The Expression of Guilt

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Abstract

Guilt is felt in response to the realization that one has brought harm to another through one’s specific action or inaction. Though aversive, the experience and expression of guilt is important to healthy social functioning. Guilt is often described as deeply visceral, and nonverbal guilty expressions are commonly described anecdotally, yet much remains unknown about the way that guilt is expressed. The present work aimed to explore the visceral experience of guilt via the autonomic nervous system, and the nonverbal display of guilt via facial, gestural, and postural expressions. Using a novel film paradigm, we explored patterns of autonomic nervous system activity during the experience of guilt in healthy adults and adults with neurodegenerative disorders. We further explored the facial, gestural, postural, and gaze behaviours associated with guilt in healthy adults. We hypothesized that in healthy adults there would be a pattern of expression that would distinguish guilt from comparison emotions. We further hypothesized that these expressions would be altered in neurodegenerative disorders. In healthy adults, we identified the electrogastrogram, swallowing rate, and electrodermal activity as related to the real-time experience of guilt. In patients with neurodegenerative disorders, we identified swallowing rate and electrodermal activity as altered during guilt. We further found a pattern of activation indicating that in certain neurodegenerative conditions there may be overactivation of the parasympathetic nervous system or underactivation of the sympathetic nervous system during guilt. Finally, we found several facial, gestural, and postural behaviours associated with guilt, suggesting that participants were equally or less likely to perform those behaviours during guilt than in other emotions. These findings suggested that the nonverbal communication of guilt may be reliant on the presence of observers. Overall, this work suggests that, in healthy adults, guilt is associated with a pattern of psychophysiological and nonverbal outputs, and that the psychophysiology of guilt may be altered in dementia. These results may be applied to future work on the topic of guilt expression in health and disease and may suggest diagnostic or treatment targets for diseases with maladaptive levels of guilt.
Keywords

Guilt, psychophysiology, emotional expression, nonverbal expression of emotion, emotion in neurodegenerative disorders, psychophysiology in neurodegenerative disorders, social emotions, moral emotions
Summary for Lay Audience

Guilt is an emotion that is caused by the realization that, through one’s specific action or failure to act, one has brought harm to another. Guilt is painful to experience, but a healthy level of guilt is necessary for normal social functioning. Though guilt is often described in terms of its expression, whether that be internally as a guilty person’s clenching stomach or externally as their averted gaze, very little is known about the expression of guilt in healthy adults, or the way it may be altered in diseases that are known to experience unhealthy levels of guilt, like frontotemporal dementia or obsessive-compulsive disorder. This thesis sought to explore the way that guilt is expressed via the autonomic nervous system and via nonverbal expressions. We hypothesized that the expression of guilt would distinguish it from other emotions such as sadness or disgust, and that this expression would be altered in neurodegenerative disorders like frontotemporal dementia. We found that there are elements of the autonomic nervous system that are impacted by the experience of guilt, particularly movement of the stomach, swallowing rate, and skin sweating. In patients, we found evidence that there are changes in the way that the body reacts to guilt that suggests underreactivity to guilt. Finally, we found that healthy adults displayed nonverbal behaviours equally or less than they did in other emotions, suggesting that the nonverbal expression of guilt may be driven by being observed. Overall, these findings contribute to existing knowledge about the way guilt is felt and expressed. They suggest future research on the topic of the expression of guilt and how it is altered in disease, and potential treatment or diagnostic targets for individuals with unhealthy levels of guilt.
Co-Authorship Statement

All chapters were written by Chloe Stewart with input from Dr. Elizabeth Finger. Chapter 2 was written with input from Dr. Derek Mitchell, Dr. Paul Tremblay, Dr. Penny MacDonald, and Kristy Coleman. Sophie Henke Tarnow, Lauryn Richardson, and Soojung Yu were involved in data collection.
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Chapter 1: Introduction

The experience of emotions is one of the most unifying experiences of humanity. Despite the seeming universality of feelings such as happiness and sadness, very little is concretely known about emotions and the mechanisms that give rise to them. Broadly, an emotion is a subjective, episodic physical and cognitive response that arises in reaction to an internal or external stimulus (Barrett et al., 2007; Mulligan & Scherer, 2012). Within this broad definition fit the primary emotions-- such as anger, disgust, fear, happiness, sadness, and surprise-- which are believed to be innate and seem to arise naturally and universally regardless of culture or experience (Ekman & Cordaro, 2011). These primary emotions are observable even in animals and very young infants, and do not appear to require any higher-level cognition to be experienced (Demoulin et al., 2004). This distinguishes them from secondary emotions, such as hope and relief, which require not only the basic emotional experience, but also the cognitive appraisal of potential outcomes and the desirability or harm thereof (Demoulin et al., 2004; Leyens et al., 2000).

Situated within the group of secondary emotions are social emotions, a class which includes emotions such as pride, pity, and elevation (Algoe & Haidt, 2009). These emotions require a combination of the basic emotional experience, as well as an awareness of the self, and an evaluation of what others might be thinking or feeling (Hareli & Parkinson, 2008; Lewis, 2011). This is the key element of the social emotions, that they require an ability to mentally represent and understand the opinions, experiences, reactions, and feelings of others (Fossati, 2012). Due to this necessary element, social emotions are often slow to develop, and have an extended maturational time course relative to the basic emotions (Saxe, Carey, & Kanwisher, 2004; Zeman et al., 2006).
Within the category of social emotions is the subcategory of moral emotions, so-called because they are believed to be representative of an individual’s moral cognitions and character (Haidt, 2003). In this context, the concept of moral cognition refers specifically to the judgment of a thought or action as right or wrong, good or bad, acceptable or unacceptable (Yoder & Decety, 2018). A moral character is a stable personality disposition composed of the presence or absence of virtues such as empathy and loyalty, and vices such as selfishness and cowardice, as well as behaviour in accordance with those traits (George, 2017). This category includes positively valenced moral emotions such as gratitude and compassion, and negatively valenced emotions such as contempt and embarrassment (Tangney, Stuewig, & Mashek, 2007). Moral emotions are believed to support the development of moral cognitions and moral character. They underpin the making of moral judgments, as well as coordinating behavioural and cognitive reactions to one’s own and other’s moral or immoral behaviour (Rees, Klug, & Bamberg, 2015; Teper, Zhong, & Inzlicht, 2015).

1.1 Guilt

Guilt is one of the major moral emotions. In order to generate guilt, an individual must perform, consider performing, or be the beneficiary of, some action or inaction, and this action or inaction must bring about some form of harm or inequity that affects a third party (Huhmann & Brotherton, 1997). This harm may be a concrete violation of the rights of an individual or group of individuals, for example stealing money from a friend; or it may be a more abstract violation of a personal moral standard or societal rule, such as a religious person committing a sin which has no victim other than the rule itself (Basile et al., 2011; Elder & Mohr, 2020). These are termed altruistic and deontological guilt, respectively (Mancini & Mancini, 2015). It is possible also to feel guilt when one is the passive recipient of a state of inequality, whether one could
have actually acted to undo the inequality or not. This occurs, for example, in the case of survivor’s guilt, in which guilt arises when one survives an incident that others did not (Wilson, Droždec, & Turkovic, 2006; Hutson, Hall, & Pack, 2015). This may be considered an outgrowth of inaction, the failure to balance fortunes with another who now suffers, as well as a consequence of one’s failure to live up to one’s ideal moral self (Basile et al., 2011; O’Connor et al., 2011). The feeling of guilt may be anticipated, in that merely imagining an action or its potential for harm is sufficient to generate a guilt response, or it may be consequential, in that it is the direct result of one’s behaviour and its outcomes (Lindsey, Yun, & Hill, 2007). It is the specific action or inaction, and the consequences thereof, that generates the emotion of guilt; absent a specific action or inaction, real or imagined, it is very difficult to arouse guilt (Baumeister, Stillwell, & Heatherton, 1994; Zeelenberg & Breugelmans, 2008). Lacking perceived agency in the harmful event, the suffering of others may arouse feelings of pity, compassion, or even anger towards the injured party; however, one would not assume guilt as the locus of control is beyond the self (Weiner, Graham, & Chandler, 1982; Graham, Doubleday, & Guarino, 1984). Combining all of these elements, guilt may be defined as the specific, negatively valanced emotional response to the awareness that one’s action or inaction has caused or may cause a harm or potential harm to someone or something else.

1.1.1 Shame and Embarrassment

There are two moral emotions that overlap and co-occur with guilt to some degree: embarrassment and shame. Some early theorists suggested that these three emotions were essentially the same, or were so similar in their antecedents, experiences, and outcomes as to make no difference (Tangney et al., 1996). Studies have shown that both guilt and shame can arise from similar situations— for example lying, cheating, or failing— and are often comingled
with one another in terms of the dimensions on which they are experienced (Smith & Ellsworth, 1985; Tangney, 1992). Similarly, embarrassment had often been conceptualized as being a component or lesser form of shame, and not meaningfully distinct (Miller & Tangney, 1994). It is certainly true that guilt, shame, and embarrassment can and do co-occur, and in everyday life it can be difficult to distinguish between them in a meaningful way (Tangney et al., 1996; Vess et al., 2014). However, more recent research and theories have established clearer delineations between guilt, shame, and embarrassment, separating them from each other in key ways.

Embarrassment—the self-conscious awareness of having lost face or esteem by having been witnessed committing some error, accident, or faux pas—is distinguished from guilt on three dimensions: the need for an audience, the intensity of the emotion, and the sense of responsibility felt. Embarrassment is felt when observed by an audience, real or imaginary, and the feeling of exposure and the awareness of being seen is highest in embarrassing situations (Miller, 1996; Tangney et al., 1996). It may be said that embarrassment is a strongly interactional emotion, as it is a violation of one’s social identity that is or may be observed by others; this is distinct from guilt, which does not require any witnesses to be felt, merely a violation of the moral self as experienced by the self. (Stonehouse & Miller, 1994; Withers & Sherblom, 2008). Embarrassment is typically more transient and less intense than guilt. It tends to evoke less additional emotions such as anger or disgust at the self (Miller & Tangney, 1994; Tangney et al., 1996). An embarrassing event is usually unexpected, unintended, or surprising, and, most importantly, the individual typically takes less responsibility for it than they would in a guilt-inducing event (Miller & Tangney, 1994). An embarrassing event also does not necessarily have any moral dimension, merely some element of social impropriety or awkwardness (Keltner & Buswell, 1996; Tangney, Mashek & Stuewig, 2005).
Shame—a negative evaluation of the self in response to an action, thought, or feeling that is deemed to be fundamentally incongruent with one’s self-concept – is also distinguished from guilt on three dimensions: the attribution of blame, the aversiveness of the experience, and the behaviours subsequent to the emotional experience. When ashamed, an individual tends to attribute negativity not to the behaviour, but to themselves, believing that the immorality lies not in the action, but in the actor (Miller & Tangney, 1994; Niedenthal, Tangney, & Gavanski, 1994; Tangney et al., 1996). Indeed, shame requires no action at all, and may arise simply from a perceived inadequacy in the self (Deem & Ramsey, 2016). Shame is typically rated as more psychologically aversive, and as an overall more intense emotional experience, relative to guilt (Tangney et al., 1996). Subsequent to feelings of shame, individuals typically feel smaller and more inferior to others, and this drives individuals to hide from others, to lash out with hostility and other-blame, and to resist admitting to what they have done (Drummond et al., 2017; Pivetti, Camodeca, & Rapino, 2016; Tangney, Stuewig & Hafez, 2011). This generalizes to a tendency to avoid making amends when experiencing shame, whereas when experiencing guilt the tendency is to seek to repair the harm and make amends (Pivetti et al., 2016; Schmader & Lickel, 2006).

1.1.2 The Purpose of Guilt

This drive towards reparative behaviours following the experience of guilt has been one of the most consistent findings associated with the emotion and is one of the principle ways in which guilt feelings are alleviated (Donohue & Tully, 2019; Graton & Ric, 2017). After experiencing guilt, individuals are much more likely to attempt to fix what they have done, to offer fair recompense to the aggrieved, to change their problematic behaviours, or to apologize for their actions (Estrada-Hollenback & Heatherton, 1998; Julle-Danière et al., 2020; Murrar et
al., 2019; Roseman, Wiest, & Swartz, 1994; Tangney, Stuewig, & Mashek, 2005). Guilt-driven apologies are seen by the injured party and observers as more sincere than those that are driven by other emotions such as pity, self-interest, or those that are coerced (Hareli & Eisikovits, 2006; Shnabel, Halabi, & SimanTov-Nachlieli, 2015; Smith, Anderson, & Straussberger, 2018). By enhancing the sincerity of apologies, guilt increases the perceived trustworthiness of the guilty individual, and makes the apology more successful at comforting the injured party (Rosenstock & O’Connor, 2018; Shore & Parkinson, 2018; Smith & Parkinson, 2018). Individuals who express apparently genuine guilt and remorse are forgiven more and punished less, and seen as generally better people, even in the context of serious criminal behaviour (Eisenberg, Garvey, & Wells, 1998; MacLin et al., 2009; Robinson, Smith-Lovin, & Tsoudis, 1994). By encouraging individuals to repay or repair the harm they have caused, whether they actually mitigate the consequences of their action or assuage hurt feelings, guilt helps to limit the negative effects that selfish or harmful actions can have on others and on society. These guilt-driven reparative behaviours enhance social ties and increase dyadic and group affiliation feelings both in the individual and in the injured party (Bachman & Guerrero, 2006; Hareli & Eisikovits, 2006).

These reparative actions are directly related to the guilt-inducing incident and the victim thereof. However, guilty individuals can also be driven to engage in more general prosocial activities in an attempt to restore their moral self (O’Keefe, 2000; Schei, Sheikh, & Schnall, 2019). In response to feeling guilty, individuals become far more likely to engage in cooperative behaviour, to offer help to others, to donate money or time or items to charities (Hibbert et al., 2007; Ketelaar & Au, 2003; Lwin & Phau, 2014; Nelissen, Dijker, & DeVries, 2007; Renner et al., 2013; Schei et al., 2019; Zemack-Rugar, Bettman, & Fitzsimons, 2007). These prosocial actions may not be targeted towards, nor providing any benefit to, the individual or individuals
who were perceived as being harmed by the transgression; nonetheless, the performance of these apparently unconnected prosocial actions alleviates guilt (Boster et al., 1999; Ding et al., 2016; Jordan, Mullen, & Murnighan, 2011; Renetzky, 2015). Similarly, the feeling of guilt has been found to encourage individuals to seek out self-improvement products and opportunities, even when this self-improvement does not relate to the initial guilty feeling or offer any mood stabilization (Allard & White, 2015). Individuals who have a high trait guilt proneness have also been found to perform prosocial behaviours and make prosocial choices in the absence of any guilt-inducing stimuli (Cohen, Panter, & Turan, 2012; Furukawa, Tangney, & Higashibara, 2012; Torstveit et al., 2016). This has been observed in children as young as toddlers, for whom guilt proneness has been positively correlated with empathic helping in a scenario where the child has no fault (Drummond et al., 2017). By encouraging prosocial behaviours in response to transgressions or internal states, guilt helps to strengthen social ties.

As guilt has a powerful function as a goad, to encourage prosocial behaviour, so too does it act as a restraint, to limit antisocial behaviour. The anticipation of guilt as a result of one’s planned actions can be an effective method of resisting negative impulses, even those that would lead to immediate and appealing outcomes (Breggin, 2015). Individuals who are guilt-prone at the trait level have been found to engage in far less delinquent behavior, such as bullying, beginning in childhood and continuing into adulthood (Cohen, Panter, & Turan, 2012; Mazzone, Camodeca, & Salmivalli, 2016; Stuewig & McCloskey, 2005). Anticipating or feeling guilt has been found to cause avoidance of risky, immoral, or unfair behaviours, including criminal behaviours (Mancini & Gangemi, 2004; Svensson et al., 2013; Tangney, Stuewig, & Mashek, 2005). Guilt proneness has also been associated with lower levels of interpersonal aggression, blame, or hostility (Tangney et al., 2011; Roos, Hodges, & Salmivalli, 2014; Colasante et al.,
On the other hand, individuals who are low in guilt are much more likely to engage in self-beneficial actions regardless of the harm it might cause to those around them, or of the rules or social norms they are violating (Cohen et al., 2012; Gong et al., 2019). Through this restraining effect on antisocial behaviours, guilt maintains social bonds and encourages individuals to behave fairly, honestly, and avoid harming others.

