led to increased rejection of unfair offers in an ultimatum game. In reverse, Royzman et al. (2014) found that anger and anticipated retaliation, not disgust, were demonstrated in response to pathogen-free purity violations (such as using a crucifix as a doorstop). Taken together, these studies suggest that disgust is not limited to purity violations and anger may not be excluded from the purity domain. Given the inconsistencies between theory and evidence, we next consider two alternative theories that distinguish anger and disgust by means other than the type (domain) of moral violation.

Social Functionalist Model (SFM)

The Social Functionalist Model (SFM) of disgust, anger, and contempt (Hutcherson & Gross, 2011) predicts different elicitation of anger and disgust to moral violations dependent on who is affected, rather than by the domain of the act. SFM predicts that anger encourages approach whereas disgust encourages avoidance, the two

emotions motivating differing directional behaviours that are appropriate for different situations. SFM proposes that anger becomes more appropriate as the threat becomes more immediate, mostly towards personal threats or (to a lesser extent) threats to close others, whilst disgust and contempt become more appropriate when a threat is less immediate, such as observer responses to threats to unknown or lesser-known others. As anger encourages risk-taking (e.g., Lerner & Keltner, 2001), it is thought to motivate a more risky, direct, confrontational response. In contrast—in the context of SFM— disgust seems to be a more appropriate response towards individuals who pose less immediate, personal risk but whose past behaviour suggests it would be beneficial to avoid them. Similarly, the authors of SFM argue that contempt, as another emotion that encourages avoidance, would motivate non-engagement with those who are not directly harmful but waste resources through incompetence. Supporting this, it has been shown, using immorality vignettes that varied in self-relevance, that disgust was strongest when immoral actions were directed at others, less when directed at a friend, and least when directed at the participant, whereas the opposite was found for anger (Hutcherson & Gross, 2011). Thus, SFM predicts that disgust should relate to harm to others (encouraging avoidance of a potential future risk of harm), anger should be elicited by those who caused you harm (responding to a current, direct threat aggressively), and contempt should be caused by incompetence (responding to undesirable but not intentionally harmful group members).

Stereotype Content Model (SCM)

A third theoretical model which can be used to generate predictions about the hostile triad is the Stereotype Content Model (SCM). Whilst it was developed to predict negative outgroup stereotypes, Fiske, Cuddy, and Glick (2007) suggest that all social

cognition can be organised along its two dimensions: warmth and competence. Warmth is determined by whether a person or group intends to help or harm, and competence by their ability to carry out their intentions. Using this framework, it has been suggested that which of the hostile triad—disgust, anger, or contempt—will be felt is determined by the perceived warmth and competence of the target (Cuddy et al., 2007; Harris & Fiske, 2006; Ufkes et al., 2012). Low-warmth would motivate anger and dislike, whereas low-competence would motivate disrespect and therefore contempt (Ufkes et al., 2012) or disgust and contempt (Harris & Fiske, 2006). It is thought that disgust would both be reserved for low-warmth individuals who have harmful intentions but are additionally limited by low competence. Disgust would be of particular use here as it can be felt equally towards nonhuman (such as food and bodily fluids) and human targets, and as such dehumanises a person that is low in both possible dimensions (Harris & Fiske, 2006). Therefore, according to this interpretation of SCM, both disgust and contempt should relate to both harm and incompetence, while anger should just relate to harm.

Current Research

Cooperative behaviour is deeply rooted in human psychology and it has been proposed that morality evolved in humans to support this cooperative behaviour by ensuring social cohesion (e.g. Curry, Mullins, & Whitehouse, 2019; Tomasello & Vaish, 2013). Cooperative behaviour is displayed towards known-others, strangers, and even members of other species early in development (Warneken, Hare, Melis, Hanus, & Tomasello, 2007; Warneken & Tomasello, 2006) and is found to some extent in our most closely related species, bonobos and chimpanzees (Boesch et al., 2010; Tan & Hare, 2013; Warneken et al., 2007; Warneken & Tomasello, 2006). In contrast to the canonical

view of the "Economic Man", based on the assumption that humans work only to maximise their self-interest (Smith, 1822/2010), the reality of social behaviour is that humans seek to create cooperative arenas: economic games, the most explicit methodology for testing whether people are self-maximisers, consistently demonstrate participants' cooperative tendencies rather than pure self-interest (for a review see Fehr & Schmidt, 2006). However, cooperation is vulnerable to cheating and free-riding (O'Gorman, Sheldon, & Wilson, 2008) and needs social mechanisms to buttress it, shared rules about how we should treat each other and behave: morality. Cross-culturally, moral framing of cooperative behaviour is widespread; ethnographic descriptions of 60 cultures suggest that many facets of cooperation are framed as morally positive, specifically: detecting and delivering benefits to genetic relatives; forming and collaborating with groups; reciprocating positively or negatively to those who help or harm; resolving conflict through displays that are "hawkish" (specifically, for Curry et al., 2019, bravery) or "dovish" (respect and obedience); recognising rights over prior possessions; and behaving fairly in compromises and division of resources (Curry et al., 2019).

Assuming that the purpose of morality is indeed to facilitate cooperation, this should extend to economic decision-making. Those who do not behave fairly and cooperatively in economic games should be judged through a moral prism driven by emotional responses. In general, it has been established that emotions impact cooperation in economic experiments; for example, the positive emotion gratitude increases cooperative behaviour (DeSteno, Bartlett, Baumann, Williams, & Dickens, 2010) and priming negative emotions, such as sadness and disgust, increase personally costly punishment of unfair behaviour (Harlé & Sanfey, 2007; Moretti & di Pellegrino, 2010). Given the inconsistencies in, and challenges of, vignette methodologies in distinguishing

the roles of disgust and anger in moral settings, we opted to test the theories outlined above (MFT, SCM, SFM) using an economic cooperative setting. While vignettes are vulnerable to the specificity of the content, economic games both simulate a core experience of our social lives and represent an objective form of social interaction. Thus, in the current study, emotions that have been shown to be core to the moral decision-making process—disgust, contempt, and anger—are examined in regard to behaviours in an economic-game setting, where participants were able to impose negative, self-interested and positive, cooperative outcomes on fellow players.

Because the three theories under consideration make different predictions based on levels of harm and incompetence, as well as dependent on who is affected by these behaviours, we developed a two-step game protocol to tease these apart. First, to create an opportunity for a display of low competence, participants undertook a memory task to earn money for their group that we anticipated would demonstrate different levels of ability between participants. Greater ability meant they earned more money for their group and would thus be considered competent, whereas an individual who earned less will appear incompetent: although not intentionally harmful, they have contributed less due to lack of ability and, therefore, are not as useful as the other members of the group. Second, after each memory task, group members received an equal portion of the group's earnings to distribute however they chose. The participants could see individual earnings from the task for that round. Unlike incompetence, and as is often the case with many moral violations such as stealing or lying, there was a clear—albeit selfish— motive to harm other players in this task, which was maximising earnings by allocating a disproportionate amount to themselves. Because participants would not be aware of how much they have been allocated until after the game finished, selfish allocations could not

prompt retaliation; the only reason to split the earnings with other group members is due to internal moral pressures. Nonetheless, behavioural economics research has shown repeatedly that many players in economics games do not play to typically maximise self-interest, suggesting there would be variability in decisions. At the end of the game, each participant was asked for their emotional reactions to the other group members' actions, based on each member's ability in the task (competence) and harm towards the participant and other group members (lack of sharing). Each participant rated how angry, disgusted and contemptuous they felt in response to the behaviours of target participants in their group (the ingroup) and to a different group playing at the same time as them (an outgroup).

The predictions of the aforementioned theoretical models (MFT, SFM, and SCM) in relation to different forms of negative outcomes in the economic tasks described above are summarised in Table 15. As can be seen, there are clear distinctions between what the models predict. Note that MFT predicts no disgust in economic games as there are no purity connotations in such settings. In contrast, both SFT and SCM predict a range of emotions depending on outcomes, due to their focus on outcomes rather than domains.

Table 15

Predictions for Which Characteristic Emotion Would Be Felt Based on Theoretical Model mapped to the economic task in the present study

	Type of Violation		
	Low Competence *Low earnings in the memory task*	**Harm to Self** *Low allocations to the participant*	**Harm to Others** *Low allocations to other group members*
MFT	None	Anger	Anger
SFM	Contempt	Anger	Disgust
SCM	Disgust Contempt	Anger Disgust Contempt	Anger Disgust Contempt

Ingroups and Outgroups

In the current research, we assessed emotional reactions to both an ingroup and an outgroup for both practical and theoretical reasons. The first practical reason to do so is that much evidence for the discussed theoretical models is based on judgements towards moral behaviour that cannot possibly harm the participant, such as vignettes. Therefore, it is possible that judgements towards members of a different group (who cannot and have not harmed the participant) may replicate previous efforts examining MFT and SCM better. Second, the SFM suggests that disgust is most relevant when harm to others is witnessed; however, it is possible that, in the ingroup, targets that have harmed other

group members will have also harmed the rater. Thus, outgroup ratings allow us to examine disgust regarding harm to others with no confound.

There are also several theoretical reasons to compare ingroup and outgroup results, the SCM is generally used to predict negative stereotypes towards outgroups; for example, predicting disgust at a group level towards those who are perceived as low-competence and low-warmth, such as drug addicts and the homeless (Buckels & Trapnell, 2013; Harris & Fiske, 2006). By including both, we can examine whether emotions differ due to group membership. Second, there is a potential role of disgust that is specific to social assessments of (even arbitrary) outgroups. For example, disgust and vulnerability to disease have been associated with ethnocentricity and negative outgroup evaluations (Hodson et al., 2013; Navarrete, Fessler, & Eng, 2007) and participants display disgusted behaviours (such as increased cleansing motivation) after contact with clothing worn by outgroup members (Reicher, Templeton, Neville, Ferrari, & Drury, 2016). Examining ingroup and outgroup attitudes separately would, therefore, allow some investigation into whether there is a meaningful difference between emotional responses to arbitrarily assigned ingroup and outgroup members.

Approach and Avoidance

Additionally, we aimed to assess whether disgust encourages avoidance and anger encourages approach, as suggested by the SFM as well as previous empirical research. The understanding of anger as an emotion which encourages approach stems from this emotion's association with hostility and verbal or physical aggression (Deffenbacher, Oetting, Lynch, & Morris, 1996). It is argued that anger encourages risky, direct, confrontational behaviour (Lerner & Keltner, 2001). Therefore, models such as SFM

suggest that anger motivates an approach response to personally affecting immoral behaviour. Disgust, on the other hand, is most clearly associated with avoidance, with the elicitors of this emotion most often being sources of disease, such as rats or bodily fluids (Curtis & Biran, 2001). There is also evidence linking disgust to avoidance of crowds of other humans (Curtis, Aunger, & Rabie, 2004) or specific groups of people, such as those of a lower caste in India (Curtis & Biran, 2001) and individuals who are homosexual (Inbar, Pizarro, Knobe, & Bloom, 2009). As such, the SFM also suggests that the purpose of disgust is to encourage avoidance of those who are a potential future threat (Hutcherson & Gross, 2011). We therefore also aim to explore whether the hostile triad are distinguishable based on whether they motivate approach or avoidance.

Methods

Participants. There were 220 participants in the study; of these 148 identified as female, 65 as male, one as other, and six preferred not to disclose their gender. Individuals were aged between 18 and 73 years (M=26.08, SD=10.18); five individuals did not specify their age. There were 118 participants who described themselves as White; 48 as Asian or Asian British; 34 as Black, African, Caribbean or Black British; one as Hispanic; two as Latina; one as Arab; six as Mixed or Multiple Ethnic Groups; and 10 did not specify.

Participants varied in their place of origin: 86 from Northern Europe (82 from the United Kingdom), 29 from Eastern Europe, 24 from Southern Europe, nine from West Europe, six from North America, five from South America, one from Northern Africa, 16 from West Africa, 12 from East Asia, 13 from South-Eastern Asia, 11 from Southern Asia, five from West Asia and three did not specify. Participants were recruited from the

University of Essex's behavioural economics participant pool.

Procedure. All sessions were conducted in a dedicated behavioural economics testing room with 30 partitioned cubicles with computers set up to run Z-Tree experimental software (Fischbacher, 2007). Upon arrival, the procedure was fully outlined to participants and they were randomly assigned to cubicles. They were asked to enter a name or pseudonym (which they were informed would be displayed to other participants throughout) to ensure more memorable 'labels' for later ratings than simple, numerical identifiers. Participants were randomly assigned by the Z-Tree script to five-person groups formed from those present. Sessions had a minimum of 10 participants (two groups) and a maximum of 25 participants (five groups). All interactions were entirely live and online-only via Z-Tree. No verbal communication was allowed. In the 'game', participants completed a memory task followed by an allocation task five times.

Memory Task. Participants (hereafter, players) simultaneously and individually were presented with a list of 10 double-digit numbers for 30 seconds. Players were instructed to memorise these numbers and then were given 60 seconds to recall as many as possible. If the player remembered less than three numbers, they earned nothing, three or four numbers earned £0.25, five or six earned £0.50, seven or eight earned £0.75, and nine or 10 earned £1.00. Each player's earnings were then put into a "group fund", so if all five players earned the maximum £1 then the group fund would total £5. This meant that, overall, each group could collectively earn a maximum of £25 (five rounds).

Allocation Task. Following the memory task, participants were asked to divide up the group fund earnings from that round. The group fund was divided evenly between group members (giving each player $1/5^{th}$ of the group fund). Each player then divided this money between all members of their group (including themselves). Players could allocate

however they wanted, including allocating all or no money to themselves. During this stage, they saw how much each player earned from the memory task, and they were provided with three potential allocations calculated for them (to ease the process): an equal split between all group members, a split proportional to memory task earnings, or all money to themselves. However, these allocations were clearly presented only as suggestions. Participants had complete freedom to choose their allocations and a calculator to assist with this. To do so, they typed their choices for allocation amounts into Z-Tree for each group member. Z-Tree determined whether it totalled correctly.

Review and Ratings. After the five rounds of memory task and allocation task were completed, participants reviewed information about their group. First, they saw their total allocations to each player and the amount per-player earned for the group fund, ordered from most to least, to remind them how they had allocated their portion of the group fund. They then saw how each player allocated their portion of the group fund to group members alongside each player's overall earnings to the group. After viewing this information, participants were asked for their emotional reactions (how angry, disgusted and contemptuous) for each fellow group member using a 7-point scale. Each participant was also asked using a 7-point scale whether they would like to play another game with their target and whether they would like to meet them in person, as well as how much they liked, admired, were envious of, and pitied the target. The data for liking, admiration, envy, and pity were not analysed for this study as they are only applicable to one of the frameworks used (SCM).

Outgroup Review and Ratings. Participants were also shown the earnings and allocations of a different group from the same session. This group was chosen by determining which group (aside from their own) had the largest total difference between

the final allocations and the overall earnings per participant (to ensure participants saw a group with high performance-reward/competence-harm discrepancies). Participants then rated the outgroup members for the same emotional reactions and approach/avoid as for their own group using 7-point scales.

Descriptive Statistics.

Although individually some members contributed the maximum £5 across the five rounds by remembering all 50 numbers presented to them, the mean earning was more modest (*M*=£3.26, *SD*=£0.90, min=£0.75, max=£5.00, *N*=220) and, overall, no group earned the full £25 available (*M*=£16.31, *SD*=£2.26, min=£9.50, max=£21.75, *N*=44). This shows that there was variation in the ability displayed in the memory task and thus the competence of individuals. Furthermore, there was harm as participants allocated more total money from the five rounds to themselves (*M*=£1.99, *SD*=£1.12, min = £0.25, max = £3.95, *N*=220) than individually to the other players in their group (*M*=£0.32, *SD*=£0.28, min=£0.00, max=£1.35, *N*=880).

The discrepancy between how players allocated to themselves compared to others can be seen in Figure 8; the highest percentage allocated to another player is 35.06% of the funds available to allocate whereas it is 100% for self-allocation. Similarly, the lowest allocation is 0% to others and 7.46% to self. There were 350 allocations of less than 5% to others (240 allocations of £0). However, considering 20% is an equal split, many participants behaved quite equitably to some of their targets: of the 880 allocations to others, there were 324 allocations of more than 15% to individual players. There was also variation in self- allocations; overall, 97 participants allocated less than 50% of the funds to themselves compared to 123 participants self-allocated over 50% of the available funds

(with 49 of these players allocating 100% of the funds to themselves).

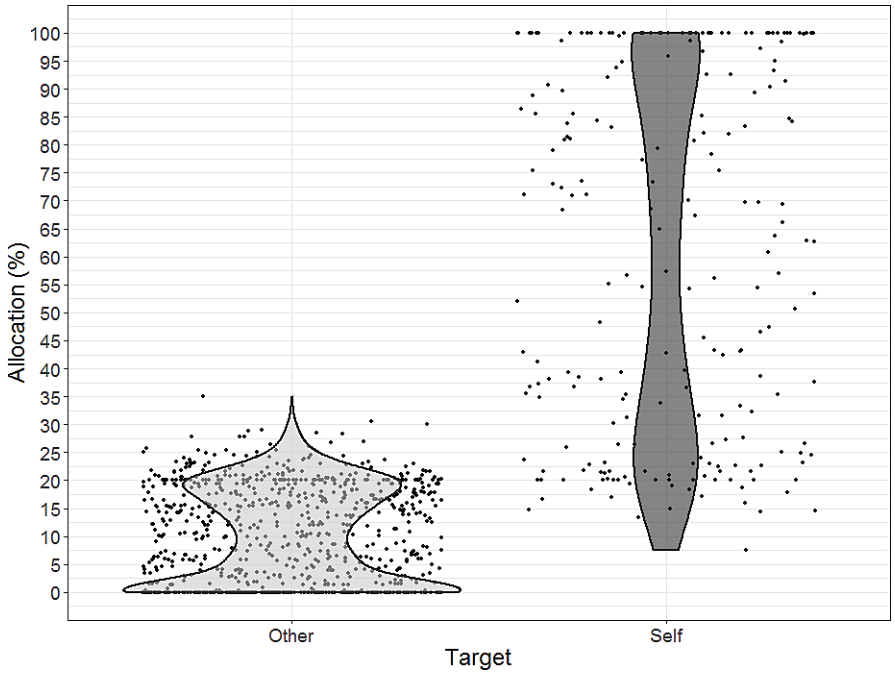

Figure 8. Violin plots show the distribution of overall allocations split into allocations from the participant to themselves compared to the four others in their team as a percentage of the amount available to allocate, dots indicate data points.