1.1.3 Maladaptive Guilt

1.1.3.1 Excessive Guilt

Though guilt is a useful and necessary emotion for healthy functioning, it is also possible for guilt to be maladaptive. In some clinical populations, excessive guilt is either a core feature or strongly associated with the disease. Two disorders that often feature maladaptive guilt are obsessive-compulsive disorder (OCD) and posttraumatic stress disorder (PTSD). Individuals with OCD have been found to be significantly more guilt-prone and more likely to experience guilt as highly negative and aversive than healthy adults (Chiang, Purdon, & Radomsky, 2016; Hennig-Fast et al., 2015; Melli et al., 2017). In particular, individuals with OCD seem to be more sensitive to the moral rules and violations thereof, which may give rise to deontological guilt (Basile et al., 2014; D’Olimpio et al., 2013; Gangemi & Mancini, 2017; Ottaviani et al., 2018). Research has consistently shown that pathological guilt—excessive and persistent guilt that leads to self-criticism and a belief in one’s inability to live up to the moral self-- and the fear of experiencing it, is strongly correlated with the severity of OCD symptoms, and compulsive behaviours such as checking and washing in particular (Giacomantonio, Salvati, & Mancini, 2019; Melli et al., 2017; Ottaviani et al., 2018; Shapiro & Stewart, 2011). Similarly, PTSD symptoms are exacerbated and complicated by posttraumatic guilt (Wilson et al., 2006). Guilt and shame are reported more frequently by survivors of traumatic events who have been
diagnosed with PTSD than those who have not (Carmassi et al., 2017). Pathological trauma-related guilt has been correlated with increased symptom severity, functional impairment and poorer outcomes in PTSD (Allard et al., 2016; Carmassi et al., 2017; Kubany et al., 1996; Norman et al., 2018). Though shame is often at the forefront of considerations of suicidal ideation, some studies have shown that both trauma-related guilt and general guilt proneness contribute to more severe suicidal ideation in veterans (Bryan et al., 2013a; Bryan et al., 2013b; Cunningham et al., 2017; Tripp & McDevitt-Murphy, 2017). When it is present, pathological levels of guilt can contribute to the worsening of a disease course, to increased harmful behaviours and thoughts, and to an overall decline in quality of life.

1.1.3.2 Deficient Guilt

However, it is also possible for guilt to be pathologically low, and this may have far-reaching consequences for individuals low in guilt, those around them, and even for society as a whole. This can be seen in individuals with psychopathic or callous-unemotional traits, and those who have experienced a traumatic brain injury to the frontal lobes. Low guilt is counted as a member of the constellation of traits that make up a psychopathic or callous-unemotional personality, alongside other traits such as low or no empathy, prosociality, or emotionality (Kimonis et al., 2008; Waller et al., 2020). Despite an awareness of right and wrong on a basic level, psychopathic and high CU individuals are willing to break moral and social rules for gain, and do not anticipate or experience guilt after having done so (Cima et al., 2010; Glenn et al., 2009; Seara-Cardoso et al., 2016). This extends beyond societal or moral rules to harming individual others; the level of care felt towards others, and the amount to which they feel the need to avoid harming others or to be fair to others, i.e., to avoid guilt, is greatly diminished (Aharoni et al., 2012; Glenn et al., 2009; Gong et al., 2019; Pletti et al., 2017; Seara-Cardoso et
al., 2013). The attribution of these behaviours to low guilt as opposed to low empathy in general is as yet unclear. However, in these individuals, low levels of guilt proneness are strongly associated with high levels of psychopathic traits and the endorsement of harmful behaviours (Prado et al., 2016; Seara-Cardoso et al., 2013; Seara-Cardoso et al., 2016). Though callous and unemotional traits typically begin in childhood or early adolescence and persist into adulthood it is possible to lose one’s ability to feel guilt in adulthood through damage to or degeneration of certain brain regions (Essau et al., 2006; Viding, Frick, & Plomin, 2007; Cipriani et al., 2013). In traumatic brain injuries (TBI) affecting regions such as the ventromedial prefrontal cortex and orbitofrontal cortex, there is a consistent finding of decreased empathy, perspective-taking, and sensitivity to future consequences, as well as increased utilitarianism and disinhibition in decision-making and behaviour (Bechara, Tranel, & Damasio, 2000; Koenigs et al., 2007; Lippert-Grüner et al., 2006; Shamay-Tsoory, Aharon-Peretz, & Perry, 2009; Taber-Thomas et al., 2014; Thomas, Croft & Tranel, 2011). Specific insensitivity to guilt, and subsequently unrestrained behaviours have been noted (Krajbich et al., 2009). Like psychopaths, individuals with frontal TBI seem to be aware of what the moral rules for engagement with others and society are, but no longer connect emotionally with those rules, or the consequences thereof, when it is of personal benefit to themselves to behave immorally (Anderson et al., 1999; Ciaramelli et al., 2007; Koenigs et al., 2007; Taber-Thomas et al., 2014). As a result, there is a tendency to behave in a disinhibited and socially inappropriate manner, and to be selfish and untrustworthy in their decisions (Anderson et al., 1999; Krajbich et al., 2009; Moretto, Sellitto & di Pelligrino, 2013). With the absence of guilt as a restraint on behavior, individuals low in guilt will struggle to perform successfully in society. As a level of guilt is necessary to support
cooperative social relationships and maintain social ties, those without it may become selfish, unrestrained, and destructive towards others.

1.1.4 Elicitation of Guilt

Autobiographical recall

Experimentally, numerous paradigms have been developed to elicit and define guilt in healthy people and across different lesion and disease models. One of the most commonly used designs is autobiographical recall, in which individuals are prompted to recall and describe one or more instances in their lives in which they had felt guilty (Shin et al., 2000; de Hooge, Zeelenberg, & Breugelmans, 2007; Nelissen, Dijker, & DeVries, 2007). This design is favoured as it is simple to administer in most cases, and it ensures that most individuals will feel guilt during the study, which is not always guaranteed in other paradigms. However, they are not appropriate for all groups; for example, young children and individuals with cognitive or language difficulties are unlikely to be able to successfully complete this task. It is also difficult to ensure that guilt feelings elicited in this paradigm are consistent in terms of cause, intensity, age, duration, or other factors that may impact its quality. A similar and very common method is the use of guilt induction scripts or statements. These texts are designed to place the participant in the frame of mind of a guilty person, without requiring the participant to generate the scenario or engage in guilt-inducing behaviour themselves. In these paradigms, participants are invited to read or listen to the text and then envision themselves in the place of the guilty person, or more rarely to simply picture the scenario without necessarily taking ownership of it (Basile et al., 2011; Finger et al., 2006; Kédia et al., 2008; Malti et al., 2016; Takahashi et al., 2004). This method is more useful for populations, such as children, who may struggle to generate their own scripts. It allows for more standardization and consistency in the guilt elicited, as all participants
are receiving the same script. However, it may be difficult to encourage individuals to take ownership of the actions of others, or of actions attributed to themselves that they know to be fictitious. It is also difficult to ensure that individuals are truly experiencing the intended emotion and not merely reporting what they know “should” be felt. Similarly, individuals may struggle with or have unexpected reactions to the content of the text.

**Economic Games**

Another very common method, particularly in the field of neuroeconomics, are economic games designed to induce guilt (Singer & Fehr, 2005). Two of the most frequently used are the dictator game and the ultimatum game. In the dictator game, individuals decide how many of a limited set of resources, if any, to allocate to others. In the ultimatum game, individuals are either a proposer or responder, and must decide what percentage of a shared resource to allocate to their partner (proposer), or whether to accept or reject their percentage, and thus whether they and their partner will earn the resource as divided, or both will earn no resource at all (responder) (Houser & McCabe, 2009). Similar games used with varying frequency include the trust game, the prisoner’s dilemma, or the public goods game (Robson et al., 2020). Individuals may feel guilty in these games when they choose a selfish option and cause economic harm to their partner(s), particularly if the partner is altruistic towards them (Robson et al., 2020). This method may also be combined with other methods, such as autobiographical recall, to see the effect of induced guilt feelings on behaviour in cooperative playing (Ketelaar & Au, 2003; Nelissen, et al., 2007). These games are simple to administer and easily repeatable, even dozens of times within the same testing session (Ketelaar & Au, 2003). They are also valuable as the qualities of the confederate, the stakes, and the fairness or unfairness of the situation can be easily manipulated. However, they are not always appropriate for patient or child populations, who may fail to grasp
the task rules, or lack the cognitive or memory capacity to perform the task adequately (Robson et al., 2019). There is also some criticism of the low ecological validity of these games, which, due to their anonymity and highly artificial nature, do not closely resemble real life scenarios (Hagen & Hammerstein, 2006).

**Feigned or Forced Wrongdoing**

Direct inductions of guilt through forced or feigned wrongdoing are also occasionally used. In these cases, participants are tricked into believing that they have caused some harm to an experimenter or a confederate, either in a public setting or in an experimental setting. For example, a participant may be asked to use a delicate piece of equipment that is rigged to break, made to believe that they have caused an experiment to fail due to lack of vigilance, or convinced that they have hurt or insulted a confederate (Cunningham, Steinberg, & Grev, 1980; Donohue, Williamson, & Tully, 2020; Julle-Danière et al., 2020; Regan, 1971; Regan, Williams, & Sparling, 1972). Otherwise, participants may be made to believe that they have failed to live up to one of their moral convictions. For example, participants may be told that their performance on the implicit association task indicated that they hold racist views (Fourie et al., 2014). These methods are excellent at generating ecologically valid situations and scenarios and eliciting true guilt. However, they are not easily repeated in individuals, and are thus often limited to only one manipulation.

**Advertising**

Advertising appeals, and in particular charitable appeals, have also been successfully used to elicit guilt. Often these take the form of print advertisements, though video or radio advertisements are also used (Basil, Ridgway, & Basil, 2006; Basil, Ridgway, & Basil, 2008; Chang, 2011; Greening et al., 2014; Lwin & Phau, 2014; Ty, Mitchell, & Finger, 2017; Turner et
al., 2017). These advertisements are often explicitly designed with the goal of eliciting guilt, as guilt appeals have traditionally been seen as successful goads towards charitable behaviour and occasionally to consumer behaviour more broadly, though the actual evidence for this is mixed (Chédotal et al., 2017; Cotte & Ritchie, 2005; Turner et al., 2017). Charity ads can therefore be useful for guilt induction as they are specifically designed and tested to elicit that emotion from as many viewers as possible (Pinto & Priest, 1991). One of the key elements determining the effectiveness of these methods are participant familiarity with the cause, and participant perception of the intentions of the advertiser (Hibbert et al., 2007; Singh, Crisafulli, & Quamina, 2020). When advertisers are perceived as manipulative, unbelievable, or intentionally invoking guilt, the ability of the ad to induce guilt is reduced (Basil, Ridgway, & Basil, 2008; Cotte, Coulter, & Moore, 2005; Peloza, White, & Shang, 2013; Turner et al., 2017). This can greatly limit the usefulness of advertising in guilt induction.

**Video Games**

More recently, efforts to elicit guilt through traditional video games or virtual reality have become more prominent. These studies often engage players in a violent or immoral in-game scenario and reframe this scenario to provide or remove moral justification for the negative actions taken (Chen et al., 2019; Cristofari & Guitton, 2014; Hartmann, Toz, & Brandon, 2010; Kandaurova & Lee, 2019; Lin, 2011). These studies have shown great success in generating guilt feelings in participants and are a useful induction technique due to the direct involvement of the participant in choosing and performing the negative behaviour; this ensures that the participant feels emotionally invested in having committed some harm (Allen & Anderson, 2019; Grizzard et al., 2014). The ability of these methods to elicit guilt can be heavily contingent on participant characteristics, however, particularly by how engaged the participant allows themselves to
become in the game, and their previous experience with gaming (Grizzard et al., 2016; Krcmar et al., 2018). Studies have shown that an individual’s prior experience of violent or immoral game behaviour can attenuate or eliminate their guilt response to even very harmful actions in a game environment (Grizzard et al., 2016; Krcmar et al., 2018; Mahood & Hanus, 2017).

1.1.5 Neuroimaging of Guilt

Numerous studies have used these induction methods in combination with neuroimaging techniques to identify the neuroanatomy of guilt, in both healthy and patient populations. Studies have sought these regions and networks using behavioural, structural, and functional techniques. Lesion studies in patient populations have been used to identify the impact of focal brain insults on behaviour and task performance (Adolphs, 2016). Structural investigations using magnetic resonance imaging (MRI) are able to identify the association between regional variations in size and cortical thickness and behaviour and trait information (Filler, 2009). Functional neuroimaging such as positron emission tomography (PET), functional MRI (fMRI), diffusion tensor imaging (DTI), and electroencephalography (EEG) have been used to identify areas of relative activation, and connectivity between brain regions (Raichle, 2009). Several regions of the brain have been identified using these methods as potentially giving rise to guilt. Regions of particular interest are the frontal lobes, the temporal lobes, the amygdala, the anterior cingulate cortex, and the insula (Bastin et al., 2016). However, no one specific region of the brain has been consistently identified as giving rise to guilt. Increasingly, research has investigated the involvement of regions throughout the brain that operate as part of a network or series of networks that generate and perpetuate guilt feelings (Nakagawa et al., 2015). These brain regions and networks must coordinate the integration of numerous complicated factors such as the sense of self, the opinions and feelings of others, emotion and empathy, internal morality, knowledge
of social rules and mores, and awareness of punishment and reward. Thus, the regions and network(s) underlying guilt are likely to be large, complex, and difficult to tease apart.

**The Frontal Lobes**

The frontal lobes have been identified in numerous studies as being involved in the experience of guilt (Bastin et al., 2016). This is likely due to the region’s importance in the representation and appraisal of the self, the understanding and internalization of social and moral rules, theory of mind, and decision-making (Gifuni, Kendal, & Jollant, 2017). Regions of the prefrontal cortex (PFC) including the dorsomedial (dmPFC), dorsolateral (dlPFC), and ventromedial (vmPFC) have been found to show increased activation while feeling guilty as opposed to neutral in healthy adults (Fourie et al., 2014; Michl et al., 2014; Wagner et al., 2011). The dmPFC has traditionally been associated with the sense of self, the self in relation to society and to other people, empathy, morality and moral judgements, and theory of mind (Ferrari et al., 2016; Gusnard, et al., 2001; Mitchell, Banaji, & Macrae, 2005; Waytz, Zaki, & Mitchell 2012). The dmPFC has been found in functional neuroimaging studies to show increased activation during the experience of guilt relative to basic emotions, as well as in comparison to shame (Basile et al., 2011; Chang et al., 2011; Finger et al., 2006; Morey et al., 2012; Wagner et al., 2011; Zhu et al., 2019). It has also been observed to exhibit greater BOLD responses during the autobiographical recall of a guilt experience, and during subsequent social decision-making; this greater BOLD response has been correlated with trait guilt proneness (Wagner et al., 2011; Ty, Mitchell, & Finger, 2017). Further discussion of the potential roles of dmPFC in guilt processing, as the region overlaps with dorsal ACC, are discussed below.

The dlPFC is responsible for the coordination of many executive functions, notably planning, working memory, and decision making (Kaller et al., 2011; Levy & Goldman-Rakic,
It has also been suggested that the dIPFC plays a role in social cognition mediated through executive functions. Of particular interest, it is notable for potentially being involved in deception, behavioural adjustment in the face of conflict, perspective-taking, and the suppression of selfishness (Ito et al., 2012; Mansouri, Buckley, & Tanaka, 2007; van den Bos et al., 2010). The dIPFC has been found to show increased activation when individuals choose a cooperative behavior over a guilt-inducing one; it has been suggested that the dIPFC may be involved in moral judgement and moral decision-making, and contribute to the resistance of temptation in favour of equitability, as a function of the dIPFC’s involvement in computations of the values of behaviours and of their potential outcomes (Chang et al., 2011; Greene et al., 2001; Kahnt et al., 2011; Knoch & Fehr, 2007). Further study is needed to establish whether this activation is related to the more basic functions of the dIPFC, such as conflict resolution, inhibitory control, or grappling with increased decision difficulty (Nejati, Salehinejad, & Nitsche, 2018; Steinbeis et al., 2016). It is possible that the dIPFC is involved in a more pragmatic origin of guilt: the reasoning that a selfish action may ultimately have less value (for example, due to loss of face, social standing, or reciprocal support) than an altruistic one.

The vmPFC is involved in decision making and emotional regulation, and particularly the intersection of these two abilities (Bechara, Tranel, & Demasio, 2000; Hänsel & von Känel, 2008 Koenigs et al., 2007). Lesions studies have demonstrated that the vmPFC is necessary for the making of decisions that relate to the self or moral judgements, as well as being necessary for the experience of social emotions (Grossman et al., 2010; Koenigs et al., 2007; Krajbich et al., 2009; Taber-Thomas et al., 2014). The vmPFC has been shown to have increased activation during the experience of guilt relative to basic emotions (Basile et al., 2011; Chang et al., 2011; Finger et al., 2006; Morey et al., 2012; Wagner et al., 2011; Zhu et al., 2019). It has also shown greater
BOLD responses to autobiographical recall of guilt paired with social decision-making related to that guilty feeling (Ty, Mitchell, & Finger, 2017; Wagner et al., 2011). In individuals with psychopathic or callous unemotional traits, the activity of the vmPFC, and its connections to the amygdala, have been found to be reduced, and this reduction is associated with increased lack of care for others (Blair, 2007). Individuals with damage to the vmPFC have been found to be untrustworthy and selfish in economic games, and to show a marked insensitivity to guilt and poor moral judgement, despite otherwise normal cognitive functioning (Funayama et al., 2019; Krajbich et al., 2009). The vmPFC has also been clearly established as having functional linkages to the parasympathetic branch of the autonomic nervous system (ANS), discussed below (Hänsel & von Känel, 2008).

The Temporal Lobes

The temporal lobes have been implicated in the experience of guilt due to their role in the processing of social meaning and concepts, as well as theory of mind (Gifuni et al., 2017; Green et al., 2012). In patients with temporal lobe epilepsy, higher seizure frequency is correlated with a dysregulation of the experience of self-conscious emotions, including guilt (Hennion et al., 2019). Of particular interest are the superior temporal sulcus (STS), temporoparietal junction (TPJ), and the superior and middle temporal gyri, all of which have shown increased activation during guilt in healthy adults (Chang et al., 2011; Finger et al., 2006; Gifuni et al., 2017; Mclatchie et al., 2016; Michl et al., 2014; Takahashi et al., 2004; Wagner et al., 2011). The STS is important for the perception of biological motion, facial perception, and theory of mind (Direito et al., 2019; Herrington, Nymberg, & Schultz, 2011; Leroy et al., 2015). Functional neuroimaging studies have found that the STS shows increased BOLD signal in response to the experience of guilt, in particular in the face of social consequences (Morey et al., 2012;
Takahashi et al., 2004). The TPJ is involved in attention, language cognition, and theory of mind (Blakemore, Wolpert, & Frith, 2002; DeWitt & Rauschecker, 2012; Lee et al., 2011). It is particularly important for the representation of the beliefs of others, which is central to the ability to feel guilty (Decety & Lamm, 2007; Gallagher et al., 2000; Samson et al., 2004; Saxe & Kanwisher, 2003). The TPJ has shown increased BOLD activation in response to guilt-inducing stimuli (Finger et al., 2006; Gifuni et al., 2017; Mclatchie et al., 2016; Takahashi et al., 2004; Wagner et al., 2011). Mean diffusivity in the white matter of the inferior parietal lobule, a constituent part of the TPJ, has been correlated with increased guilty feelings (Nakagawa et al., 2019). The superior temporal gyrus is involved in facial emotion perception and language perception and is also important as a point of connection between the PFC and the amygdala (Bigler et al., 2007; Radua et al., 2010; Takahashi et al., 2004). The middle temporal gyrus is involved in facial recognition and understanding word meanings (Acheson & Hagoort, 2013; Platek et al., 2006). Research on these gyri is still scant, however there is evidence that they show increased BOLD activation in response to guilt induction (Gifuni et al., 2017; Takahashi et al., 2004). In patients with OCD, the experience of guilt is associated with increased activity in the superior and middle temporal gyri, along with a decrease in conjunctive activation between the temporal lobes and fronto-limbic structures (Hennig-Fast et al., 2015).

**The Amygdala**

The amygdala has been implicated in the development and maintenance of guilt, though evidence of its role is mixed (Michl et al., 2014). In healthy adults, increased activity of the amygdala has been observed during the recollection of guilty memories, as well as when anticipating or imagining feeling guilty (Chang et al., 2011; Mclatchie et al., 2016; Michl et al., 2014; Wagner et al., 2011). Individuals high in psychopathy tend to show reduced amygdala
activity and responsiveness to moral decision-making paradigms and to the distress of others (Blair, 2013; Glenn, Raine, & Schug, 2009; Hareniski et al., 2010; Marsh et al., 2013). Patients with amygdala damage have been found to be impaired in recognizing social emotions including guilt, and to be significantly more impaired in recognizing social emotions relative to basic emotions (Adolphs, Baron-Cohen, & Tranel, 2002). Increased responsiveness of the amygdala generally has also been associated with guilt and may be useful to distinguish guilt from shame (Michl et al., 2014). The reason for this dichotomy between shame and guilt is unclear, however it has been theorized to be related to empathy towards the harmed party, social judgement, and anticipation the consequences of the guilt-inducing behaviours (Adolphs, Tranel, & Demasio, 1998; Blair, 2013; Michl et al., 2014). Connections of the amygdala with the frontal cortex, and the anterior temporal lobe have been noted by some studies as being important to the experience of guilt (Blair, 2007; Shin et al., 2000). It has been suggested that by its connection to the vmPFC the amygdala allows the emotional learning about the negative associations between one’s behaviour and the distress of others to be used to inform moral decision making (Blair, 2007). Reduction in the connections between the amygdala and the vmPFC have been associated with psychopathy and callousness, along with a decrease in care for others (Blair, 2008). The amygdala’s connections to the temporal poles have been suggested to inform anxiety and the overall negative emotional reaction to guilt feelings (Shin et al., 2000).

**The Anterior Cingulate Cortex and Insula**

Two further regions of interest are the anterior cingulate cortex (ACC) and the insula. The ACC and particularly the dorsal ACC (dACC) has been found to be associated with guilt, likely as a result of its involvement in the representation and integration of emotions, social rejection, and pain (Gifuni et al., 2017). In healthy adults, the ACC shows greater activation in
response to both imagined and recollected guilt, as well as for instances of collective guilt (Fourie et al., 2014; Li et al., 2020; Mclatchie et al., 2016) These studies suggest that the ACC is activated by guilt both in comparison to neutral experiences and basic emotions (Basile et al., 2011; Green et al., 2012; Shin et al., 2000). In OCD, the ACC has been shown to have reduced activation relative to controls during the experience of guilt, particularly deontological guilt, which may represent a heightened neural efficiency due to high levels of guilt in these patients (Basile et al., 2014). The ACC also plays a part in the functioning of the ANS, discussed below; in particular, research has suggested that the ACC has a parasympathetic modulatory role (Critchley, Mathias, & Dolan, 2001; Critchley et al., 2003; Hohenschurz-Schmidt et al., 2020; Matthews et al., 2004).

The insula’s association with guilt may be related to its involvement in disgust, an emotion which often ties into moral judgement, as well as its role in interoception (Bastin et al., 2016; Gasquoine, 2014; Gifuni et al., 2017). In healthy adults, the insula is activated when feeling personal and collective guilt, as well as when recollecting guilty memories (Finger et al., 2006; Fourie et al., 2014; Li et al., 2020; Mclatchie et al., 2016). Neural responsiveness in the insula has been suggested to be a distinguishing feature of guilt (Michl et al., 2014). This may be related to the self-disgust elicited by guilt, or to the emotional regulatory function of the insula (Michl et al., 2014). In children with major depressive disorder, the experience of pathological guilt has been associated with reduced bilateral anterior insula volumes (Belden et al., 2015). Though both have implications for the experience of guilt in isolation, the interaction between the ACC and the insula have also been specifically connected to guilt. Coactivation of the dorsal anterior insula and the dorsal ACC during a charity decision task has been linked to the decision to avoid harm to others (Greening et al., 2014).
1.2 The Autonomic Expression of Guilt

1.2.1 The Autonomic Nervous System

Research has suggested that the insula and the ACC working together are responsible for the construction and representation of the self via the integration of cognitive, affective, and physical experience (Medford & Critchley, 2010). This raises an important facet of the nervous system not yet fully considered—the autonomic nervous system (ANS). Both the insula and the ACC have been found to modulate the ANS, as has the vmPFC (de Morree et al., 2016; Hänsel & von Känel, 2008; Matthews et al., 2004). The ANS is a division of the peripheral nervous system that is responsible for the largely unconscious innervation of inner organs and the regulation of their functions, such as heart rate, digestion, and pupillary response (Jänig & Häbler, 2003; McCorry, 2007). The ANS is segmented into interrelated yet distinct branches. The sympathetic nervous system (SNS) and the parasympathetic nervous system (PSNS) are the predominant and most closely related divisions, while the enteric nervous system (ENS) operates largely independently and is sometimes considered to be completely distinct from the ANS due to its degree of autonomy (Furness, 2007; Jänig, 2006; McCorry, 2007). All divisions of the ANS are tonically active, meaning that they continuously activate their target tissues at all times (Cramer & Darby, 2017; McCorry, 2007). The PSNS and SNS operate and interact complementarily, rather than antagonistically, with each division operating within a shared balance of activity (McCorry, 2007). It is through this constant coactivation that homeostasis is maintained in their target organs and throughout the body (Jänig, 2006; McCorry, 2007; Seoane-Collazo et al., 2015). In response to external or internal stimuli, however, it is possible for the balance to tip and for the SNS or PSNS to become more activated, and thus cause their respective physiological cascade to predominate (Cramer & Darby, 2017; McCorry, 2007).
The Sympathetic Nervous System

The preganglionic neurons of the SNS arise primarily in the thoracic and lumbar regions of the spinal cord, and synapse either directly with effectors, or with them via the postganglionic neurons that extend throughout the body (Benarroch, 2012). The SNS is responsible for what is often termed the “fight-or-flight” response, the activation of bodily systems in preparation to respond to the detection of threat or stress (Jansen et al., 1995; McCorry, 2007). As part of this response, the SNS activates organs that will aid in responding to threat, by, for example, increasing heart rate and dilating the bronchioles in the lungs and blood vessels in skeletal muscles (Alshak & Das, 2020; Hamill, Shapiro, & Vizzard, 2012). At the same time, it inhibits organs that would prove an unnecessary energy cost, such as by slowing digestion and decreasing salivation and lacrimation (McCorry, 2007).

The Parasympathetic Nervous System

A majority of the preganglionic neurons of the PSNS, by contrast, arise in several nuclei of the brainstem, and exit the brain as cranial nerves III, VII, IX and X, which synapse with effectors directly or via the parasympathetic ganglia; some PSNS neurons also emerge from the sacral region of the spine, and synapse directly with effectors (Birder et al., 2010; Hamill, Shapiro, & Vizzard, 2012). The PSNS is responsible for “rest-and-digest” or “feed-and-breed” activity, which occurs when the body is conserving energy (ten Donkelaar et al., 2020; Tindle & Tadi, 2020). This involves the inhibition of the threat response, such as by deceleration of the heart and constriction of breathing, and the activation of organs responsible for relaxation and digestion, such as the stomach and intestines (Hamill, Shapiro, & Vizzard, 2012; McCorry, 2007). Both the SNS and the PSNS innervate the same structures throughout the body, connecting to structures of the head and neck (eyes; lacrimal glands; mucous membranes of the
mouth and nose; submaxillary, sublingual, and parotid glands; larynx), the thoracic viscera (heart, trachea, bronchi) abdominal viscera (esophagus, stomach, large and small intestines, liver and bile duct, spleen, gallbladder, adrenal gland, kidneys, pancreas), and pelvic viscera (urinary bladder, rectum, gonads, external genitalia) (Anderson, 1998; Li, Johansson, & Grimelius, 1999; McCorry 2007; Moore, Agur, & Dalley, 2004). However, the SNS is solely responsible for the innervation of skin blood vessels and sweat glands (Critchley, 2002; Langworthy & Richter, 1930; McCorry, 2007).

The Enteric Nervous System

The ENS consists of a diverse network of neurons and supporting glia that are organized into two ganglionated plexuses, the submucosal and myenteric (Furness, 2007). This network is spread throughout the walls of the esophagus, stomach, small and large intestines, pancreas, gallbladder, and biliary tract, and innervates almost every aspect of these organs (Furness, 2007; Schneider, Wright, & Heuckeroth, 2019). The ENS coordinates the intrinsic innervation of the gastrointestinal tract and thus the regulation of digestion; as such it is responsible for coordinating motility in its target organs, secretion of gastric and pancreatic acids and gastrointestinal hormones, as well as local blood flow and fluid exchange (Furness, 2007; Furness, 2012; Schneider et al., 2019). The ENS has been noted for its resemblance to the CNS in terms of the number and structure of its neurons, as well as the presence of neurotransmitters and receptors throughout it (Gershon, 1999; Furness, 2007; Schneider et al., 2019). It receives input from both the SNS and PSNS and is also tightly connected to the rest of the CNS via reciprocal connections, however it has been found to be capable of operating without CNS input (Gershon, 1999; Powley, 2000; Furness, 2007; Furness, 2012).
1.2.2 Cortical Control of the ANS

While the moment-to-moment reflexive functions of the ANS are mediated by the spinal cord, the system as a whole is controlled centrally by an interconnected network made up of regions in the brainstem and forebrain (Benarroch, 2012; Napadow et al., 2008; Valenza et al., 2019). In the brainstem, ANS activity is coordinated by the periaqueductal grey, parabrachial complex and adjacent pontine structures, nucleus tractus solitarius, the rostral ventrolateral medulla, caudal ventrolateral medulla, ventromedial medulla, and caudal raphe nuclei (Benarroch, 2012; Critchley, Mathias, & Dolan, 2001; Hohenschurz-Schmidt et al., 2020; Macefield & Henderson, 2019; Napadow et al., 2008). These brainstem regions are predominantly responsible for acting as relays between various afferent inputs and the midbrain and forebrain. They are also responsible for the relay of various autonomic reflexes from the brain to the body and participate in the control of various systems including cardiovascular function, pain modulation, and thermoregulation (Benarroch, 2012; Macefield & Henderson, 2019). In the forebrain, the insula, ACC, amygdala, and hypothalamus have all been implicated in autonomic control (Benarroch, 2012; Gianaros et al., 2012; Napadow et al., 2008). The insula is responsible for interoception, the integration of bodily signals into an overall conscious awareness of the internal state of the body; it has also been implicated in the encoding of peripheral physical responses to emotion (Benarroch, 2011; Craig, 2002; Craig, 2009; Harrison et al., 2010). Through its connections to the hypothalamus, it directs the activation of the PSNS and SNS, while its connections to limbic and frontal circuits give rise to consciousness about the body and integration of this awareness with emotion and cognition (Craig, 2002; de Morree et al., 2016; Nagai, Hoshide, & Kario, 2010). Via its connections to the brainstem, the ACC regulates some autonomic and endocrine functions, particularly the PSNS (Devinsky, Morrell, &
Vogt, 1995; Matthews et al., 2004). As part of the default mode network, is responsible for the direction of attention to and representation of the body, as well as the motivation to respond to bodily states, particularly pain and homeostatic distress (Casey 1999; Craig, 2002; Talbot et al., 1991). Through its reciprocal connections to the insula and amygdala, the ACC has been implicated in the integration of bodily states with emotional and cognitive information, as well as emotional learning and expression (Critchley et al., 2001; Devinsky et al., 1995; Matthews et al., 2004). The amygdala is responsible for the assignment of emotional values to external inputs, and for learning and memory related to emotion (Blair et al., 2001; Maren, 1999; Tang et al., 2020). Via connections to the PFC, hypothalamus and brainstem, the amygdala is also involved in generating the psychological stress response and triggering the autonomic reaction to stress and fear (Benarroch, 2012; Davis, 1992; Ulrich-Lai & Herman, 2009). The hypothalamus is responsible for orchestrating endocrine and autonomic responses necessary for the maintenance of homeostasis, and in response to external stimuli such as stress (Benarroch, 2012; Buijs et al., 2001; Craig, 2002; Thompson & Swanson, 2003). As noted above, these forebrain regions notably overlap with several of those that have been identified as being particularly involved in the development and experience of guilt.