Although many participants behaved equitably by choosing to give ~20% to others, looking at Figure 9, allocations are not strongly related to the amount earned in the task. Most participants were allocated less than they earned by their teammates and allocated more than they earned to themselves. For allocations to others, 105 were higher than task earnings, 43 were equal to task earnings, and 732 were less than task earnings. For self-allocations, 203 self-allocated more than they earned in the task, 8 participants allocated to themselves exactly what they earned, and 9 self-allocated less than they earned.

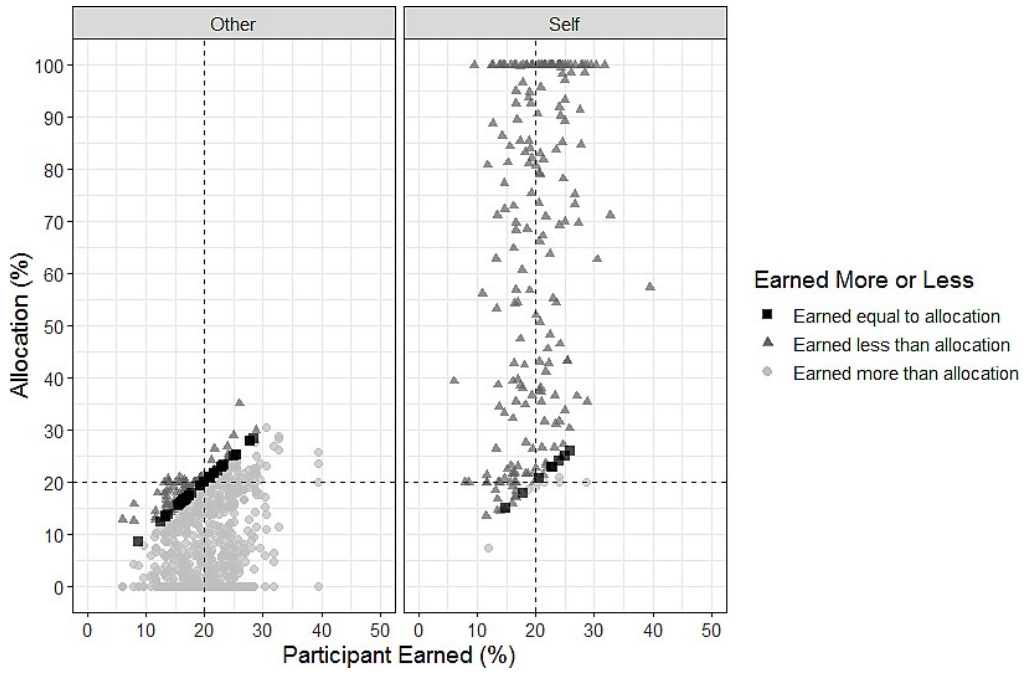

Figure 9. Plots of other-allocations (n=880) and self-allocations (n=220) comparing percentage earned overall in the memory tasks compared to the percentage of available funds allocated. Dashed lines at 20% indicate equal allocations and equal contribution to group fund from task earnings. Square points indicate an allocation exactly equal to the amount contributed, triangles indicate that the player contributed less than they were allocated, and circles indicate players who contributed more than they were allocated.

Despite the differences in choices of allocations and the disconnect between the amount earned in the tasks and allocated, there is an almost even split between those who earned less than they were paid and those who earned more than they were paid; which can be seen in Figure 10. As such half of participants were in a financially worse position than they would have been if they had just received back exactly what they earned (and were therefore harmed by the task).

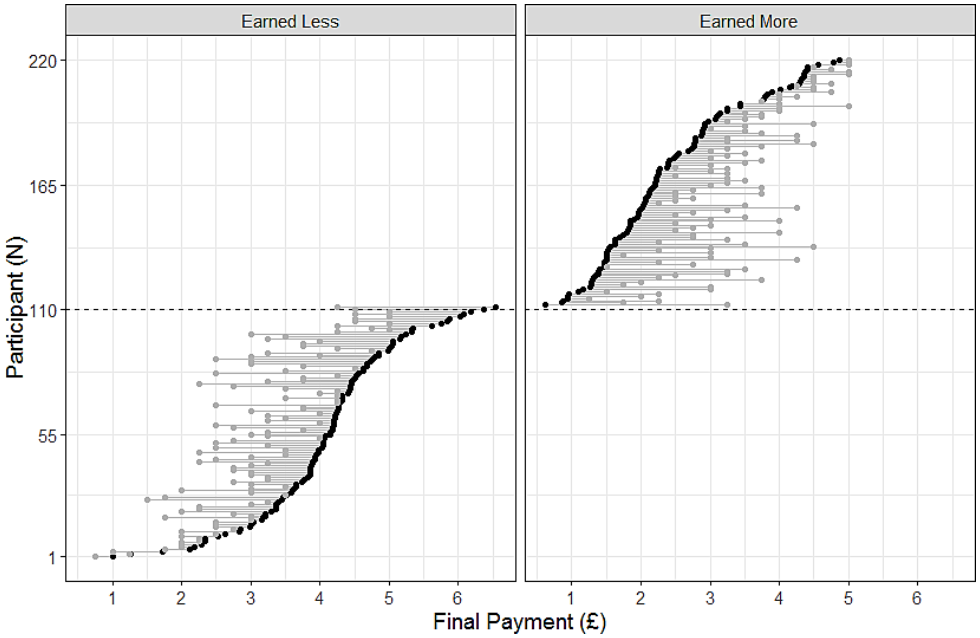

Figure 10. Plot of difference between the amount the participant was allocated overall (indicated by black points), compared to the amount they earned in total across the five memory tasks (indicated by grey points). These are split into those who earned less than their final winnings (harmed), and those who earned more than their final winnings (not harmed). Each participant (n=220) has their own data point.

Results

We analysed the data from the participant's 'ingroup', that being, their emotional responses to the behaviours of members of their own group, as well as the data from the participant's 'outgroup', meaning their emotional responses to the behaviours of a different group playing at the same time as them. For each ingroup linear model in our main analyses, there were three continuous independent variables of interest: Allocate2participant, Allocate2others, and Target_earned. Allocate2participant is the amount the participant was allocated by the target group member, Allocate2others is a sum of the allocations the target made to the other three members of the group excluding the target's self-allocations and the allocations to the participant, and Target_earned is the

sum of the amount the target contributed to the group fund through their overall skill at the memory tasks. For the outgroup models, there were only two independent variables of interest, Allocate2others, and Target_earned; Allocate2participant was not applicable to this analysis as the participants were not part of the outgroup (by definition) and received no allocation.

In addition to including the other two emotion variables as controls, we also included two additional control variables, Participant_earned and Group_earned (the participant's own group or the outgroup being rated), to control for the participant's own competence and the overall amount of money the group had available to allocate. By controlling for Participant_earned and Group_earned, Allocate2participant and Allocate2others act as a proxy for harm (to self and others respectively) when the participant's own skill and the amount available to allocate is held constant. Target_earned indicates the level of incompetence, with lower amounts indicating incompetence.

Correlations

Before conducting our main analyses, correlations between the predictors and outcome variables in the ingroup and outgroup models were investigated. First, for the ingroup models, the results of these correlations show that allocations to others in the team (excluding allocations to the participant giving the ratings and self-allocations by the target) and allocations to the participant are significantly, negatively correlated with ratings for all of the hostile triad ($p < .01$; see Table 16); however, anger (to participant $r = -.38$, to others $r = -.39$) and disgust (participant $r = -.39$, others $r = -.40$) had a stronger relationship than contempt (participant $r = -.13$, others $r = -.15$). No emotion had a

negative correlation with the amount the target earned, but disgust has a slight but significant positive correlation (r = .08).

Table 16

Pearson Correlation Matrix Ingroup Variables

Variable	M	SD	1	2	3	4	5	6	7
1. Anger	2.31	2.01	1						
2. Contempt	2.42	2.09	.41***	1					
3. Disgust	2.83	2.06	.86***	.41***	1				
4. Allocate2participant	0.32	0.28	-.38***	-.13***	-.39***	1			
5. Allocate2others	0.96	0.80	-.39***	-.15***	-.40***	.88***	1		
6. Target_earned	3.26	0.90	.04	-.03	.08*	-.18***	-.20***	1	
7. Participant_earned	3.26	0.90	.03	.02	.04	.26***	.03	.06	1
8. Group_earned	16.31	2.25	.03	-.01	.05	.07*	.07*	.50***	.50***

*p <.05. ***p <.001. n=880

Second, the correlations were examined for the variables in the outgroup models. The results of these correlations showed that higher allocations to other team members were negatively correlated with ratings for anger, disgust, and contempt ($p < .01$; see Table 17); however, anger (r = -.38) and disgust (r = -.41) had a stronger relationship than contempt (r = -.15). No emotion correlated with the amount the target earned.

Table 17

Pearson Correlation Matrix Outgroup Variables

Variables	M	SD	1	2	3	4	5	6
1. Anger	2.11	1.88	1					
2. Contempt	2.76	2.07	.45***	1				
3. Disgust	2.27	1.97	.87***	.49***	1			
4. Allocate2others	1.16	1.11	-.38***	-.15***	-.41***	1		
5. Target_earned	3.25	0.82	.03	.02	.05	.03	1	
6. Participant_earned	3.26	0.90	-.04	-.06*	-.04	-.02	-.05	1
7. Group_earned	16.27	2.18	.00	.03	.00	.18***	.53***	-.10***

*p <.05. ***p <.001. n=1110

Main Analyses

The data were modelled using linear mixed-effects models, fitted with the lme4 R package (Bates & Sarkar, 2007). Significance was evaluated using p-values produced using Satterthwaite approximations and 95% Wald confidence intervals (lmerTest R package; Kuznetsova, Brockhoff, & Christensen, 2017), beta values and confidence intervals were standardised using the sjstats R package (Lüdecke, 2018). Each model included a random intercept for participants. For all six models, there are three dependent variables of interest: disgust, anger, and contempt.

To test for issues of multicollinearity we used Variance Inflation Factors (VIF for lmer; Frank, 2019) which indicated that most variables in both ingroup and outgroup models had VIF of 4 or below. However, in the ingroup models, Allocate2participant

(disgust VIF = 6.743; anger VIF = 6.536; contempt VIF=6.819) and Allocate2others (disgust VIF= 7.044; anger VIF = 6.662; contempt VIF=7.018) were somewhat collinear, but not above the conventional cut off for severe multicollinearity (VIF=10, Hair, Anderson, Tatham, & Black, 1995). This is supported by a very high correlation between Allocate2participant and Allocate2others (r =.88); this is not surprising as both are two parts of any player's allocations (the third being self-allocation by the target). However, it is important to include both variables to allow a full examination of the hypotheses, that being the relative emotional influence of the amount the participant was harmed by the target compared to the amount the others in the group were harmed, and vice versa.

To investigate the potential effects of this collinearity we conducted further tests, according to the guidelines by Hendrickx (2012) in the documentation of the perturb R package. Using the colldiag function we calculated condition indexes and variance decomposition proportions of the independent variables in the regression models without random effects. This analysis indicated that there was not a large condition index for any model (below 30; disgust = 5.687, anger = 5.705, contempt = 6.145), which does not suggest collinearity (Belsley, Kuh, & Welsch, 2005; Hendrickx, 2012).

The results of all mixed-effects models can be found in Figure 11. The ingroup models indicated that when the rater's competence (earnings in the task), the amount available to allocate (total group earnings) and the other emotional responses were held constant, only lower anger was significantly predicted by increased Target_earned (B = -0.081, β = -.036, p=.022), which suggests that participants experienced a small increase in anger for lower competence (i.e. lower task earnings). Whereas, disgust was significantly predicted by Allocate2participant (B = -0.557, β = -.075, p=.045): participants felt more disgust toward players who made lower allocations to them. There were no significant

predictors for the contempt model.

For the outgroup models, when controlling for the other emotional responses, amount available to allocate, and amount the participant earned, higher values for Allocate2others significantly predicted lower ratings for anger (B = -0.057, β = -.034, p=.018) and lower ratings of disgust (B = -0.198, β = -.111, p<.001). So, when the outgroup target gave less money to others the participant felt more anger and, to a greater extent, disgust. Again, there were no significant predictors in the contempt model. This suggested that the response to outgroup members harming their group is different to the emotional response to ingroup members.

Overall, the strongest predictors for all emotions are the other emotional responses, especially in the case of disgust and anger which have a very strong relationship. This suggests a large amount of overall covariance in negative emotional reactions and that the unique relationships between the behaviours and emotions, compared to overall negative affect, are relatively weak.

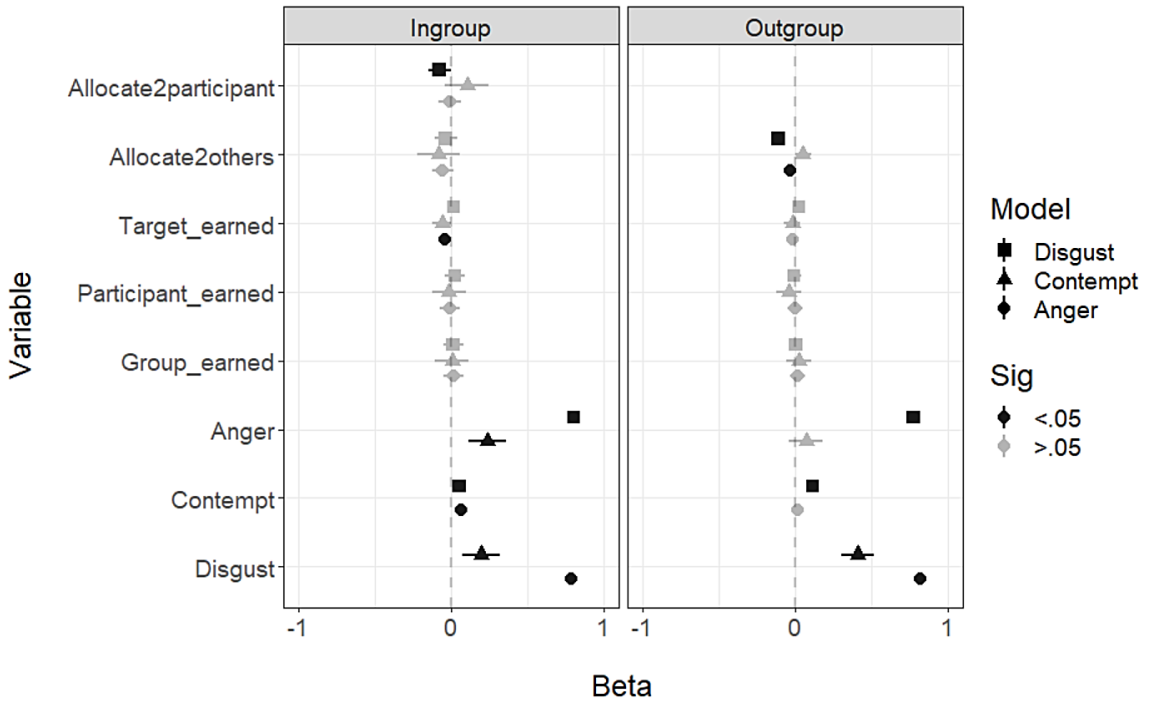

Figure 11. Plots of standardised estimates and 95% confidence intervals from 6 Linear Mixed Effects Models (3 for the ingroup data, 3 for the outgroup). Estimates from the models with disgust as a DV indicated by square points, estimates from the contempt DV models indicated by triangular points, and estimates from the anger DV models indicated by circular points. Estimates with confidence intervals excluding 0 highlighted in black.

Approach or Avoidance. Many of the discussed theoretical models, especially SFM, argue that the reason anger and disgust are functionally different is due to the behaviours they motivate; anger being related to approach and disgust to avoidance. To investigate this explanation, participants were asked two questions related to approach/avoidance: whether they would want to meet the target in person and whether they would like to play the game with them again.

To explore which of the hostile triad of emotions would be related to these motivations, we constructed models of which of these emotions predicted willingness to repeat the experiment with the target (*Approach_game*) and to meet them in person

(*Approach_person*). As such, there were two dependent variables of interest: Avoidance_person and Avoidance_game. The independent variables were anger, disgust, and contempt. As the emotional ratings for both the ingroup and outgroup were included, the dummy-coded, control variable Group was also included as a categorical variable with ingroup as the reference category. To test for issues of multicollinearity we tested the individual predictors in linear models using VIF (Frank, 2019). For both models, all VIF were below 4. Therefore, it does not seem that these models are affected by multicollinearity.

Linear Mixed-Effects Models. The results of the approach motivation mixed-effects models can be found in Figure 12. The models indicated that all predictors had significant effects on the DVs. Decreases in both disgust (B = - 0.395, β = - .395, p< .001) and anger (B = - 0.292, β = - .072, p<.001) predicted increased willingness to meet the target participant. However, increases in contempt (B = 0.089, β = .090, p< .001) predicted increased willingness to meet the target in person. The same pattern can be found for willingness to repeat the game; where higher willingness was predicted by lower values of disgust (B = - 0.179, β = - .155, p< .001) and anger (B = - 0.179, β = - .155, p<.001), but higher values of contempt (B = 0.112, β = .103, p< .001). In both models, disgust had the strongest effect on avoidance motivation.

This is somewhat contrary to current theoretical frameworks of the motivational functions of these emotions. It is argued that anger is related to approach motivation whereas disgust and contempt are related to avoidance motivation. Whilst disgust was, as predicted, more strongly related to avoidance motivation than anger, anger still predicted avoidance rather than approach. Contempt, on the other hand, motivated approach (albeit weakly), which does not fit with the prediction that contempt will be related to avoidance.