1.2.3 The ANS in Emotion

Studies of basic emotions, such as anger, happiness, and fear, have demonstrated consistently that the ANS is activated by and during the experience of emotions (Kreibig, 2010; Pace-Schott et al., 2019). There is considerable evidence that suggests that the ANS produces patterns of activation that can be used to distinguish between emotions, though some aspects of this finding have been controversial, and the extent to which emotions are truly completely dissociable by physiological response alone is as yet unknown (Harrison et al., 2010; Levenson,
The ANS is not only activated by emotions; it also provides feedback to the brain about the body’s current physical experiences via interoception (Critchley & Garfinkel, 2017; Damasio & Carvalho, 2013; Pace-Schott et al., 2019; Seth, 2013). In this way, the ANS may influence the emotional state or appraisal of the situation at hand (Seth & Friston, 2016). Schachter and Singer (1962) proposed that cognitive appraisal and autonomic activation went hand in hand to generate the emotional experience. This theory has received criticism for various aspects including the essentialness of autonomic activity, however aspects of this theory have been borne out in later empirical research (Cotton, 1981). Several studies have successfully elicited emotional states by generating unrelated autonomic arousal. In one notable example, individuals reported increased attraction to a female confederate following a fear-inducing experience; in this experiment, the racing of the subjects’ hearts were reinterpreted as romantic interest (Dutton & Aron, 1974). Subsequent studies have successfully manipulated emotions by eliciting or eliminating autonomic signals through exercise, comedy routines, shock anxiety, and drug administration, amongst others (Barlow, Sakheim, & Beck, 1983; Meston & Frohlich, 2003; Tracy, Steckler, & Heltzel, 2019; White, Fishbein, & Rutstein, 1981). Research has clearly demonstrated that bodily arousal also impacts behaviour and decision-making (Damasio, 1996; Landy & Piazza, 2019). Notably, the elicitation and soothing of physical and cognitive disgust has been shown repeatedly to affect moral judgements and decisions, with stronger disgust reactions resulting in harsher judgements and opinions (Liuzza et al., 2019; Miller et al., 2017; Nord et al., 2020; Smith et al., 2011; Tracy, Steckler, & Heltzel, 2019; Wheatley & Haidt, 2005; Zakrzewska et al., 2020). However, autonomic and emotional arousal are not sufficient to generate a moral judgement of otherwise neutral stimuli; instead, physical and cognitive experiences of emotion work in concert with contextual information to amplify or influence decision making and moral judgements.
(Jylkkä, Härkönen, & Hyönä, 2020; Landy & Goodwin, 2015). These augmenting and influencing effects have been demonstrated with other emotions as well, including both positive and negative emotions (Clore, Gasper, & Garvin, 2001; Landy & Piazza, 2019; Storbeck & Clore, 2008). It is clear that basic emotions are experienced physically as well as cognitively, and that the cognitive and physical experiences of emotion influence each other and interact to shape behavior. Emotions, autonomic sensitivity, and the combination thereof can affect opinions, judgements and decisions, including in domains beyond the moral.

**The ANS in Guilt**

Though guilt is often reported as a deeply visceral experience (Boden & Eatough, 2019; Breugelmans et al., 2005; Potrac et al., 2017; Tangney et al., 1996), and efforts have been made in law enforcement and criminology fields to capture and exploit the physiological experience of guilt (Marston, 1938; Oswald 2020), very little is actually known about the role the ANS plays in guilt. In children, guilt-inducing transgressions have been linked with activation of the SNS based on peripheral nasal vasoconstriction, while transgression has been linked to PSNS activity via respiratory sinus arrhythmia withdrawal and heart rate deceleration (Colasante et al., 2018; Ioannou et al., 2013; Malti et al., 2016). Further studies have linked inappropriately high or low PSNS activation—measured through resting heart rate, respiratory sinus arrhythmia, and skin conductance—with low guilt and high transgressiveness in children (Colasante & Malti, 2017; Colasante et al., 2020). Taken together, these findings suggest SNS and PSNS codominance in the experience of guilt in children.

Research on individuals with pathological levels guilt have also suggested a connection between guilt and the body. These studies have often noted disturbances in the ANS at rest and in its response to emotional situations and related this specifically to moral judgements. Anxiety
disorders such as PTSD, OCD, generalized anxiety disorder (GAD), and panic disorder have consistently been associated with autonomic dysregulation (Pittig et al., 2013). At rest, individuals with these anxiety disorders display autonomic inflexibility as indexed by depressed heart rate variability relative to healthy controls (Klein et al., 1995; Monk et al., 2001; Pittig et al., 2013; Tan et al., 2011). In response to some emotional stimuli, and particularly specific anxiety-related stimuli such as phobic objects or social stress, anxious individuals display autonomic hyperreactivity (De Zorzi et al., 2021; Friedman & Thayer, 1998; Haines et al., 1998; Hoehn-Saric & McLeod, 2000; Hoehn-Saric, McLeod, & Zimmerli, 1991; Pruneti et al., 2010; Pruneti et al., 2016;). However, this hyperarousal has not been consistently observed across diagnoses. Some, particularly OCD, seem to have normal reactivity to emotions such as disgust, and a pervasive autonomic inflexibility and underreactivity even in the face of emotional stimuli (Hoehn-Saric & McLeod, 2000; Pruneti et al., 2010; Pruneti et al., 2016; Whitton, Henry, & Grisham, 2015). Despite this apparent difference in actual autonomic reactivity across diagnoses, most anxiety disorders, including OCD, have been associated with hypervigilance to bodily states and bodily changes, as well as increased subjective ratings of autonomic arousal (De Berardis et al., 2007; Hoehn-Saric, McLeod, & Hipsley, 1995; Hoehn-Saric et al., 2004; Olatunji et al., 2007; Pineles & Mineka, 2005). This does not necessarily represent actual increased autonomic arousal in anxiety disorders, but instead a tendency to perceive one’s body as being in a state of heightened arousal, as well as an attentional bias towards body sensations that may relate to anxiety (Anderson & Hope, 2009; Hoehn-Saric & McLeod, 2000; Hoehn-Saric, McLeod, & Zimmerli, 1989; Judah et al., 2018; Pang et al., 2019). This hypervigilance to the body often corresponds to increased interoceptive sensibility, defined as the subjective awareness of internal bodily states, as well as with interoceptive sensitivity, accurate detection and
reporting of internal bodily states (Domschke et al., 2010; Murphy et al., 2017; Paulus, 2013). Increased interoceptive sensibility and sensitivity have been specifically observed in panic disorder, OCD, and social anxiety (Ehlers et al., 1995; Pineles & Mineka, 2005; Richards & Bertram, 2000; Van der Does et al., 2000; Yoris et al., 2017; Zoellner & Craske, 1999). Increased body vigilance and interoceptive sensibility have also been observed in subclinical high anxiety populations (Eley et al., 2004; Pollatos et al., 2007; Richards & Bertram, 2000; Stewart, Buffett-Jerrott, & Kokaram, 2001; Takahashi et al., 2005). No research to date has explicitly connected autonomic hyperreactivity and bodily hypervigilance in anxiety disorders to moral emotions or feelings, however it is clear that many anxiety disorders often have pathologically high guilt (Chiang, Purdon, & Melli et al., 2017; Hennig-Fast et al., 2015; Norman et al., 2018). Further, some research has suggested that increased interoceptive sensibility and sensitivity is correlated with compassion, empathy, and altruism, which are closely related to guilt (Grynberg & Pollatos, 2015; Piech et al., 2017; Terasawa et al., 2014).

Conversely, individuals with psychopathy, callous-unemotional traits, or frontal damage show patterns of under-reactivity or absence of autonomic reactivity in the face of both emotional and nonemotional elicitors, such as when viewing emotional faces or startled by a loud noise, respectively (Fung et al., 2005; Ishikawa et al., 2001; Moretto et al., 2010). A low resting heart rate has been consistently found to relate to psychopathic traits, increased aggression and low empathy (Bergström & Farrington, 2018; Brzozowski et al., 2018; Colasante & Malti, 2017). Closely linked to these autonomic findings, psychopathic and callous-unemotional individuals show overall impairments in empathy, emotion recognition, and moral behaviours (Dawel et al., 2012; Gillespie et al., 2019; Glenn et al., 2009; Gong et al., 2019; Pletti et al., 2017). There is little research directly connecting these autonomic disturbances in callous-
unemotional or psychopathic individuals specifically to guilt, though guilt recognition and the experience of guilt are impaired in both (Daigmorte et al., 2019; Darby, Edersheim, & Price, 2016; Moretto et al., 2010; Prado et al., 2016; Seara-Cardoso et al., 2013; Sturm et al., 2008; Waller et al., 2020). These populations demonstrate the ways in which autonomic under-reactivity may feed into emotional blunting, which in turn leads to disturbance of moral knowledge and behaviours.

1.2.4 The ANS and Guilt in Neurodegeneration

As guilt is reliant on such a complex interplay of neuronal functioning throughout the brain and requires higher level skills such as theory of mind, insight, and social cognition, the way that guilt is affected by neurodegeneration of relevant networks is of particular interest. Often these neurodegenerative conditions have marked involvement of brain regions that are important for both the regulation and experience of guilt and those that are key to the control and monitoring of the ANS. However, though some neurodegenerative conditions are associated with dysfunction of both emotion cognition and the ANS, others are associated with ANS dysfunction but have a less clear association with emotional dysfunction, and others still have not been clearly associated with either. These conditions therefore allow for an investigation of the dysfunction of guilt, the dysfunction of the ANS, and the intersection between these two systems. Through patterns of neurodegeneration in regions responsible for emotion and ANS regulation, different kinds of dementia may offer unique insights into the brain and its relationship with the body.

Frontotemporal Dementia

Frontotemporal dementia (FTD) is a neurodegenerative disorder that has an early onset, typically between 45 and 65, and is the second most common cause of dementia after
Alzheimer’s disease (Rabinovici & Miller, 2010; Snowden, Neary & Mann, 2002). There are three core subtypes of FTD which often share some degree of overlap in terms of symptomatology, particularly over the course of disease progression, though each subtype has predominant features that distinguish between them (Olney, Spina, & Miller, 2017; Rabinovici & Miller, 2010). The behavioural variant (bvFTD) is the most commonly diagnosed (Olney, Spina, & Miller, 2017). It is characterized by behavioural and personality changes, with patients typically displaying impulsive, childish, and socially disinhibited behaviour, or becoming apathetic, listless, and withdrawn (Peet, Suarez, & Miller, 2021; Rascovsky et al., 2011). The other two subtypes are classed together as primary progressive aphasias (PPA), as their predominant symptom is a disorder of language (Gorno-Tempini et al., 2011; Olney, Spina, & Miller, 2017). The semantic variant (svPPA) is characterized by gradual deterioration of the knowledge of word meanings while knowledge of grammar and ability to produce speech remains relatively intact (Gorno-Tempini et al., 2011; Hodges & Patterson, 2007). The nonfluent/agrammatic variant (nfvPPA) is characterized by a progressive difficulty in generating speech, characterized by halting, effortful speech with agrammatism and speech sound errors or distortions, while single word knowledge remains relatively intact (Gorno-Tempini et al., 2011; Grossman, 2012). From early in the disease, many individuals with FTD, particularly bvFTD, persistently commit impulsive, unplanned moral and legal violations, from insulting a person within hearing range, to traffic violations, to petty theft; a small but notable number also commit violent or sexual crimes (Cipriani et al., 2013; Mendez, 2010; Moll et al., 2011; Daigmorte et al., 2019). Individuals with FTD seem to be aware of what the moral rules for engagement with others and society are, but no longer engage emotionally with those rules, or the consequences thereof (Mendez, Anderson, & Shapira, 2005; Mendez, 2006; Mendez, 2010; Mendez,
Anderson, & Shapira, 2005; Mendez & Shapira, 2009). While some may express guilt or remorse for their actions, this is often judged as non-genuine, and typically no attempts at reparative behaviours or behavioural modification of any sort are made (Mendez et al., 2005; Mendez, 2010; Viskontas, Possin, & Miller, 2007).

FTD is characterized by focal atrophy of the frontal and anterior temporal lobes, leaving other brain regions relatively spared even quite late in the disease (Olney, Spina, & Miller, 2017). Each subtype has subtly different patterns of atrophy, though as in symptomatology there is overlap. In bvFTD atrophy of the frontal lobes, particularly in the frontoinsular network, the anterior cingulate cortex, and the striatum, is typically observed (Rosen et al., 2005; Seeley et al., 2009; Tosun et al., 2012). In svPPA, the anterior temporal cortex and in particular the temporal poles are most sensitive to degeneration, most often in the left hemisphere, with degeneration moving to encompass more frontal lobe and more caudal regions of the temporal lobes as the disease progresses (Collins et al., 2017; Hodges & Patterson, 2007). In nfvPPA atrophy is often more focal than other FTD subtypes, beginning in the left frontal lobes, particularly the fronto-opercular region and the insula, and remaining localized there for much of the disease course (Gorno-Tempini et al., 2004; Jordan & Hillis, 2006; Josephs et al., 2006; Ogar et al., 2006; Seeley et al., 2009).

Patients with FTD have been observed to have less physiological reactivity and disturbed autonomic outflow relative to healthy older adults and to individuals with other types of dementia (Sturm et al., 2018a). In patients with bvFTD, there is a noted blunting, or even complete absence, of autonomic responses to emotional stimuli, such as emotional faces, and to situations which elicit strong moral reactions in others, such as the trolley problem (Balconi et al., 2015; Fong et al., 2017; Hoefer et al., 2008; Marshall et al., 2019; Sturm et al., 2013). These
disturbances of autonomic reactivity occur concomitantly with declines in moral behaviour, emotional expression and comprehension, and social cognition (Fong et al., 2017; Marshall et al., 2019; O’Callaghan et al., 2016; Strikwerda-Brown et al., 2020; Sturm et al., 2018b). There is some evidence that interoceptive accuracy is impaired in some or all subtypes of FTD, though evidence for this is mixed, likely as a result of the difficulty in assessing this skill in a population that struggles with understanding instructions and with focusing attention (Abrevaya et al., 2020; García-Cordero et al., 2016; Marshall et al., 2017).

Alzheimer’s Disease

Alzheimer’s disease (AD) is a progressive neurodegenerative dementia that has a typical onset of clinically diagnosable symptoms after 65 years of age, though the onset of disease-related changes may occur years before notable symptoms develop (Dubois et al., 2007; Sperling et al., 2011). AD most often begins as a decline in memory for recent events that worsens over time (Burns & Iliffe, 2009). Other common early symptoms are word-finding and language fluency deficits, executive dysfunction, and difficulty with spatial navigation (Allison et al., 2016; Arnáiz & Almkvist, 2003; Bäckman et al., 2004; Grober et al., 2008; Henderson, Mack, & Williams, 1989; Morris, 2005; Weiner et al., 2008). Structural and functional imaging studies of AD have identified the medial temporal lobes, particularly the hippocampus, as the early site for hypometabolism and atrophy (De Santi et al., 2001; Du et al., 2001; Jack et al., 1997; Jack et al., 2002; Visser et al., 1999). Atrophy and hypometabolism in AD is often diffuse and may involve the wider temporal lobes as well as the parietal lobes and some areas of the frontal lobes, particularly the posterior cingulate cortex (Chen et al., 2011; Huang et al., 2020; Minoshima et al., 1997; Mosconi et al., 2006; Nestor et al., 2003; Wenk, 2003).
AD often has concomitant emotional disturbances such as depression, irritability, and agitation, particularly as the disease progresses (Burke et al., 2019; Lyketsos & Olin, 2002). Whether there is a disturbance of basic emotional processes is less clear. While the subjective experience of emotions appears to be unchanged in AD, the expression of emotion via the face and the voice has been found to alter, consistent with a disruption in emotional regulation and emotional behavioural suppression (Burton & Kaszniak, 2006; Henry et al., 2009; Smith, 1995). There is mixed evidence as to whether emotional processing skills, measured through facial affect and prosody recognition, remain intact in AD (Bucks & Radford, 2004; Torres Mendonça de Melo Fádel et al., 2019; Wiechetek et al., 2011). While emotional priming and conditioning appear to be disrupted in AD (Hoefer et al., 2008; Padovan et al., 2002), there is no evidence that ANS responses to emotion are disturbed in AD; indeed, normal responses have been observed in AD in response to emotional distress and fear conditioning (Hoefer et al., 2008; Fong et al., 2017). There is also little evidence to suggest that patients with AD lose their theory of mind or ability to feel guilty in concept, though their recognition of their responsibility or understanding of guilt-inducing situations is likely to decline over the course of the disease as a function of cognitive deficits (Fong et al., 2017; Heitz et al., 2016). No study to date has investigated the way in which guilt may be affected specifically in AD.