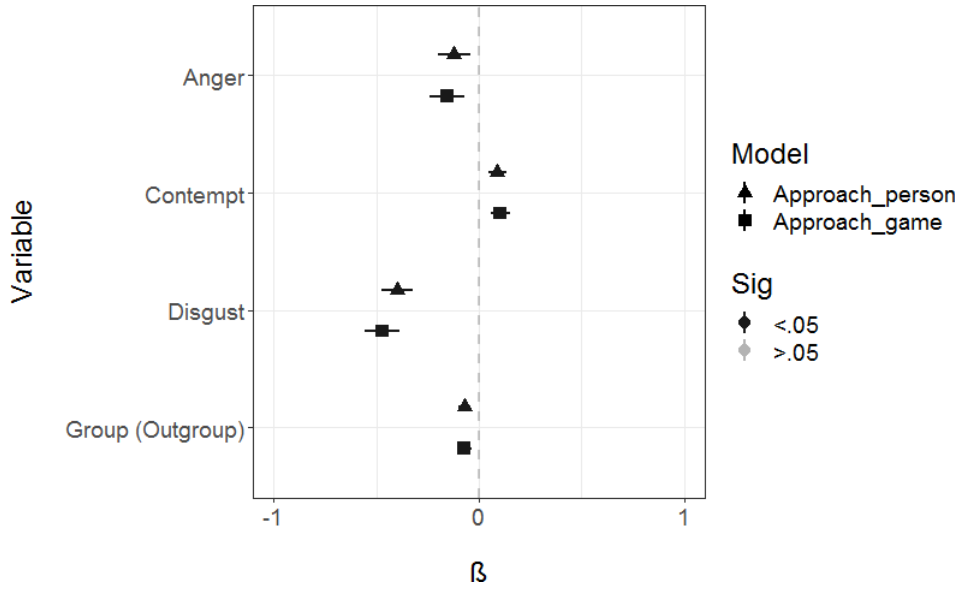

Figure 12. Plots of standardised estimates and 95% confidence intervals from 2 Linear Mixed Effects Models. Estimates from the models with approach_person as a DV indicated by triangle points and estimates from the approach_game DV model indicated by square points. Estimates with confidence intervals excluding 0 highlighted in black.

Discussion

In the current study, no discussed theoretical model fit entirely with the observed results (see Table 18 for a summary of theoretical predictions and actual results). When controlling for mixed emotional responses, financial harm to the participant (i.e. being personally harmed by lower allocations) predicts increases in disgust, and incompetence (i.e. lower earnings for the group) elicits anger. Emotional reactions to outgroup behaviours are somewhat different; in this case, both anger and disgust are elicited when a participant has harmed others in their own group. Contempt was not found to be uniquely associated with any of the assessed behaviours. Additionally, in our analyses of approach

and avoidance motivation, both disgust and (to a lesser extent) anger predicted motivation to avoid the target in person and in future games of this kind. Contempt, on the other hand, weakly predicted approach motivation both in person and in future games.

There are several surprising findings in these results. First, the lack of a characteristic emotion in response to harm to ingroup others is particularly unexpected. Second, and also noteworthy, is the difference between incompetence which negatively affects the participant and incompetence which does not. The difference in these results demonstrates the importance of comparing personal experiences of negative behaviours to observed negative behaviours. Third, and again in disagreement with current theory, both disgust and anger appear to predict avoidance—although this motivation was stronger for disgust—whereas contempt predicted approach. These findings do not fit neatly with any of the discussed theoretical frameworks.

Table 18

Predictions for which characteristic emotion would be felt based on the theoretical models and mapped to the economic task in the present study

		Type of Violation		
		Low Competence	**Harm to Self**	**Harm to Others**
		Low earnings in the memory task	*Low allocations to the participant*	*Low allocations to other group members*
Predictions	**MFT**	None	Anger	Anger
	SFM	Contempt	Anger	Disgust
	SCM	Disgust Contempt	Anger Disgust Contempt	Anger Disgust Contempt
Results	**Ingroup Results**	Anger	Disgust	None
	Outgroup Results	None	N/A	Anger Disgust

Looking first at MFT (and its precursor, the CAD Hypothesis), this theory predicts that disgust will be elicited exclusively towards purity violations. There are no purity violations in the experimental game, yet disgust was found. Disgust responded to financial harm, in both the ingroup and outgroup, something MFT places within the purview of anger. Harm of a financial kind would not easily be classed as a purity violation and it would similarly be difficult to argue that the game outcomes involved any pathogen risks (Royzman et al., 2014). This suggests that, in this experiment, disgust was

elicited by non-purity, non- pathogenic, moral violations and to a greater extent than anger.

Additionally, for MFT, the results for anger are also inconsistent. For both MFT and CAD, anger is generally associated with harm (e.g. Haidt & Joseph, 2008; Rozin et al., 1999), especially intentional harm (e.g. Russell & Giner-Sorolla, 2011). However, anger towards ingroup members was characteristic in response to incompetence, with anger towards harm only characteristic in response to the outgroup. Although incompetence in the game is harmful (to the extent that it reduces group earnings), it is difficult to argue that this harm was intentional (as it hurt participants themselves as much as group members). As such, this harm cannot easily be equated to the harm often displayed in the literature (such as theft or lying). So, whilst anger was related to harm toward outgroup members, it was not characteristic of personal harm or harm to participants' group members, and was also characteristic in response to ingroup incompetence.

We look next to SFM, which predicts harm to the participant would cause the most anger, harm to others would cause the most disgust, and incompetence would cause the most contempt. This, again, was not found in the present study; the characteristic response for harm to the participant was disgust (but not anger), harm to others only predicted disgust in the outgroup where it also elicited anger, and incompetence was only associated with anger. As such, the SFM conception of incompetence, harm to others, personal harm, and the associated emotional responses are not supported by this study. Additionally, although all three emotions were elicited, they do not fit suggested functional roles. First, contempt did not appear to have a specific functional role; it was only elicited as part of a generally negative response rather than having a unique

contribution. Second, our results do not fit well with anger's suggested role as motivating an aggressive response to a direct threat. Previous work, which informs or is informed by SFM, has suggested that anger's purpose is to motivate a high risk (Lerner & Keltner, 2001) and/or aggressive response (Molho et al., 2017). Neither incompetence nor harm towards others would generally be considered directly threatening and thus would not (and, in this task, could not) elicit an aggressive response. As such, using SFM there would be no clear reason for these acts to elicit anger, but this emotion was found in response to both actions. Even self-reported, anger-motivated approach responses were not found in this study; both anger and disgust were related to avoidance motivation, with only contempt weakly motivating approach. Finally, SFM's suggested role for disgust is not supported. SFM argues that this emotion should motivate avoidance of immoral others (just as one would avoid a physically disgusting stimulus) and as such is argued to be less useful in response to direct threats. Yet, in this study, disgust was found to be characteristic of direct harm to the participant. However, there is some support for the idea that disgust motivates avoidance; disgust had the strongest effect on lowering motivation to meet the target in person or to play another game with them. As such, disgust may fulfil the functional role of an avoidance motivating emotion but in response to a wider range of actions than SFM would suggest.

The final discussed theoretical framework, SCM, is also not supported by the results of this study. SCM predicts all three negative emotions in response to harmful, low-warmth individuals, but only disgust and contempt in response to low-competence, as they are both related to disrespect. Overall harmful (low-warmth) individuals were associated (albeit somewhat variably across model specifications) with both anger and disgust which does somewhat fit with this model. However, the same was not true for

contempt. Similarly, low-competence was only related to increases in anger, rather than disgust and contempt as predicted. In this study, therefore, disgust and contempt were not associated with both low-warmth and low-competence and anger was not associated only with low-warmth.

In summary, first, and importantly, the presence of the moral emotions anger, disgust, and (somewhat) contempt suggest that these uncooperative economic behaviours can be framed morally, as indicated by Curry et al. (2019). However, the negative emotions are not consistently related to a specific violation type, direction of harm, or to indicators of the violator's personality (as low-warmth and/or low-competence). Instead, disgust appeared to be elicited to a greater extent than the other emotions in response to harm, especially when that harm is directed at the participant, whereas anger was elicited by harm to outgroup others (the least personally threatening of the uncooperative behaviours) and to incompetence. One possible explanation for finding disgust in response to this type of harm rather than anger could be due to the lack of retaliatory responses available. All participants were aware that aggression, even to the extent of financial retaliation, was not possible in this game. As such, alternative avoidant or indirect strategies (such as gossip or social exclusion) and the associated disgust emotion may be more appropriate. This emotional pattern, therefore, may be different in games which involve options for punishment.

However, this view does not offer a clear explanation for the anger found in response to ingroup incompetence. If we retain the assumption that anger motivates aggression, anger would be less relevant when retaliation is not an option. So, we should not find anger in response to ingroup incompetence. The emotional response to incompetence, specifically incompetence which has a negative effect on the participant,

has interesting implications for current moral emotional theory. Rather than incompetence causing a consistent emotional response, it depended on the personal consequences of that incompetence. Since the negative personal consequences appear to be important, the role of anger could be as a short-term negative response to correct unhelpful or damaging behaviour, but with potential for reconciliation. This is supported by evidence that anger motivates short-term aggression when a relationship with that person is still viable in the long-term, whereas other negative emotions are intended for permanent exclusion from the social network (Fischer & Roseman, 2007).

This also explains the disgust displayed in this study as, in some conceptions of moral disgust, it is thought of as an emotion with more permanent effects than anger, evidenced by difficulty in reversing elicited disgust even with mitigating, contextual information (Rozin et al., 1986; Russell & Giner-Sorolla, 2013). Some authors have suggested that disgust functions to guard against 'social parasites'—those who behave selfishly and damage the group—worthy of being punished and ostracised (Biran & Curtis, 2001, p.29). Therefore, disgust may be more long term and inflexible compared to anger which can be decreased over time and is lessened by additional facts and mitigating circumstances (Goldberg et al., 1999; Russell & Giner-Sorolla, 2011b). The higher self-reported disgust displayed in the current study could, therefore, indicate increased unwillingness to form any kind of social relationship with the target (evidenced by the in-person and online avoidance indicated), whereas increases in expressed anger may reflect slightly lower willingness to approach this person but, as the effect is weaker, with more chance to forgive. As such, disgust may be more common towards offences that are less easily forgiven (such as being personally financially harmed) compared to frustrating, unintentional harm (ingroup incompetence) or witnessing someone else being financially

harmed (outgroup harm).

The current study offers a different perspective on moral emotional reactions compared to the predominate vignette-based methodology often seen in studies of moral behaviour. Although we cannot assume that this is reflective of natural social interactions, as these are anonymous, online exchanges, it does offer a view into immediate moral emotional reactions to behaviours that directly affect the participant. Online economic game experiments also offer an opportunity to study directly harmful behaviours in a context where there is no other social information available that could independently induce these emotions. The difference in emotional reactions found in this study compared to prior work suggests that there are important differences in emotional reactions to hypothetical compared to experienced harm. Additionally, the differences found within this study in response to actions of the participant's group members compared to an observed outgroup further show that the personal relevance and immediacy of violations likely affects the emotions felt.

Limitations

The first limitation of this study is that it is a novel game and as such the results have not been replicated by further experiments or in different labs. Although our sample does appear to be quite diverse in age, gender, and cultural background, it would be especially interesting to compare the results of this experiment outside of the current university setting and in non-WEIRD societies (Henrich et al., 2010) which may have different moral values and norms. Second, as mentioned above, using methodology from behavioural economics differs importantly both from the vignette-based methodology often used to study the frameworks used in this study and from real-life social

interactions. These interactions do allow some insight into actual emotional reactions to immediate harm, albeit not severe harm. Unlike methodology such as the recall of actual events, this does not allow us to comment as clearly on real-world interactions but does overcome the limitation of emotional distance from the event. Whereas, unlike methodology such as vignette studies, we cannot comment on more severe forms of harm, but we do overcome the limitation of being limited to hypotheticals or third-party judgements. Third, there is evidence that punishment and social exclusion are importantly related to disgust, anger, and contempt (e.g., Molho et al., 2017; Seip, Dijk, & Rotteveel, 2014), but these responses were not possible in this game, thus we cannot say whether the results would be different if these options were available. Finally, as this was an exploratory, correlational design, we cannot make any causal claims; further controlled, lab-based studies manipulating harm and incompetence directly would improve our understanding of the observed results and ability to make causal inferences.

Future Directions

With these limitations in mind, this study opens interesting avenues for further research of moral emotional reactions to group behaviour. Specifically, future studies should assess the conditions required for anger to be elicited by incompetence and the motivational differences between disgust and anger in response to harm. This could involve assessing differences in longevity of emotional reactions and the potential of future reconciliation.

Further research would also be useful to investigate differences in emotional responses to ingroup compared to outgroup behaviours. Whilst there is a difference in this study, it is difficult to ascertain whether the difference is due to the outgroup being

selected specifically because of their inequitable behaviour, rather than randomly, or due to their position as an outgroup. It does seem clearer, however, that there is a difference between how ingroup and outgroup incompetence is reacted to. As such, it would be of further interest to see if this is affected by the severity and type of incompetence. A final issue, which is somewhat addressed by this study, is how emotions are related to approach-avoidance motivation. As prior research indicates that anger should be related to approach motivation it would be of use to know when, specifically, that will be the case. As we only addressed this issue using self-report, it would be ideal to investigate this question more thoroughly with behavioural measures. One potential avenue would be to introduce the option to punish deviant group members, which would allow an approach motivated negative response.

Overall, as expected, this study shows that disgust and anger play a relevant role in social interactions concerning economic decision-making, suggesting these behaviours are framed morally. Only disgust and anger are predicted when other emotional responses are held constant, suggesting these two emotions are particularly vital to moral judgment comparative to contempt. Furthermore, the difference in results for the ingroup and outgroup suggest that different emotional responses are elicited when the incompetence and harm personally affect you, compared to simply witnessing these violations targeted at others. Disgust and anger were also more distinctly elicited by harm (disgust) and incompetence (anger) in the ingroup. Finally, this study suggests that, as expected, disgust is clearly associated with avoidance, but anger also predicts avoidance, albeit to a lesser extent. This offers new lines of investigation into the differences in immediate compared to witnessed immorality and the effects this may have on our moral emotional experiences.

Chapter 5: General Discussion

In all chapters of this thesis, we were able to find important distinctions between disgust and anger, using both pupillometry and responses to economic behaviours. In Chapter 2, across two studies, we found that self-reported feelings of disgust predicted significant pupil dilation to emotionally engaging sounds and images. In this chapter there is a consistent increase in pupil size from baseline exclusively for disgust; with fear and happiness only rarely showing this effect in specific models, and anger never significantly predicting increases or decreases in pupil size. This data suggests there are differences in pupil dilation for different emotional responses and, importantly, that measures of pupil diameter would be useful in distinguishing disgust from anger. These results suggest a physiological difference between anger and disgust, in opposition to work which suggests that these emotions are cultural constructs and as such cannot be distinguished based on physiology (Barrett, 2013; Lindquist, 2013; Mauss & Robinson, 2009; Stearns, Gendron, & Barrett, 2009).

Building on the results of Chapter 2, in Chapter 3 we found that (as with general disgust) moral disgust predicts pupil dilation towards a specific category of moral violations: purity violations. This fits theoretically with the CAD hypothesis and moral foundations theory which suggests that disgust's role is to respond to this sub-category of immorality. However, the results of this chapter also indicate two further interesting aspects of disgust and impurity: first, individual judgements that an act is animalistic and degrading (i.e. impure) do predict higher disgust but do not predict concurrent pupil dilation, and second, perceived disease risk predicts higher disgust but decreases in pupil size. As such, purity violations are more disgusting—reflected in physiology as well as

self-report—but there may be more to this judgement than how animalistic and degrading the scenario is. Additionally, this chapter offers some evidence that there may be two distinct disgust pathways, with disease-relevant disgust driving a different pupillary response to moral disgust.

Finally, in Chapter 4 we assessed further, alternative theoretical models of disgust and anger's role in morality. Additionally, by investigating cases of direct, personal, immediate immorality, we can see if there are differences between the emotional reactions found in this chapter compared to the hypothetical moral judgements of Chapter 3. Using an economic game which allowed participants to display incompetence and financial harm, we found that the group of assessed theoretical models—the CAD hypothesis, moral foundations theory, the social functionalist model, and the stereotype content model—could not offer a complete explanation for our results. When controlling for mixed emotions of anger, disgust, and contempt, our results indicated that in the player's own group disgust responds to harm to the player and anger responds to incompetence. Furthermore, in response to the actions of a group the player was not a part of we found there were different emotional responses: both anger and disgust were found in response to harm. This suggests that in a group setting, in response to direct, immediate harm, anger and disgust do not function as hypothesised and functioned differently depending on whether the violator is a member of your own group. In addition to differing from the theoretical frameworks assessed, these results also differ from Chapter 3, suggesting the need for separate theoretical frameworks for emotional reactions to hypothetical versus non-hypothetical moral judgements.

Disgust and Anger as Discrete Emotions

This thesis contributes to our understanding of disgust and anger as discrete emotions. Our finding that disgust is marked by the psychophysiological correlate of pupil dilation, while anger is not, provides evidence that they are not purely descriptive categories as some would suggest (Barrett, 2013; Lindquist, 2013; Mauss & Robinson, 2009; Stearns et al., 2009). Since these emotions are similar in arousal and valence, if the differences between them were entirely descriptive and based on cultural conceptualisation we would not expect to find any physiological differences. As such, finding a noticeable and quite consistent difference between a psychophysiological correlate of disgust compared to anger provides evidence that they are not indistinguishable. Similarly, based on these results, we also have evidence that disgust is not a synonym for anger (Herz & Hinds, 2013; Nabi, 2002). If these emotions were semantic equivalents then both emotions would, again, be indistinguishable based on psychophysiological measures.