**Dementia with Lewy Bodies and Parkinson’s Disease**

Dementia with Lewy Bodies (DLB) and Parkinson’s disease (PD) are two disorders on the spectrum of synucleinopathies, neurodegenerative diseases that are caused by the abnormal aggregation of the protein alpha-synuclein in the brain (Mendoza-Velásquez et al, 2019; Villar-Piqué et al., 2015). DLB is characterized by a predominance of early cognitive changes that include hallucinations, cognitive fluctuations, and REM sleep behaviour disorder, along with
motor symptoms which appear at the same time as, or subsequent to, cognitive complaints (McKeith et al., 2017; Walker et al., 2015). PD, by contrast, begins predominantly as a movement disorder, with symptoms of slowness of movement, rigidity, tremor, and postural instability, which later often progress to include cognitive and neuropsychiatric symptoms (Aarsland, Marsh, & Schrag, 2009; Politis et al., 2010; Postuma et al., 2015; Sveinbjornsdottir, 2016). Both disorders frequently include a significant degree of dysautonomia, the dysregulation or dysfunction of the ANS, and these symptoms may predate the clear onset of either motor or cognitive complaints (Mendoza-Velásquez et al, 2019; Palma, 2018). This dysautonomia may arise centrally, stemming from dysfunction in cortical structures, or peripherally, due to damage of structures in the peripheral nervous system (Coon, Cutsforth-Gregory, & Benarroch, 2018). In PD and DLB, symptoms of dysautonomia occur heterogeneously and may affect any autonomic component, such as thermoregulatory, gastrointestinal, urogenital, or cardiovascular systems (Leclair-Visonneau et al., 2018; Mendoza-Velásquez et al, 2019). Atrophy typically begins in the medulla oblongata and olfactory bulb, before progressing to include the basal ganglia, particularly the substantia nigra pars compacta, which is often most sensitive to and hardest affected by degeneration (Braak et al., 2006; Davie, 2008). In both disorders other brain regions such as the nucleus basalis, limbic cortex, cingulate cortex, and other cortical and subcortical structures have been observed to be affected with varying degrees of frequency (Jellinger, 2004). DLB in particular seems to be more likely to feature widespread pathology of the cortex (Donaghy & McKeith, 2014; Jellinger, 2004).

Like AD, both PD and DLB have been associated with emotional disturbance, particularly depression and anxiety (Aarsland et al., 2009; McKeith et al., 2017; Poewe, 2008). There is some evidence that both disorders feature decrements in social cognition, particularly
around theory of mind, and emotional cognition particularly as it relates to basic emotion recognition, but research on the topic is scant and there is some evidence that these changes may be tied to global cognitive functioning (Alonso-Recio et al., 2020; Freedman & Stuss, 2011; Gossink et al., 2018; Gray & Tickle-Degnen, 2010; Heitz et al., 2016). There is no research that directly addresses the question of guilt in either DLB or PD, though studies of depression in PD have found that patients tend to not express pathological guilt (Ehrt et al., 2006; Gotham, Brown, & Marsden, 1986). Little research has investigated ANS responses to emotions in either disorder, thus it is unknown if the known dysfunction or abnormalities in the ANS are related to these observed emotional changes. Some research has found interoceptive sensitivity and accuracy to be low in PD patients relative to healthy controls (Ricciardi et al., 2016; Santangelo et al., 2018). While no studies have investigated interoception in DLB, the insula has been found to be particularly affected in DLB, suggestive of a potential link (Fathy et al., 2019; Philippi et al., 2020; Roquet et al., 2017). Further research is needed to investigate the ways in which dysfunction in the ANS is related to emotion in both DLB and PD.

1.3 The Nonverbal Expression of Guilt

1.3.1 The Nonverbal Expression of Emotion

The conveyance of one’s internal emotional state nonverbally, whether via the face or the body, has been well established as a key element of human social interactions and communication (Ekman & Oster, 1979; Matsumoto, Yoo, & Fontaine, 2008). Facial expressions are undoubtedly the most studied form of nonverbal expression of emotion, while less research has focused on the role that bodily features such as gesture, gaze direction, or posture may play in the communication of emotion to observers. However, there is evidence to suggest that all of these features are useful indicators of the emotional state of the actor to observers, and that all
bodily and facial signals acting together are often the most successful at conveying emotion rather than any one signal in isolation (Adams & Kleck, 2003; Castellano, Kessou, & Caridakis, 2008; Dael, Goudbeek, & Scherer, 2013).

Facial expressions are movements of the muscles of the face that deform the eyes, forehead, nose, cheeks, and mouth in ways that can convey emotional meaning to observers (Russell & Fernández-Dols, 1997). Though the exact features and universality of the facial expression of emotion are in question, that facial expressions occur and convey emotional meanings is not in doubt (Jack et al., 2012; Hwang & Matsumoto, 2015). Despite the controversies, there are established systems in place for analyzing the movements of various facial muscles or muscle groups and assigning them an emotional label. The Facial Action Coding System (FACS) is perhaps the most commonly used, segmenting the face into 44 distinct action units (AU) commonly associated with emotional expressions based on underlying musculature (Ekman & Friesen, 1976). By the action of an AU, or more commonly a combination of AUs, an expression is created that may be perceived to have emotional meaning by an observer (Wojdeł & Rothkrantz, 2005). Examples of emotional facial features that are common in Western cultures are the wide smile associated with happiness, described by the AU12-Lip Corner Puller, or the flared nose and curled lip of disgust, described by AU9-Nose Wrinkler and AU10-Upper Lip Raiser, respectively (Ekman & Friesen, 1976; Wojdeł & Rothkrantz, 2005). Facial expressions may be spontaneous, instinctive and automatically triggered without intentional input from the actor, or volitional, under conscious control, and thus able to be feigned, exaggerated, or suppressed (Granhag & Strömwall, 2002; Matsumoto & Lee, 1993; Perusquía-Hernández, Ayabe-Kanamura, & Suzuki, 2019). For example, an individual may spontaneously widen their eyes and raise their eyebrows when frightened by a loud noise.
They may also offer a volitional polite smile to a friend who has told a bad joke (Ambadar, Cohn, & Reed, 2009; Gunnery, Hall, & Ruben, 2013). Gestures, the movement of some part or parts of the body alone or in conjunction to convey emotional, symbolic, or semantic meaning, have attracted some study as to how they are used to display emotion, and how successfully they are understood by observers (Dael, Mortillaro, & Scherer, 2012; McHugh et al., 2010). Gestures may be carried out by parts of the face, as in the eye-roll to indicate contempt or exasperation, or blowing a raspberry to signal derision; one or both hands, as in the rocking backward and forward of a downwards facing open hand to convey that things are “so-so;” by the head, such as by an up and down nod to indicate agreement; by the shoulders, as in a shrug to convey nonchalance or uncertainty; by the feet, as in the kick of a single foot to convey bashfulness; or by a combination of one or more of these, as in the raising of the palm of a hand with splayed fingers to meet the face to convey exasperation or disappointment (Dael, Mortillaro, & Scherer, 2012; Debras, 2017; Goodwin & Alim, 2010; Kipp & Martin, 2009; Poggi, D’Errico, & Vincze, 2010:). Gestures may accompany or enhance speech or occur independently of it, such as by mimicking actions that are being described, or by applauding (Caridakis et al., 2007; Kendon, 2018). While some gestures may be common across many cultures, most have culturally specific meanings that can vary widely from place to place (Archer, 1997; Kita, 2009; Matsumoto & Hwang, 2013). For example, in much of North America and Europe an open palm waved from side to side with the palm towards the observer indicates “hello” or “goodbye,” while in parts of Africa, Europe, and the Middle East it is an insulting, offensive gesture (Lefevre, 2011). Oftentimes gestures are specifically engineered and consciously used to convey meanings to observers as an element of verbal speech (Buck & VanLear, 2006; Kita et al., 2007). However, gestures can also occur instinctively, or against the
wishes of the actor. For example, when startled or frightened an individual may fling their arms and hands up to shield their head, or when feeling uncomfortable or defensive one may cross their arms over their chest (Buck & VanLear, 2006; Gregersen, 2005). Leakage of unintended gestures is sometimes used for deception detection in interpersonal interactions or by law enforcement (Avola et al., 2020; Cohen, Beattie, & Shovelton, 2010; Hillman, Vrig, & Mann, 2012; Pérez-Rosas et al., 2015).

Closely related to gesture is posture, the way in which the body is held in space. Like gesture, posture involves the position of the limbs, head, and torso relative to one another. However, posture is distinct from gesture as it is a held action that does not change rapidly or involve a single intentional movement, as gestures typically do (Dael et al., 2012). Taken as a whole, the position of the body can convey broad emotional states, such as openness, by an easy posture with shoulders back and relaxed and head held level, and defensiveness, as by huddled shoulders, crossed arms, and a ducked or averted head (Gregersen, 2005; Kudoh & Matsumoto, 1985; Mehrabian & Friar, 1969). Postures may also convey precise meaning, such as leaning the torso and head towards an observer to express interest (Dael et al., 2012). The evidence for postural signifiers of emotions cross-culturally is unclear, as little research has explored the topic, though what exists suggest that cultural variations do occur in posture as in other signals (Kleinsmith, De Silva, & Bianchi-Berthouze, 2006; Kudoh & Matsumoto, 1985). Posture is typically assumed at least semi-unconsciously, reflecting the internal state in a broad manner without thought (Gregersen, 2005). Like gesture, posture is often used to assess mood by law enforcement and the media (Spitters et al., 2013). However, it can easily be adopted or altered consciously either to convey meaning to an observer, or else to attempt to alter the internal state
of the actor, as in the controversial theory of “power posing” (Oosterwijk et al., 2009; Körner & Schütz, 2020).

Gaze direction is more infrequently studied, though it has attracted increasing attention in recent years. Working with other signals such as facial expression or posture, gaze at or away from an observer or a reference object may signal diverse emotional intention. One common interpretation of gaze’s involvement in the emotional expression is that it signals whether something is to be approached (by the actor directing their own gaze to an object) or avoided (by the actor looking away from an object), and thus provides an enhancement of the emotional meaning of the rest of the actor’s behaviour (Adams & Kleck, 2003; Bayliss et al., 2007). Extended into the purely social sphere, direct eye contact is often associated with aggression and dominance displays, while gaze aversion is associated with submission and withdrawal (Holland et al., 2017; Tang & Schmeichel, 2015; Toscano, Schubert, & Giessner, 2018). Emotional gaze direction often seems volitional, with the actor deciding how and where they wish to direct their gaze in order to extract information from their surroundings (Thompson et al., 2019). However, gaze redirection by emotional stimuli can also occur without conscious thought, as in for example the automatic orientation of gaze to threatening stimuli, or the orientation of gaze away from a phobic object (March, Gartner, & Olson, 2017; Staab, 2014).

1.3.2 Nonverbal Expression in Guilt

The communication of guilt to observers is key to its social function. Research has shown that expressing guilt enhances the sincerity and acceptability of apology or reparation efforts, a main feature of guilt’s ameliorative function in the wake of transgression (Hareli & Eisikovits, 2006; Smith, Anderson, & Straussberger, 2018). Given that it is therefore often expedient to express guilt in the face of wrongdoing whether it is sincerely felt or not, the verbal or textual
expression of guilt alone is often viewed with mistrust and judged to be dishonest or manipulative by observers (Khalil & Feltovich, 2018; Okimoto, Wenzel, & Hornsey, 2015). Being able to express guilt in a manner that is believable to observers is therefore of primary importance to guilt. If verbal or textual guilt is not sufficient, possessing and displaying extraverbal features of expression that are able to convey sincere guilt is paramount (Shnabel, Halabi, & SimanTov-Nachlieli, 2015; Smith, Anderson, & Straussberger, 2018).

When remorse is embodied by signals such as facial expressions, tears, or postural changes, the reparative action is judged as more sincere, and often the transgressor is viewed more positively (Hornsey et al., 2020; MacLin et al., 2009). Thus, the bodily and facial expression of guilt is key to its social utility as an emotion that is able to rapidly restore social equilibrium in the face of transgression. Despite this, only two studies to date have attempted to explore the specific facial and postural experience of guilt. Other studies have focused on the expression of shame and embarrassment, which are similar to guilt but whose expression does not necessarily have the same goals as guilt. While the expression of guilt is primarily necessary to offer apology, reparation, or contrition, the expression of shame and embarrassment serve mainly to convey submission and appeasement towards observers (Keltner & Anderson, 2000; Keltner & Buswell, 1997; Keltner, Young, & Buswell, 1997). That is, submission and appeasement are the ends of the emotional display for shame and embarrassment, while the emotional display of guilt is a component of the wider reparative or remedial action.

Keltner & Buswell (1996) sought to establish a facial expression of guilt based on three candidate expressions: self-contempt, sympathy, and pain. They did not find that any of these three emotions could be reliably identified as guilt by viewers and concluded that there was no distinct nonverbal display of guilt (Keltner & Buswell, 1996). Julle-Danière and colleagues
(2020) investigated a diverse sample of participants using a single instance of guilt induction via feigned wrong-doing, in which the participant was informed that they had accidentally destroyed critical data. This study found engagement of action units in the brow and lips, as well touching the neck with a hand, was associated with feeling guilt. When observed, guilt was identified particularly by lowering of the brow and touching of the neck (Julle-Danière et al., 2020). Neither of these studies investigated specific body postures, though past studies of shame and embarrassment have identified postural actions, specifically the collapsing of the upper body, lowering of the eyes, and tilting down of the head, as specifically important to the recognition of self-conscious emotions (Keltner, 1995; Haidt & Keltner 1999; Keltner & Anderson, 2000; Tracy & Matsumoto, 2008). Indeed, research suggests that aiming to identify shame and embarrassment predisposes the observer’s attention towards the body, and away from facial expression (App et al., 2011). There is some evidence that gaze aversion is an important expression of guilty feelings, with a guilty individual more likely to avert their eyes to the side or downwards, though evidence for this is mixed (Keltner, 1995; Pivetti et al., 2016; Yu, Duan, & Zhou, 2017). However, whether this is because a guilty person instinctually shifts their gaze to avoid looking at guilt-inducing stimuli, to convey submission, or to avoid being perceived as feeling guilty by disengaging with an observer is unclear (Yu, Duan, & Zhou, 2017). As such, while the existing research suggests the importance and ubiquity of nonverbal expressions of guilt, the precise nonverbal expression of guilt remains unclear.

1.4 Thesis Objectives and Hypothesis

The overall purpose of this thesis is to explore the expression of guilt in health and disease through two channels of expression, the autonomic nervous system and nonverbal behaviour.

This goal was addressed by three studies in which guilt was elicited in healthy adults and adults
with neurodegenerative disorders where disease related alterations in the ANS and/or central brain regions provide an opportunity to explore the impact this pathophysiology on guilt. The central hypothesis of this thesis is that guilt is an emotion that is uniquely expressed relative to other emotions in health, and the expression of guilt is affected in neurodegenerative diseases with ANS dysfunction, or frontal, insular or amygdala pathology. The results of these studies expand upon existing work in the field of the ANS in emotion, of nonverbal expressions of emotion, and of guilt in health and in disease. The results of these studies suggest further areas for research related to these topics, as well as potential treatment or diagnostic targets for disorders in which guilt is pathological.