It is of further interest that the pupil dilation response demonstrated does not fit with prior psychophysiological results, particularly for anger. Anger is usually associated with a suite of sympathetic activity, such as increases in skin conductance levels (Christie & Friedman, 2004; Tsai, Chentsova-Dutton, Freire-Bebeau, & Przymus, 2002) as well as increased heart rate and low heart rate variability (Foster & Webster, 2001; Rainville et al., 2006; Vrana, 1993). So, as pupil dilation is a marker of sympathetic activity, we would expect it to correlate with anger rather than (or as well as) disgust. Consequently, this thesis provides evidence that anger does not elicit sympathetic activity in every effector organ. This fits with evidence that the autonomic nervous system is not a simple, all-or-nothing system; instead, there is independent sympathetic and parasympathetic

activation in different effector organs (Folkow, 2000). This has been found previously with disgust, which has been associated with a suite of both sympathetic and parasympathetic activity in different organs (Kreibig, 2010): parasympathetic activity, such as lowered heart rate and/or high heart rate variability (Christie & Friedman, 2004; Codispoti et al., 2008; de Jong et al., 2011; Konishi et al., 2019; Ottaviani et al., 2013; Rohrmann & Hopp, 2008; Shenhav & Mendes, 2014), as well as sympathetic, such as galvanic skin response (Christie & Friedman, 2004; Codispoti et al., 2008; de Jong et al., 2011; Rohrmann & Hopp, 2008; Tsai et al., 2002). To offer further evidence for this hypothesis it would be ideal to concurrently measure a range of effector organs to ascertain a whole-body reaction which may distinguish disgust from anger further.

In addition to finding a physiological distinction between disgust and anger, this thesis also offers some evidence of a psychophysiological distinction between subcategories of disgust. It has previously been suggested that specific types of disgust—mutilation and moral—are associated with parasympathetic cardiovascular activity (Konishi et al., 2019; Kreibig, 2010) whereas contamination disgust is associated with sympathetic cardiovascular activity (Kreibig, 2010; Shenhav & Mendes, 2014). In support of this view, in Chapter 3, we found that increases in moral disgust were associated with increases in pupil diameter, but only when controlling for the decreases in pupil diameter associated with disease risk. This suggests that there may be two subcategories of disgust at play both of which are distinct from anger and are marked by a distinct associated physiological response. This would fit logically with theories such as Tybur et al. (2009), where moral, sexual, and pathogen disgust evolved simultaneously to motivate different adaptive behaviours. It would be fair to assume, therefore, that these subtypes of disgust may be marked by differences in physiology as well as behaviour.

This view of disgust and anger fits with the evolutionary approach to emotion. In this approach, disgust and anger are superordinate mechanisms coordinating memory, attention, physiology, behaviour, motivational priorities, and energy allocation (Al-Shawaf et al., 2016; Cosmides & Tooby, 2000; Tooby & Cosmides, 2008). In this conception, not every instance of an emotion is required to be identical dependent on differences in, for example, motivational priorities, which may be marked by differences in physiology. So, whilst moral disgust or disgust elicited by exposure to certain stimuli (such as mutilation) may elicit a sympathetic pupillary reaction, this could be due to required physiological preparations that are distinct from those necessary for responding to disease risk. As mentioned above, smaller pupil sizes are associated with increased visual acuity, decreased field of view, and increased depth of field. Pupil dilation, on the other hand, is associated with increased visual sensitivity and increased field of view (Campbell & Gregory, 1960; Mathôt & Van der Stigchel, 2015). This suggests that moral and other types of disgust may be associated with attentional vigilance for further environmental threats whereas judgements that a stimulus is a disease risk motivate increased focus. Similarly, the lack of associated pupil dilation during anger could indicate there is not a clear associated need for increased visual sensitivity compared to normal vision.

Moral Disgust and Moral Anger

In addition to providing evidence that disgust and anger appear to be biologically distinct, this thesis demonstrates that moral anger and moral disgust specifically can be distinguished both physiologically and behaviourally. However, although these emotions appear to be somewhat distinct, we found they were differently elicited dependent on the personal relevance of the moral violation. It was found that judgement of third-party,

hypothetical moral violations (using vignette methodology) elicit anger and disgust differently to violations that directly and recently affected the participants (using an economic game). This has interesting implications for the moral theories discussed in this thesis.

Disgust to Impurity: The CAD Hypothesis and Moral Foundations Theory. The CAD hypothesis and moral foundations theory (MFT) both suggest that disgust will be characteristic or exclusive to purity violations, while anger will be elicited by other types of immorality, such as unfairness (Graham et al., 2013, 2011; Haidt & Joseph, 2004, 2008; Rozin et al., 1999). Chapter 3 provides evidence for the theoretical understanding of disgust presented by the CAD hypothesis and MFT; however, Chapter 4 does not. Chapter 3 demonstrated that self-reported disgust was higher in response to impure and physically disgusting vignettes compared to other non-purity immoral vignettes and that this disgust response to the impure vignettes was associated with the same increases in pupil diameter demonstrated in Chapter 2. Similarly, anger was found to respond to the non-purity violations and was not marked, as expected, by any changes in pupil diameter. However, this result is complicated by the same disgust-pupillary responses not being found towards individual judgements of how impure (i.e. animalistic and degrading) the scenario was. As such, this partly supports the disgust- impurity connection, insofar as these scenarios are considered more disgusting (both via self- report and physiologically), but this may be driven by more than just judgements of how animalistic and degrading the acts are.

Additionally, disgust having an exclusive role in responding to impurity is not supported by the results of Chapter 4. Using this theoretical framework, we would expect anger to be elicited by the financially harmful behaviours displayed by participants, but

not disgust. However, we found that disgust was elicited when the participant was harmed and when they witnessed harm to others in the outgroup. It was expected that anger, on the other hand, would be elicited when the participant and others were harmed but it was only characteristic of ingroup incompetence and harm to others in the outgroup. So, while our findings in Chapter 3 support the understanding of disgust put forward by the CAD hypothesis and MFT, where disgust was elicited during third-party judgements of impurity, we did not find the same pattern in response to specific harmful behaviours in a group, economic setting.

Recalibrational Theory of Anger. The recalibrational theory of anger suggests that anger's role is to recalibrate others when they do not appropriately weight your needs with their own (Sell et al., 2009). In this way, anger is adaptively suited to increasing and maintaining one's own economic and social interests. Neither Chapter 3 nor Chapter 4 provides evidence of this. According to this theory, anger should not have been elicited by any of the violations in Chapter 3, as they did not affect the participant's welfare or the welfare of any close others. However, self-reported anger was elicited by the non-purity moral violations, as has been found in prior work (Horberg et al., 2009; Rozin et al., 1999; Russell & Giner-Sorolla, 2011a). Similarly, in Chapter 4, we would have expected anger to be elicited most strongly when the participant received low allocations—evidence that their needs are not being appropriately considered. Instead, anger was elicited by accidental harm from a group member's incompetence and by witnessing harm to others in a different group to your own. While the anger to outgroup harm and the anger displayed in Chapter 3 could be explained as a rhetorical device used to give weight to a moral judgement (Batson et al., 2007), this does not offer an explanation for anger towards incompetence, which by itself is not clearly immoral or intentionally harmful. It

similarly does not explain why it was disgust that was elicited by direct harm, fulfilling the suggested role of anger.

Social Functionalist Model. Similar to the recalibrational theory of anger, the results of Chapter 3 and 4 also do not fit entirely with the social functionalist model (SFM). This model suggests that the direction of harm decides the emotion felt, with disgust being strongest for harm to others and anger being strongest when you are personally harmed. As such, this theory uses an understanding of anger equivalent to the recalibrational theory of anger— which, as we have seen, is not supported by the results of our studies. The SFM understanding of disgust is also not supported. While disgust was, as this theory suggests, elicited when outgroup others were harmed, it was also characteristic when the participants were personally, directly harmed. Since being harmed is suggested to motivate a high-risk, aggressive, approach response, it is surprising that this would elicit disgust—an emotion which motivates avoidance and low risk-taking.

Stereotype Content Model. The stereotype content model would suggest that the dimensions of warmth and competence will be differentially associated with disgust, anger, and contempt (Cuddy et al., 2007; Harris & Fiske, 2006; Ufkes et al., 2012). For this model, anger is associated with judgements that a person or group is low-warmth, regardless of competence, whereas disgust is associated with concurrent low-warmth and low-competence. Feelings of disgust would encourage dehumanisation of the target as this emotion is equally applicable to non-humans such as disgusting objects or animals (Harris & Fiske, 2006). As such, it is thought that anger is related to dislike whereas disgust encourages both dislike and disrespect. This framework is also not supported by our results as—in Chapter 4—disgust was most strongly related to low-warmth whereas anger appears to be elicited by low- warmth and low-competence. It may still be that the

participants who felt disgusted were indicating that they felt concurrent dislike and disrespect for their target, thinking of them as worse than those who elicited anger, but this was more closely related to behaviour tied to low-warmth.