1.4.1 Study I: The psychophysiology of guilt in healthy adults

Though guilt is described and experienced as a deeply visceral emotion, little is yet known about the psychophysiology of guilt in healthy adults (Boden & Eatough, 2019; Breugelmans et al., 2005; Potrac et al., 2017; Tangney et al., 1996). The first objective of study I was to identify whether a psychophysiological signal of guilt is detectable in healthy adults. The second objective was to establish what specific autonomic features are key to the experience of guilt in comparison to other emotions. The third objective was to characterize the potential connection between awareness of the body and guilt feelings. We hypothesized that the cognitive experience of guilt would be associated with a pattern of autonomic activations common across individuals and distinct from other emotions, and that this pattern would be marked by sympathetic nervous system predominance (Jansen et al., 1995). We further hypothesized that higher levels of awareness and attention to bodily signals would be correlated with greater experience of guilt.
### 1.4.2 Study II: The psychophysiology of guilt in neurodegenerative disorders

Past research has suggested that in FTD there are dysfunctions both of emotional responding to guilt-inducing situations and of ANS activation in response to guilt (Sturm et al., 2013; Balconi et al., 2015). In both DLB and PD there is known dysfunction of the ANS, but whether or how this relates to emotion in general and guilt in particular is not known (Mendoza-Velásquez et al., 2019; Palma, 2018). Patients with AD do not typically display the changes in emotional responding or ANS pathology seen in FTD and DLB/PD and were used primarily as a neurodegeneration comparison group. The first objective of study 2 was to identify differences between neurodegenerative disorders and healthy controls on the autonomic experience of guilt and comparison emotions. The second objective was to identify the relationship between autonomic reactivity and guilt. The third objective was to explore the differences between patient groups and healthy controls in the experience of trait guilt and actual guilt. Building on existing research as above, we hypothesized that the patient groups, particularly FTD, DLB, and PD, would display altered patterns of ANS responding to emotions in general and guilt in particular relative to their healthy peers, and that this difference would further distinguish between diagnoses. We further hypothesized that FTD patients would show autonomic hyporeactivity to guilt stimuli relative to HCs and other groups. Finally, we hypothesized that patients would show altered interoceptive awareness, and that FTD patients in particular would report lower trait guilt and display less guilt behaviours.

### 1.4.3 Study III: The nonverbal expression of guilt in healthy adults

Guilt must be expressed in order to serve its function in society (MacLin et al., 2009; Hornsey et al., 2020). It is not yet known what nonverbal features are key to the expression of guilt. Thus, the first objective of study 3 was to identify whether there is a distinct nonverbal
expression associated with the real-time experience of guilt in healthy adults. The second objective was to establish which features represent the nonverbal expression of guilt. We hypothesized that there is a unique nonverbal signature of guilt that is distinct from other emotions. Based on existing literature around self-conscious emotions including guilt, we further hypothesized that this would be characterized by negatively valanced, submissive expressions, gestures, and postures.
1.5 References


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Chapter 2: The psychophysiology of guilt in healthy adults

2.1 Introduction

Guilt is a negative moral emotion, cause by the awareness that one has performed, might perform, has been or could be the beneficiary of an action or inaction that has caused or could cause some harm or inequality to befall another party (Huhmann & Brotherton, 1997; Zeelenberg & Breugelmans, 2008). Though guilt is aversive to experience, a healthy amount of it is necessary for healthy social functioning, as it encourages prosocial behaviour and discourages antisocial behaviour (Breggin, 2015; Donohue & Tully, 2019; Tangney, Stuewig, & Mashek, 2007). Despite the importance of guilt, much remains unknown about the way that guilt is experienced in the body.

2.1.1 The Autonomic Nervous System and Emotion

The autonomic nervous system (ANS) coordinates the largely unconscious physiological regulation of the body via its two major subdivisions, the sympathetic nervous system (SNS), responsible for activation of the body in response to external or internal threat, and the parasympathetic nervous system (PSNS), responsible for energy conservation (Jänig & Häbler, 2003; Jänig, 2006; McCorry, 2007). Studies have demonstrated consistently that the ANS is activated by and during the experience of basic emotions such as anger, fear, and happiness (Kreibig, 2010; Pace-Schott et al., 2019). While both divisions are tonically active at all times, and the experience of each emotion often involves mixed SNS and PSNS activation and withdrawal, there are some clear patterns of activation. The SNS in particular appears to be activated principally for emotions which require immediate behavioural preparedness and orientation towards the stimulus, such as fear, anxiety or anger (Aue, Flykt, & Scherer, 2007;
The PSNS, by contrast, appears to be predominant in emotions which involve soothing or relaxing, such as relief or contentment (Bradley, Silakowski, & Lang, 2008; Chan & Lovibond, 1996; Christie & Friedman, 2004; Palomba et al., 2000), or emotions which involve passivity or a lack of available potential behavioural outputs to respond to or ameliorate them, such as sadness (Britton et al., 2006; Christie & Friedman, 2004; Gross, Frederickson, & Levenson, 1994; Kreibig, 2010; Schwartz, Weinberger, & Singer, 1981).

### 2.1.2 The Autonomic Nervous System and Guilt

In popular culture and in anecdotal experiences, guilt is often described as a very visceral, embodied emotion, the physical components of which are central to its experience (Boden & Eatough, 2019; Breugelmans et al., 2005; Day & Bobocel, 2013; Norbury, 2012; Potrac et al., 2017; Tangney et al., 1996). In individuals with maladaptive guilt, guilt that is excessive or not sufficient, there is evidence that the activation of the ANS is also affected. In anxiety disorders where guilt is excessive as such as posttraumatic stress disorder, obsessive-compulsive disorder, or generalized anxiety disorder, hyperreactivity of, and hypervigilance to, the ANS has been observed (De Zorzi et al., 2021; Domschke et al., 2010; Friedman & Thayer, 1998; Haines et al., 1998; Hoehn-Saric & McLeod, 2000; Hoehn-Saric, McLeod, & Zimmerli, 1991; Murphy et al., 2017; Paulus, 2013; Pruneti et al., 2010; Pruneti et al., 2016; Yoris et al., 2017). By contrast, in personality disorders where guilt is deficient, such as psychopathy, under-reactivity or absence of ANS response to emotion, and low awareness of the ANS in general, has been observed (Fung et al., 2005; Ishikawa et al., 2001; Lyons & Hughes, 2015; Nentjes et al., 2013).

In typically developing children, guilt-inducing transgressions have been linked with activation of the SNS based on peripheral nasal vasoconstriction, and with PSNS activity via
respiratory sinus arrhythmia withdrawal and heart rate deceleration (Colasante et al., 2018; Ioannou et al., 2013; Malti et al., 2016). Further studies have linked inappropriately high or low PSNS activation--measured through resting heart rate, respiratory sinus arrhythmia, and skin conductance—with low guilt and high transgressiveness in children (Colasante & Malti, 2017; Colasante et al., 2020). Taken together, these findings suggest that in healthy children there is ANS reactivity to guilty feelings, and that SNS and PSNS co-dominate in this experience.

Despite this evidence of ANS engagement in guilt, little is known concretely about the physiologic components that attend guilt. How the ANS is affected by the experience of guilt, or indeed the extent to which the ANS becomes engaged by guilt at all, has never been established in healthy adults.

2.1.3 The present study

As the extant literature thus suggests a relationship between guilt and the ANS, but has as yet failed to characterize this relationship, the objectives of the present study were to 1) investigate ANS activation during the experience of guilt in healthy adults, 2) identify the signals that were important for distinguishing guilt from other emotions, and 3) explore the connections between trait guilt, state guilt, and interoception. We hypothesized that the cognitive and affective experience of guilt would be associated with a pattern of autonomic activations common across individuals and distinct from other emotions. Based on the existing literature surrounding the bodily experience of emotion, and embarrassment and shame in particular, as well as the behaviour-focused, motivational drive of guilt, we predicted that the overall pattern of activation would show predominance of the sympathetic division of the ANS (Jansen et al., 1995; Gerlach, Wilhelm, & Roth, 2003). We further hypothesized that higher levels of awareness and attention to bodily signals would be correlated with greater cognitive, affective, and
behavioural experience of guilt. To this end, healthy adults were recruited to participate in a novel video task designed to elicit guilt and comparison emotions during the continuous monitoring of psychophysiological signals.

2.2 Method

2.2.1 Participant Characteristics and Enrollment

The sample was comprised of healthy adults recruited from the community. Participants were recruited through word of mouth, as well as flyers and advertisements placed throughout the community and on local public transit which invited interested participants to take part in research on emotion. Inclusion criteria included: age 18 to 80, normal or corrected to normal vision, normal or corrected to normal hearing, and fluency in English. Exclusion criteria included any current major neurological or psychological disorder, or the use of beta blockers. All study procedures were approved by the University of Western Ontario Research Ethics Board. Participants provided written informed consent prior to undertaking study procedures and were compensated for their time.

2.2.1.1 Sample size calculations. Using MANOVA procedures, a targeted sample size of N=100 was designed to maintain a minimum power (1-ß) of 0.95 and detect a small effect size between .14 and .23 with alpha = 0.05. Power calculations were determined using G* Power 3.1.7 (Faul et al., 2007) based on a MANOVA procedures with 1 group and 6 response variables. The power calculation was based upon estimates from a similar study which detected significant group effects with similar measures and similar tasks (Müller-Pinzler et al., 2012).

2.2.2 Stimuli

2.2.2.1 Opinions and behaviour questionnaire. Participants were asked to complete a computer-based 103-item questionnaire that they were informed would extract their opinions and
behaviours on a number of topics, including charitable giving, environmental conservation, and national identity. This questionnaire was developed by the authors based on questionnaires on similar topics created by Statistics Canada (Statistics Canada, 2021). Participants responded using yes/no, a scale from 1 (not at all) to 5 (very much), multiple choice, or free answer depending on the question (see Appendix A.1 for sample questions and response options). Before beginning the questionnaire, participants were informed that their responses would generate feedback about themselves that they would receive during the video task, and that this feedback would be based on previous survey responses (see below).

**2.2.2.2 Feedback statements.** After completing the questionnaire and before undertaking the video task, participants were reminded that they would see feedback statements. They were again told the statements would be providing them true feedback about themselves, which would be based on comparisons from Statistics Canada and prior participants. Before the onset of every video clip a linked short statement purporting to be derived from the opinions and behaviour questionnaire was presented. Each video had only one statement associated with it, which directly related to the video content. Thus, regardless of their responses on the questionnaire, every participant received the same standard set of feedback statements (see Appendix A.2). These statements were designed to make each video clip personally relevant to the participant, specifically by beginning with “You...” and containing either a comparison of themselves to others, or a description of themselves or their behaviour (i.e., “You bake less than the average Canadian” or “You feel connected to Canada”) that was related to the video’s content to maintain consistency between the comparison emotions and the guilt condition. For the guilt condition, feedback statements were written to enhance the experience of guilt by informing the participant that they were performing harmfully, or else that their inaction was bringing harm.
For example, before a video about starving children in need of donations, a participant would see “You donate less than the average Canadian,” whereas a video describing the negative environmental impacts of laundry would be preceded by the statement: “Your laundry habits waste more water than two-thirds of Canadians.” All guilt feedback statements were specifically written with the subject put in comparison with the average Canadian or person, under the assumption that most participants would not know the true average engagement of others in civic or charitable behaviours, or else were written as broad statements that the average person could accept as true about themselves, such as “You sometimes ignore charity appeals.”

2.2.2.3 Video clips. Forty short video clips from various television shows, movies, charitable agencies, and advertising campaigns were chosen to elicit the target emotions of guilt, amusement, disgust, neutral, pride, and sadness (see Appendix A.3). These emotions were selected to ensure comparisons to emotions closely related to guilt (disgust, sadness), social emotions (pride), an emotion distinct from guilt (amusement), and a baseline unemotional state (neutral). 10 videos were selected to elicit guilt, while 6 videos were chosen to elicit each of the comparison emotions. These clips were selected by the authors and tested in a pilot study of 14 people (8 female) to ensure they reliably elicited the target emotions, and to ensure that intensity, arousal, and valence ratings were consistent across emotion categories (see Appendix C). Clips lasted from 20 seconds to 2 minutes, with an average length of 1 minute. The time window in which the emotions occurred most strongly in each video were identified in the pilot study using CARMA video rating software, and only these windows were used in analysis (Girard, 2014).

2.2.2.4 State and Trait Measures. Four self-administered paper questionnaires were chosen to assess the state and trait qualities of the sample. The State-Trait Anxiety Inventory and Body
Perception Questionnaire were added to the protocol after the first 36 participants (28 female) had participated in the study.

**The Guilt Inventory**, a 45-item questionnaire, was used as a measure of guilt proneness. Participants rated their level of agreement from 1 (*agree strongly*) to 5 (*disagree strongly*) with a series of statements that are designed to establish their state guilt, trait guilt, and attachment to moral standards and rules (Jones, Schratter, & Kugler, 2000).

**The Empathy Quotient** (EQ), a 60-item questionnaire, was used to assess trait empathy. Participants rated their level of agreement from 1 (*strongly agree*) to 4 (*strongly disagree*) on a series of questions designed to establish their understanding of and connection to the emotions and opinions of others (Baron-Cohen & Wheelwright, 2004).

**The State-Trait Anxiety Inventory** (STAI), a 40-item questionnaire, was used as a measure of participant anxiety during the time of testing and in their daily lives. Participants rated their level of agreement from 1 (*not at all*) to 4 (*very much so*) on a series of statements describing their current level of anxiety, and between 1 (*almost never*) to 4 (*almost always*) on a series of statements describing their usual level of anxiety (Spielberger, Gorsuch, & Lushene, 1970).

**The Body Perception Questionnaire-Short Form** (BPQ), a 46-item questionnaire, was used to assess awareness of bodily states and autonomic reactivity with three subscales: Body Awareness (sensitivity to internal body feelings and functions), supradiaphragmatic reactivity (responsivity of organs above the diaphragm), and subdiaphragmatic reactivity (responsivity of organs below the diaphragm). Participants rated from 1 (*never*) to 5 (*always*) their level of awareness of their body and how it typically behaved (Cabrera et al., 2018).
2.2.3 Procedure

Following informed consent and demographic information collection, participants were placed in the psychophysiological monitors to allow them to become comfortable and familiar with the equipment before testing began (see Psychophysiological Assessment, below). Participants were seated in a comfortable chair in front of a computer monitor and asked to complete the opinions and behaviour questionnaire themselves. Following completion of this task the psychophysiological equipment was turned on and participants received the full task instructions. During data collection a research coordinator was separated from the participant by a standing screen. This allowed the coordinator to respond to questions, concerns, or emotional distress during the study, while reducing distraction for the participant.

2.2.3.1 Video task. The task was programmed and run in E-Prime version 3.0 (Psychology Software Tools., Pittsburgh, PA). A single feedback statement appeared on the screen and remained until the participant clicked to acknowledge it. Participants then viewed the linked video clip. After the video ended, participants were shown a black screen lasting ten seconds, during which they were instructed to think about the video and what the contents of the video made them feel. Participants then reported via selection from a list of 12 emotion words the primary emotion they felt while watching the clip (Table 2.1); participants were allowed to select only one word and instructed to pick the emotion that they felt most strongly during the video. This emotion words list contained the six target emotions as well as words potentially related to guilt (anger, contempt, embarrassment, shame), and remaining basic emotions (fear, happiness).

<table>
<thead>
<tr>
<th>Amusement</th>
<th>Embarrassment</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anger</td>
<td>Fear</td>
<td>Pride</td>
</tr>
<tr>
<td>Contempt</td>
<td>Guilt</td>
<td>Sadness</td>
</tr>
<tr>
<td>Disgust</td>
<td>Happiness</td>
<td>Shame</td>
</tr>
</tbody>
</table>

Table 2.1. Emotion options presented to participants after each video
Participants were then presented with the same 12 emotion words and asked to select any additional emotions that they felt while watching the video; during this selection they were free to pick as many of the words as they felt described their experience, or none. This was followed by a 20-second white screen which marked a rest period. This repeated in an individually randomized order until the participant had watched all 40 videos (Figure 2.1). On average, the entire video task took approximately one hour and twenty minutes.

**Fig 2.1.** Schematic of the trial design, depicting context statement, emotional video, and post-video questions.

### 2.2.3.2 Charity question.

Upon completion of the entire video task, participants were given one opportunity to donate some or all of their remuneration to a charitable organization of their choosing. After deciding whether or not to donate, participants were prompted to select the total amount out of $50 they wished to give and were able to donate any whole dollar amount between $0 and $50. Finally, participants were asked to identify the primary emotion they felt while making that decision, again selecting a single emotion from the list of 12 emotion words.
2.2.3.3 **Interoceptive awareness.** Following the charitable donation questions, participants were instructed to count their heartbeats without feeling for their pulses at their throats, wrists, or chests (Ainley, Brass, & Tsakiris, 2014; Barrett et al., 2004; Schandry, 1981). This task was added to the protocol after the first 36 participants (28 female) had participated in the study. Participants completed this task six times, twice each for intervals of 25, 35, and 45 seconds. Time intervals were randomized, so that participants were not aware of and could not anticipate the length of time they would be asked to count for. Interoceptive accuracy was calculated by dividing the number of counted heartbeats by the number of recorded heartbeats to extract a percent correct for each time period and then averaged to create one interoceptive accuracy score. Participants were instructed to report only the heartbeats that they were certain they had actually sensed, rather than to provide an estimate. After completion of the task, participants were asked to report if they had estimated or guessed while counting their heartbeat. Any who acknowledged that they had done so were removed from analysis. After this task, all psychophysiological recording equipment was removed.

2.2.3.4 **State and Trait Measures.** Following the interoceptive awareness task, self-administered paper questionnaires were completed by the participants to characterize the state and trait qualities of the sample (see 2.2.2.4 State and Trait Measures, above)

2.2.3.5 **Debrief.** Following the conclusion of all task activities, a deception check was carried out. Participants were asked to rate on a scale from 1 (*agree strongly*) to 5 (*disagree strongly*) whether they believed, on average, that the feedback statements they received were accurate and applied to them. Participants were then debriefed about the nature of the study’s deception and given the opportunity to withdraw their consent to be included in the final analysis.
2.2.4 Psychophysiological Assessment

Psychophysiological data was collected during a baseline 3-minute rest period, the entirety of the video task, the charity question, and the interoceptive awareness task. Psychophysiological data was recorded using a Biopac MP160 system at 1 kHz (Biopac Systems Inc., Goleta, CA). All psychophysiological data was collected, cleaned, and analyzed in Biopac’s AcqKnowledge 5.0 software. Electrocardiogram (ECG) signals were recorded using a standard three-electrode system, with an Ag-AgCl electrode placed below the right shoulder, one below the left shoulder, and one near the bottom of the rib cage on the left. Electrodermal activity (EDA) was recorded using two Ag-AgCl electrodes placed on the volar surface of the medial phalanges of the index and middle finger of the participant’s nondominant hand. Swallowing electromyography (EMG) was recorded using a three-electrode configuration with two Ag-AgCl electrodes placed on the right side of the larynx and a ground electrode placed on the right shoulder. Electrogastrography (EGG) was recorded using a standard three-electrode system, with one Ag-AgCl electrode placed an inch above the umbilicus, a second approximately six inches away on a 45-degree angle from the first, and a third ground electrode placed above the right hip. Respiration was recorded using the TSD201 Respiratory Effort Transducer, an elasticized belt which was fastened snugly around the participant’s torso at the approximate height of the sternum (see Appendix A Figure A.1).

2.2.5 Psychophysiological Data Cleaning and Analysis

All psychophysiological data was scored within analysis windows delineated by the onset of the emotion as identified in the pilot study, and the offset of each video. As the EGG has a slow response time, the 30 seconds immediately post video offset was also included in the analysis window for this signal. All data was examined for movement artifacts, which were confirmed
using discreetly recorded videos of participants taken throughout the task. Movement artifacts were removed from the data once identified. Data for individual videos were averaged across all videos of the same emotion as identified by the participants to create a composite score for each psychophysiological measure in each emotion. Missing data points for individuals who were missing single data points due to brief technical glitches or failures but for whom the rest of the data was usable were imputed using multivariate imputation by chained equations via the mice package version 3.11.0 (van Buuren & Groothuis-Oudshoorn, 2011) in R Studio v1.3.959 (R Core Team, 2018; RStudio Team, 2016). All psychophysioologic measures were transformed into percent of maximum possible (POMP) scores to account for individual variation and enable comparison between participants (Cohen et al., 1999). Psychophysioologic measures were chosen to reflect standard measurements reported in previous studies of emotion psychophysiology (Cacioppo, Tassinary, & Berntson, 2016; Kreibig, 2010).

Respiratory Sinus Arrhythmia (RSA) was chosen as a marker of heart rate variability, as RSA has been well validated in the literature as a measurement of parasympathetic cardiac control (Berntson et al., 1997; Berntson et al., 2016). Respiratory Sinus Arrhythmia (RSA) data was cleaned and scored using AcqKnowledge’s automated RSA analysis software, which measures the minimum and maximum R-R intervals during each cycle of respiration.

IBI was selected as a measure of heart rate that would accurately reflect changes in autonomic branch activation regardless of baseline IBI, and which is more sensitive to moment-to-moment changes in emotional state in the short term (Berntson, Cacioppo, & Quigley, 1995; Berntson et al., 2007; Lohani et al., 2018). IBI data was calculated using AcqKnowledge’s automated Find Rate function. Raw heart rate data was converted to IBI by dividing 60,000 by the identified heart rate (Berntson et al., 2016).
**Tonic EDA magnitude** was selected as a measure of electrodermal activity to account for participants who did not display measurable specific skin conductance responses related to the video stimuli (Boucsein, 2012; Dawson, Schell, & Filion, 2017). EDA data was processed through a low pass filter (0.1 Hz). Specific skin conductance responses were identified using AcqKnowledge’s automated skin conductance response program, which identified any fluctuation of 0.05 microsiemens or greater.

**Respiratory rate** was selected as a simple and effective marker of respiratory effort that has been validated in previous research (Lorig, 2016). Respiration rate data was rescaled and processed through a bandpass filter (0.05-1 Hz). Respiration rate was calculated using AcqKnowledge’s automated respiration rate program, which calculates the number of peak-to-peak breath cycles within an identified time window.

**Swallowing rate** was selected as a measurement which has been previously validated in studies of swallowing and emotion (Cuevas et al., 1995; Ritz & Thôns, 2006). Swallowing EMG data was cleaned through the removal of movement, breath and speech artifacts. EMG responses were counted as the number of absolute pulses detected in each analysis window.

**Dominant frequency of the EGG signal** was selected as a measurement which has previously been used to identify the dominant power spectra in relation to emotional experience (Stern, 2002; Levine, 2017). EGG data was amplified and filtered offline using a bandpass filter (0.01-0.5 Hz) and cleaned of breath contamination by an adaptive filter set to use the respiration channel as noise. The maximum frequency of each analysis window was extracted using a fast Fourier transform.
2.2.6 Analytic approach

All data analysis was carried out in R Studio v1.3.959 (R Core Team, 2018; RStudio Team, 2016). To account for non-normally distributed data and small sample sizes in the state, trait and charity donation data, tests were performed with bootstrapping where appropriate. Bootstrapped independent samples t-tests were carried out using the `boot.test2` function in the Rfast package v2.0.1 (Papadakis et al., 2018). Bivariate correlations between state and trait variables were performed using the `cor.test` function in the stats package v4.1.0 and the `boot` function in the boot package v1.3-25 (Canty & Ripley, 2012; Venables & Ripley, 2002). Bootstrapped ANOVAs were performed using the `aov` function in the stats package v4.1.0 and the `boot` function in the boot package v1.3-25 (Canty & Ripley, 2021; Venables & Ripley, 2002). All graphs were made using the ggplot2 package v3.3.5, and in-graph calculations were performed using the ggrepur package v0.4.0 (Kassambara, 2020; Wickham, 2016).

2.2.6.1 Relationship between emotions and psychophysiological signals

To identify the psychophysiological differences of the six psychophysiological measures across the six emotional categories, psychophysiological data was entered into a repeated-measures multivariate analysis of variance (MANOVA), with age entered as a covariate and gender entered as a between-subjects factor. As the psychophysiological data was non-normally distributed, a semi-parametric MANOVA, which allows for resampling to account for non-normal outcomes, was run using the MANOVA.RM package v0.4.2 (Friedrich, Konietschke, & Pauly, 2021). Using the repeated measures design, each of the six physiological parameter measures was compared within subjects across each of the six emotional experience to describe the overall pattern of psychophysiological differences between each emotion. To delineate significant effects observed in the MANOVA, multinominal logistic regression was carried out,
with all psychophysiological signals entered as independent variables and guilt as the reference group, Multinomial logistic regression was carried out using the `multinom` function in the `nnet` package v7.3-16 (Ripley, Venables, & Ripley, 2016). All reported $p$ values are Holm-Bonferroni corrected unless otherwise indicated.

**2.2.6.2 Trait and State measures.**

Bootstrapped independent samples t-tests were performed to compare means between genders for all state and trait measurements, as previous research has consistently found gender differences on the EQ, and in bodily and interoceptive awareness (Grabauskaitė, Baranauskas, & Griškova-Bulanova, 2017; Wakabayashi, Baron-Cohen, & Wheelwright, 2006). Bootstrapped bivariate correlations investigated the relationships between the Guilt Inventory, the EQ, the BPQ, the STAI, and selection of guilt as the primary emotion in the video task.

**2.2.6.3 Interoceptive awareness.**

To test the hypothesis that higher levels of awareness of bodily signals would be correlated with greater trait guilt, bootstrapped bivariate correlations were performed to identify the relationship between Guilt Inventory scores and heartbeat accuracy. To investigate the hypothesis that attention to bodily signals would be correlated with greater experience of guilt, bivariate correlations were performed to identify the relationship between Guilt Inventory scores and the BPQ subscales.

**2.2.6.4 Charity Donation Decision.**

To investigate the relationship between guilt and prosocial decision-making, a bootstrapped independent samples t-test was performed to comparing the Guilt Inventory scores of those who chose to donate compared to those who did not.
To explore the relationship between guilt, empathy, and charitable giving, bivariate correlations were performed between amount donated and score on the Guilt Inventory and EQ.

To analyze whether emotion affected charitable decision-making, a bootstrapped ANOVA was carried out with the emotion the participant reported feeling while making the decision to donate as the dependent variable and amount donated as the outcome variable. This was followed by post-hoc t-tests to identify specific emotion effect on the total amount donated.

2.3 Results

2.3.1 Participant demographics.

108 participants ranging in age from 18 to 77 (M=39, Med=31) participated in the study. Participants reported attending between 6 and 23 years of formal education (M=15.963, Med=16). Participants were excluded from the main analysis for failure to endorse feeling guilt as the primary emotion for any video during the video task (7), technical errors in recording of physiological data (3), and incomplete recording due to power or equipment failure (3). Thus, 95 participants (49 female) were included in the final psychophysiological data analysis.

2.3.2 Trait and state ratings.

Mean values on the EQ (Preti et al., 2011; Ohtsubo et al., 2019), the Guilt Inventory (Jones, Schratte, & Kugler, 2000; O’Connor, Berry, & Weiss, 1999), the STAI (Knight, Waal-Manning, & Spears, 1983), the BPQ (Porges. 2015), and the heartbeat accuracy task (Marshall et al., 2018; Marshall et al., 2019) were comparable to previous studies in similar populations (Table 2.2).

Significant differences were noted between genders on the EQ. Women (M=46.691, SD=10.593) scored higher than men (M=40.943, SD=9.848) on the EQ ($t(106)=2.918$, CI $[1.842, 9.653]$, $p=.004$), indicating higher mean trait empathy in the female group compared to the male group, as expected given existing knowledge about gendered differences in empathy.
(Wakabayashi et al., 2006). No differences between genders were found for the other trait and state ratings scales (Table 2.2).

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guilt Inventory</td>
<td>128.565</td>
<td>21.377</td>
<td>75-190</td>
</tr>
<tr>
<td>Empathy Quotient</td>
<td>43.870</td>
<td>10.588</td>
<td>17-73</td>
</tr>
<tr>
<td>State-Trait Anxiety Inventory</td>
<td>28.417</td>
<td>7.881</td>
<td>20-55</td>
</tr>
<tr>
<td>Trait</td>
<td>38.972</td>
<td>11.835</td>
<td>20-74</td>
</tr>
<tr>
<td>Body Perception Questionnaire</td>
<td>71.694</td>
<td>21.677</td>
<td>30-118</td>
</tr>
<tr>
<td>Body Awareness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supradiaphragmatic reactivity</td>
<td>22.347</td>
<td>7.710</td>
<td>15-48</td>
</tr>
<tr>
<td>Subdiaphragmatic reactivity</td>
<td>9.431</td>
<td>3.297</td>
<td>6-19</td>
</tr>
<tr>
<td>Heartbeat accuracy</td>
<td>0.626</td>
<td>0.202</td>
<td>0-0.95</td>
</tr>
</tbody>
</table>

Table 2.2. Means, standard deviations, and ranges for trait and state characteristics. 108 participants (55 female) completed the Guilt Inventory and EQ; 72 participants (27 female) completed the STAI, BPQ, and the heartbeat counting task.

2.3.3 Psychophysiology Results

2.3.3.1 Omnibus MANOVA. Using Pillai’s Trace, there was a significant effect of emotion category on psychophysiological signals, $F(25, 68)=3.651, p<.001, \eta^2_p=.573$ (Figure 2.2).

![Fig 2.2](image-url) Patterns of physiological measures across all emotions, showing a significant interaction between emotion and physiological signal, $F(25, 68)=3.651, p<.001, \eta^2_p=.573$
2.3.3.2 Multinomial Logistic Regression. A multinomial logistic regression confirmed that the psychophysiological signals were able to distinguish between guilt and the comparison emotions (Table 2.3).
<table>
<thead>
<tr>
<th></th>
<th>Amusement</th>
<th></th>
<th></th>
<th>Disgust</th>
<th></th>
<th></th>
<th>Neutral</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Coeff</td>
<td>SE</td>
<td>z</td>
<td>p</td>
<td>Coeff</td>
<td>SE</td>
<td>z</td>
<td>p</td>
<td>Coeff</td>
</tr>
<tr>
<td>Swallowing</td>
<td>-0.020</td>
<td>0.005</td>
<td>-1.817</td>
<td>0.069</td>
<td>0.033</td>
<td>0.004</td>
<td>3.979</td>
<td>&lt;0.001***</td>
<td>-0.041</td>
</tr>
<tr>
<td>RSA</td>
<td>-0.005</td>
<td>0.001</td>
<td>-0.552</td>
<td>0.581</td>
<td>-0.014</td>
<td>0.001</td>
<td>-1.753</td>
<td>0.080</td>
<td>-0.020</td>
</tr>
<tr>
<td>Respiration</td>
<td>0.036</td>
<td>0.001</td>
<td>3.605</td>
<td>&lt;0.001***</td>
<td>-0.006</td>
<td>0.001</td>
<td>-0.615</td>
<td>0.538</td>
<td>-0.011</td>
</tr>
<tr>
<td>EGG</td>
<td>0.057</td>
<td>0.001</td>
<td>4.814</td>
<td>&lt;0.001***</td>
<td>-0.053</td>
<td>0.001</td>
<td>-4.454</td>
<td>&lt;0.001***</td>
<td>0.038</td>
</tr>
<tr>
<td>EDA</td>
<td>0.021</td>
<td>0.001</td>
<td>2.460</td>
<td>0.014*</td>
<td>0.024</td>
<td>0.001</td>
<td>2.846</td>
<td>0.004**</td>
<td>0.016</td>
</tr>
<tr>
<td>HP</td>
<td>-0.007</td>
<td>0.001</td>
<td>-0.673</td>
<td>0.501</td>
<td>0.002</td>
<td>0.001</td>
<td>0.164</td>
<td>0.870</td>
<td>-0.014</td>
</tr>
</tbody>
</table>

|                | Pride      |           |           | Sad      |           |           |          |           |          |
|                | Coeff      | SE        | z         | p        | Coeff     | SE        | z         | p        |            |           |          |          |
| Swallowing     | 0.002      | 0.004     | 0.233     | 0.816    | 0.022     | 0.004     | 2.687     | 0.007**  |            |           |          |          |
| RSA            | 0.021      | 0.001     | -2.501    | 0.012*   | -0.023    | 0.001     | -2.840    | 0.005**  |            |           |          |          |
| Respiration    | 0.012      | 0.001     | 1.290     | 0.197    | -0.008    | 0.001     | -0.822    | 0.411    |            |           |          |          |
| EGG            | -0.075     | 0.002     | -6.047    | <0.001***| -0.042    | 0.001     | -3.656    | <0.001***|            |           |          |          |
| EDA            | 0.030      | 0.001     | 3.435     | 0.001*** | 0.017     | 0.001     | 1.969     | 0.049*   |            |           |          |          |
| HP             | -0.027     | 0.001     | -2.664    | 0.008**  | -0.003    | 0.001     | -0.295    | 0.768    |            |           |          |          |

Table 2.3. Results of multinomial logistic regression using guilt as the reference group. *=significant at the 0.05 level**=significant at the 0.01 level, ***=significant at the 0.001 level
**Electrogastrography.** EGG was able to distinguish between guilt and amusement ($z=4.814$, $p<.001$), disgust ($z=-4.454$, $p<.001$), neutral ($z=3.388$, $p<.001$), pride ($z=-6.047$, $p<.001$), and sadness ($z=-3.656$, $p<.001$), indicating that EGG is slower in guilt relative to amusement and neutral, and faster relative to disgust, pride, and sadness. (Figure 2.3)

**Electrodermal Activity.** EDA was able to distinguish between guilt and amusement ($z=2.460$, $p=.014$), disgust ($z=2.846$, $p=.004$), pride ($z=3.435$, $p<.001$), and sadness ($z=1.969$, $p<.049$), indicating that EDA magnitude is lower in guilt relative to amusement, disgust, pride, and
sadness. There was no significant effect detected for EDA when comparing guilt to neutral 
($z=1.924, p=.054$) (Figure 2.4).