Limitations

There are several limitations to the collection of studies above. The first, which is relevant to all four experiments, is the use of convenience samples. In all cases the participants were drawn from the University participation pool and as such many of these experiments come with the standard drawback of being WEIRD (Henrich et al., 2010). While we can say that there is good reason to believe emotions are expressed similarly cross-culturally (Ekman & Davidson, 1994; Elfenbein & Ambady, 2002), there are also studies which undermine this claim—finding certain populations can only recognise emotional valence, not specific discrete emotions (Gendron, Roberson, & Barrett, 2015; Gendron, Roberson, van der Vyver, & Barrett, 2014). As such, to strengthen our claim, it would be important to provide further evidence of both behavioural and physiological distinctions between disgust and anger in non-WEIRD populations. This is similarly true for morality: moral values have been found to vary cross-culturally (Haidt, Koller, & Dias, 1993) as such the scenarios used in Chapter 3 and any selfish behaviours in Chapter 4 may not always be responded to in the same way. With that being said, in the case of Chapter 4 specifically, recent cross-cultural work has demonstrated that non-cooperative behaviours are framed morally across cultures so this consistency may be reflected by consistency in emotional responses (Curry et al., 2019). A further complication comes from the use of novel methodology with convenience samples. Neither pupillometry as a measure of discrete emotions and the economic game we designed for use in Chapter 4

have been previously used. Consequently, it would be ideal to repeat these experiments in different labs as well as with different sample populations.

A further issue raised by this thesis is the ability to elicit emotional and moral reactions strongly. In Chapter 2, there were repeated difficulties eliciting emotions strongly, with emotions consistently being rated below the mid-point of the scale. This was especially relevant for Chapter 2, Study 2 where the initial difficulty finding emotional engaging stimuli in the pilot study led to lowered emotional ratings in the main study. The natural, financial interactions in Chapter 4 were also responded to with weaker disgust and anger because any moral transgressions were, by necessity, very mild. The strongest self-reported emotional reactions can be found in Chapter 3, in response to the immoral vignettes. This is somewhat surprising as, while these were the strongest immoral scenarios (especially in comparison to chapter 4), they were purely descriptive and they relied more on interpretation than the visual and auditory stimuli of Chapter 2 (which included vivid depictions of violence).

The issue of ecological validity was mostly addressed by Chapter 4, as the closest to actual social interactions (with real cases of harm, albeit not severe harm). However, the actions in this study did not elicit emotional reactions as strongly as Chapter 3 where more extreme (albeit hypothetical) immoral actions were reacted to. Additionally, while both are useful, neither methodology allows us to comment clearly on real-world interactions. Based on the differences in emotional reactions found in this thesis alone there is reason to believe personal, natural experiences of immoral behaviour would elicit different emotional reactions to hypothetical judgement and anonymous online interactions. However, the investigation of real-world experiences of immorality would usually involve recall of distant events and would thus introduce different limitations. As

such, the comparison of different methods, as shown in this thesis, provides a useful overview of morality and emotion in different situations.

A limitation relevant to all chapters which used pupillometry were the difficulties inherent in using this physiological measure. Compared to cardiovascular or neurological measures, pupillometry is a relatively easy to use and unobtrusive methodology. As pupillometry relies only on a camera to collect data it is quite natural and comfortable for participants. However, as any excessive movements or eye closures affect the collection of results, there is an increased risk of missing data. This was found especially in the longest experiment, Chapter 1 Study 1, where data from 26 participants were excluded due to excessive missing pupil samples in response to some stimuli. Issues such as this limit the number of stimuli which can be comfortably presented to participants and increases the length of the experimental sessions compared to self-report studies. To address this within the thesis, all subsequent experiments were shorter, had participant breaks programmed, and larger samples were collected to ensure sufficient power. Careful planning of experimental procedures is therefore especially important in studies reliant on this methodology.

Future Directions

The results of this thesis open several potential avenues for further investigation. First, all studies used novel methodologies so it would be important to replicate these results using different stimuli and participants. This could involve combinations of the methodology used in this thesis, for example, using measurements of pupil diameter (as in Chapters 2 and 3) concurrently with actual social interactions (as in Chapter 4). It would also be interesting to see these results further replicated using different stimuli, such as

measuring pupillary reactions to tactile or olfactory stimuli, based on prior research showing differences in autonomic responses such as skin conductance and systolic blood pressure depending on whether a disgusting stimulus is visual, auditory, haptic, or olfactory (Croy, Laqua, Süß, Joraschky, Ziemssen, & Hummel, 2013). Furthermore, to get a more complete picture of autonomic disgust and anger responses, it would be ideal to include additional physiological measures, such as heart rate, alongside pupillometry as suggested by Kreibig (2010). Finally, it would be important to replicate these findings in different populations and cultures. As mentioned above there are suggestions that both emotions (Gendron et al., 2015, 2014) and moral norms (Haidt et al., 1993) vary cross-culturally. So, by using the methodology described in this thesis, we can investigate if populations vary in their emotional reactions to immorality and, if they do, in what way.

Second, as we have seen, this thesis draws into question whether certain moral theories, such as moral foundations theory and the CAD hypothesis, can be applied to all aspects of immorality. Our results suggest that there are some differences between emotional reactions to different sets of emotionally engaging images and sounds, hypothetical moral scenarios, and in actual social interactions – either in the strength of reaction or in behaviour responded to. This should be investigated further and more directly, for example comparing reactions to the same violation when hypothetical, directed at others, and when directed at you. Other studies have found differences in what participants will endorse in hypothetical moral judgement compared to their actual moral behaviour (FeldmanHall et al., 2012), so investigating emotional differences in a similar way could yield interesting results. Additionally, while purity violations may be judged as more disgusting, it is not completely clear why that may be. The judgement that the scenario is animalistic and degrading is not sufficient for driving the physiological disgust

reaction. This reaction also appears not to be driven by anger, disease risk, harm, or immorality. Perhaps qualitative investigations of the purity vignettes could reveal what specific judgements participants are making about these scenarios. Through these investigations, current theory could be expanded to cover a range of different emotional reactions suitable during different types of moral judgements, decisions, and behaviours.

Conclusion

As discussed in the introduction, in this thesis we aimed to address several shortcomings in the literature. First, we addressed the difficulty in distinguishing disgust from anger physiologically. Controversies in this area cast the existence of biologically-based emotional categories into doubt (e.g. Barrett, 2006, 2017; Barrett, Gendron, & Huang, 2009; Mauss & Robinson, 2009) and contributed to claims that moral anger and moral disgust are not distinct emotions (e.g. Herz & Hinds, 2013; Nabi, 2002). We found that by using measures of pupil diameter we can distinguish between disgust and anger, with disgust, not anger, driving pupil dilation. We found this for both general disgust and specifically moral disgust to purity violations.

Second, we addressed the issue of specific adaptive roles for moral anger and moral disgust; whether they are differentially activated by types of moral violations such as impurity (Graham et al., 2013, 2011; Rozin et al., 1999); by who is affected by the immoral action—you, close others, or distant others (Hutcherson & Gross, 2011); or in response to indicators of personality traits such as warmth/competence (Cuddy et al., 2008; Fiske et al., 2007). We provided evidence that, for third party judgements, disgust and anger appear to be differentially activated by type of moral violation, as suggested by the CAD hypothesis and MFT (Graham et al., 2013, 2011; Rozin et al., 1999). However,

in Chapter 4, when the participant was personally affected by immorality, disgust and anger were elicited differently: disgust was no longer limited to impurity and was elicited to a greater extent than anger to direct, financial harm.

Consequently, we suggest that disgust and anger function differently depending on whether they are responding to third-party moral judgements or responding to anonymous, direct threats in a group setting. Potentially, therefore, when participants rate immoral vignettes, they may be expressing their moral values but not necessarily how they would feel when confronted with the scenario themselves. This has been found in previous work using a pain versus gain experiment (FeldmanHall et al., 2012). In this experiment, participants had to pay money from an endowment to prevent an electric shock to another person. It was found that whilst participants expect that, hypothetically, others will make personal financial sacrifices to prevent physical harm to another, in the real-life version of this scenario, participants will not behave this way. Instead, participants will keep over half of the endowment on average, limiting the pain but not preventing it (FeldmanHall et al., 2012). The results of this study suggest that moral judgements and decisions change as ecological validity increases, which is also indicated by this thesis.

Based on these results we suggest that the adaptive purposes of disgust and anger are to motivate different responses, albeit not necessarily in the way models such as SFM suggest. Previous studies have found that moral disgust is an emotion with more permanent effects than anger, evidenced by difficulty in reversing elicited disgust even with mitigating, contextual information (Rozin et al., 1986; Russell & Giner-Sorolla, 2013) compared to anger which is decreased over time and by information of mitigating circumstances (Goldberg et al., 1999; Russell & Giner-Sorolla, 2011b). As such, disgust

may be elicited by the more severe harm as it indicates a stronger, more permanent emotional reaction. This is evidenced in Chapter 4 by disgust motivating a stronger desire to avoid the target in-person and online compared to anger. This may equally explain disgust towards impurity: violations of this kind may be seen as permanently tainting and unforgivable. Thus, the expression of disgust rather than anger would be seen as reflecting an important distinction in whether the violation would taint and morally contaminate the immoral actor.

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