**Fig 2.4.** Electrodermal activity, showing a significant difference when comparing guilt (Mdn=26.76) to amusement (Mdn=37.82) $p=.014$, guilt to disgust (Mdn=36.97) $p=.004$, and guilt to pride (Mdn=38.60) $p<.001$, ns=not significant, *=significant at the 0.05 level, **=significant at the 0.01 level.

**Swallowing Electromyography.** Swallowing rate was able to distinguish between guilt and disgust ($z=3.979, p<.001$), neutral ($z=-3.457, p<.001$), and sadness ($z=2.687, p=.007$), indicating that swallowing is lower in guilt relative to disgust and sadness, and higher in guilt relative to neutral. There was no significant effect detected for swallowing rate when comparing guilt to amusement ($z=-1.817, p=.069$) or guilt to pride ($z=.233, p=.816$) (Figure 2.5)
Fig 2.5. Swallowing rates showing a significant difference when comparing guilt (Mdn=0) to disgust (Mdn=25) $p<.001$, guilt to neutral (Mdn=7.14) $p<.001$, and guilt to sadness (Mdn=22.22) $Z=2529$, $p=.007$, $r=.306$. ns=not significant, **=significant at the 0.01 level, ***=significant at the 0.001 level

**Respiratory Sinus Arrythmia.** RSA was able to distinguish between guilt and neutral ($z=-2.510$, $p=.012$), pride ($z=-2.501$, $p=.012$), and sadness ($z=-2.840$, $p=.005$), indicating an increase in RSA and thus an increase in parasympathetic heart control in guilt relative to those emotions. There was no significant effect detected for RSA when comparing guilt to amusement ($z=-0.552$, $p=.581$) or disgust ($z=-1.753$, $p=.080$)

**Interbeat Interval.** IBI was able to distinguish between guilt and pride ($z=-2.664$, $p=.008$) indicating an increase in IBI and slowing of heart rate in guilt relative to pride. There was no
significant effect detected for IBI when comparing guilt to amusement ($z=-0.673, p=.501$), disgust ($z=0.164, p=.870$), neutral ($z=-1.427, p=.154$) or sadness ($z=-0.295, p=.768$).

**Respiration Rate.** Respiration rate was able to distinguish between guilt and amusement ($z=3.605, p<.001$), indicating that respiration is lower in guilt relative to amusement. There was no effect detected for respiration when comparing guilt to disgust ($z=-0.615, p=.538$), neutral ($z=-1.132, p=.257$), pride ($z=1.290, p=.197$), or sadness ($z=-0.822, p=.411$).

### 2.3.4 Trait guilt, body awareness, and bodily reactivity

The Guilt Inventory was positively correlated with the body awareness subscale of the BPQ, $\tau =.190$, 95% BCa CI [.011, .357], $p=.019$. There was also a positive correlation between the Guilt Inventory and the subdiaphragmatic reactivity subscale of the BPQ, $\tau =.203$, 95% BCa CI [.041, .352], $p=.017$, though the correlation with the supradiaphragmatic reactivity subscale did not reach significance, $\tau =.160$, 95% BCa CI [-.014, .308], $p=.056$. There was a negative correlation between Guilt Inventory and heartbeat accuracy, $\tau =-.247$ 95% BCa CI [-.395, -.094], $p=.002$.

### 2.3.5 Charitable giving and guilt

107 participants (55 female) responded to the charity question and were included in analysis. Three participants were excluded from the emotion identified calculation for failing to select an emotion following the donation decision.

**Donation decision.** There was no difference detected on the Guilt Inventory score between those who chose to donate ($M=127.898, SD= 20.522$) and those who chose not to ($M=129.146, SD=22.736$), $t(105)=.298$, 95% BCa CI [-7.055, 9.550], $p=.766$.

**Amount donated.** The average amount of money donated was $13.64 (SD=17.77). There was no relationship between the amount donated and the Guilt Inventory score ($\tau=-.045$, 95% BCa CI [-.197, .117], $p=.531$) or the EQ score ($\tau=.045$, 95% BCa CI [-.097, .193], $p=.533$).
Emotion identified. A bootstrapped ANOVA found a significant effect of identified emotion on amount donated, $F(3, 99)=4.939, p=.003$. Follow-up t-tests suggested that this difference was driven by higher donation amounts during positive emotions, pride and happiness ($M=25.29$, $SD=19.91$), when compared to guilt ($M=11.3$, $SD=15.25$), $t(60)=-3.067$, $p=.003$. There was no significant difference between amount donated when feeling guilty compared to neutral ($M=8.21$, $SD=15.36$), $t(73)=-.883$, $p=.380$.

2.4 General Discussion

That the ANS is responsive to basic emotional states and produces patterns of activation that are both identifiable and observable has been well established (Christie & Friedman, 2004; Kreibig, 2010; Levenson, 2014). We sought to identify whether the emotion of guilt also has an autonomic signature distinguishable from the signatures of other emotions, and to delineate the specific pattern of autonomic activations that characterize guilt. This study has provided perhaps the first evidence in healthy adults that guilt, too, generates a unique autonomic response that is detectable and unique.

First, the results establish that the cognitive experience of guilt occurs alongside a detectable pattern of autonomic outflow. Second, we found that for the autonomic outputs indexed, guilt differed from all of the other investigated emotions (amusement, disgust, neutrality, pride, sadness) on at least one measure. Finally, the results point to three prominent measures that were particularly useful to distinguish/differentiate between guilt and other emotions. These were the electrogastrogram (EGG), swallowing rate, respiratory sinus arrhythmia (RSA), and potentially electrodermal activity (EDA).

The EGG was the only signal where guilt differed from all comparison emotions. Relative to guilt, EGG activity was found to be increased, i.e., the regular contractile rhythm of
the stomach was more frequent, in amusement and neutrality, suggesting heightened activity of
the SNS and decreased activity of the PSNS during guilt relative to those emotions (Stern, 2002).
By contrast, EGG activity was lower in disgust, pride, and sadness relative to guilt, suggesting
increased influence of the PSNS and decreased SNS activity during guilt. This indicates that
guilt’s influence on stomach motility is driven by the SNS more than in amusement or neutral,
but less so than in disgust, pride, or sadness. No previous study has identified a link between the
activity of the gut and guilt. However, some research has found that sensitivity to, and reactivity
of, the gut is linked to emotional arousal and emotional experiences in healthy adults and those
with gastrointestinal disorders such as Crohn’s disease (Houghton et al., 2002; Vianna & Tranel,
2006). These results suggest a link that might be a valuable avenue for future study, particularly
as the underlying evolutionary or adaptive reason for guilt’s relative activation and inactivation
of the SNS and PSNS is not yet clear.

Swallowing rate was found to be lower in guilt relative to disgust or sadness, and higher
in guilt relative to neutral. A decrease in swallowing in guilt relative to disgust and sadness
might be suggestive of a relative increase in SNS activation in guilt, and could be related to the
sensation of subjective dry mouth, as well as actual decrease in salivation, that has been reported
during emotional upset, anxiety, and guilt (Bates & Adams, 1968; Bergdahl, Bergdahl, &
Johansson, 1997; Gemba, Teranaka, & Takemura, 1996; Gholami et al., 2017; Kubany et al.,
1996; Queiroz et al., 2002; Wesner, Noyes, & Davis, 1990). By contrast, the physical response to
sadness often necessitates the swallowing down of tears, mucous, or the lump in the throat
produced by crying or the urge to cry (Hepburn, 2004; Mori & Iwanaga, 2017; Vingerhoets et
al., 1997). Similarly, when disgusted one must swallow the excess saliva that is produced by
nausea and the urge to vomit (Horn, 2008; Hornby, 2001; van Overveld, de Jong, & Peters,
This dry mouth, combined with these contributors to swallowing in the other emotions, is the likely reason for this observed difference in swallowing response. This finding provides a useful confirmation of guilt’s uniqueness from sadness and disgust. Both disgust and sadness have, at times, been conceptualized as progenitors for, or the predominant emotion underlying, guilt (Power & Dalgleish, 2015; Turner, 2007). As negative, aversive emotions that can be elicited in moral situations and stirred by the suffering of others, sadness (for others, for oneself, for the situation) and disgust (moral disgust, disgust with oneself) often co-occur with guilt (Gangemi & Mancini, 2017; Malti et al., 2016; Olatunji, David, & Ciesielski, 2012; Ottaviani et al., 2018; Turner, 2007). In interpersonal contexts, disgust might be elicited by the moral transgressions of others (e.g., cheating, sexual deviance, theft) that could elicit guilt in the self, suggestive of a close relationship between the two emotions (Bomyea & Allard, 2017; Chapman & Anderson, 2013; Olatunji & Sawchuk, 2005). Similarly, sadness is often elicited by witnessing another being transgressed against, and the sadness of others can easily stir guilt if the observer attributes blame for that sadness to themselves (Roos, Salmivalli, & Hodges, 2011; Turner, 2007; Turner & Stets, 2006).

RSA differed between guilt and neutral pride, and sadness, with the increased RSA in guilt relative to these emotions suggestive of a vagally-mediated deceleration of the heart, and thus increased PSNS activity (Butler, Wilhelm, & Gross, 2006). This aligns well with existing research that has associated heart rate deceleration with moral emotions, and suggests that it is particularly useful for the experience of emotions that are both negative and moral (Malti et al., 2016; Colasante et al., 2018). Previous research has suggested that increased vagal tone at rest and in response to emotional stimuli is correlated with sustained attention, arousal, and emotional regulation (Balzarotti et al., 2017; Butler et al., 2006; Frazier, Strauss, & Steinhauer,
 Increased RSA in guilt may be reflective of heightened attention directed towards negative information about the self, and employment of emotional regulation strategies to cognitively respond to or modify the negative feelings elicited (Sharvit et al., 2015; Thompson, 1991; van Dijk et al., 2017).

EDA magnitude was found to be higher in amusement, disgust, pride, and sadness relative to guilt. This finding was unexpected, as guilt is typically conceptualized as an arousing and motivating experience which would be expected to increase EDA reactivity in healthy adults (Boucsein, 2012; Bradley et al., 2001; Cuthbert et al., 2000). Instead, these results suggest that there is less SNS activation of the skin in guilt relative to these other emotions. The reason for this unexpected result is unclear, although one previous study did find a nonsignificant decline in EDA signal in children in between the anticipation and act of transgression (Colasante et al., 2018), while another suggests that EDA is less reactive when confronted with negative social stimuli compared to negative nonsocial stimuli or positive social stimuli (Britton et al., 2006). There is also evidence that emotions that evoke passivity or to which there is no immediate action available, such as depression or contentment, tend to show SNS withdrawal and PSNS activation (Kreibig, 2010). It is possible that during the video task participants became passive as they knew that there was no action that could be taken to alleviate guilt in the short-term, as there was nobody to make reparations or apologies to, and no way to halt the guilt-inducing behaviour. Thus, SNS withdrawal predominated as there was no need for increased ANS activation to prepare for or prompt a behavioural response. Further research is needed to confirm and develop upon these findings.

The other psychophysiological signals differed between guilt and only one other emotion. IBI distinguished between guilt and pride, with a lengthened IBI observed during guilt compared
to pride, suggestive of a comparative deceleration in heart rate, and therefore an increase in PSNS control of the heart, in guilt. A similar lengthening of IBI has been observed in sadness relative to happiness and in fear relative to neutrality and appears to be related to valence in emotional situations rather than arousal (Frazier et al., 2004; Fredrickson & Levenson, 1998; Krumhansl, 1997). As guilt and pride are both social emotions that differ in terms of valence, IBI might be useful along the spectrum of negativity and positivity in social emotions. Respiration rate was lower in guilt compared to amusement, suggesting an increase in relative PSNS control of breathing in guilt. This difference might be due to laughter, which participants often engaged in during amusement videos but not during guilt videos. However, there was no effect of crying during sadness videos on the respiration rate, while participants typically did not cry during guilt videos.

Overall, the observed pattern of EGG, swallowing rate, RSA, and EDA in guilt relative to other emotions suggests a mixed picture of SNS and PSNS activation and deactivation across the various effectors measured, with relative activations of either branch dependent on the comparison emotion. This aligns well with autonomic patterns observed for basic emotions such as sadness, which displays a mix of SNS and PSNS activity, and even coactivation (Gross et al., 1994; Hendriks, Rottenberg, & Vingerhoets, 2007; Mori & Iwanaga, 2017).

**Body perception, interoception and guilt.** Based on the body of literature that has linked interoceptive awareness and body sensitivity with empathy and emotional awareness (Craig, 2002; Grynberg & Pollatos, 2015; Mul et al., 2018; Stoica & Depue, 2020; Terasawa et al., 2014), self-reports of bodily awareness and interoceptive accuracy of heartbeat were included to test the hypothesis that higher levels of awareness of bodily signals in would be correlated with greater trait guilt. We found that self-reported trait guilt proneness was correlated with self-
reported bodily awareness and reactivity of subdiaphragmatic organs. This coincides well with
the finding that the EGG in particular appears to be part of the physiologic signature of guilt and
likely useful for distinguishing guilt from other emotions. In our sample, trait guilt was
negatively correlated with heartbeat accuracy, suggesting that increased guilt proneness is
associated with decreased ability to accurately detect cardiac-related interoceptive information.
This finding seems counterintuitive, given the above finding about body awareness, as well as
previous studies suggesting that anxious and empathic individuals are typically more attuned to
their bodily states than others (Domschke et al., 2010; Dunn et al., 2010; Mul et al., 2018; Tan et
al., 2018). The reason for this unexpected correlation is unclear. Although debriefing at the end
of the task did not reveal different strategies to account for this finding, it is possible that
individuals high in guilt proneness were more likely to follow the rules and not attempt to count
seconds, estimate a heart rate, or surreptitiously measure their own heartrate, while individuals
low in guilt were more likely to do so. As this was an unpredicted finding, it will be important to
determine its replicability.

**Guilt and the Charity Decision.** Previous research has suggested that trait empathy is associated
with increased charitable giving, while the evidence for the involvement of trait guilt is less clear
(Kim & Kou, 2014; Loewen, Lyle, & Nachshen, 2009; McGeever, 2019; Torstveit, Sütterlin, &
Lugo, 2016). We found no effect of Guilt Inventory score on intention to donate or amount of
money donated. We were also unable to detect an effect of Empathy Quotient on amount
donated. This suggests that the decision to donate to charity in our sample was not connected to
trait guilt or empathy. It is possible that this difference is driven by the interaction of
characteristics beyond guilt and empathy that were not captured in this study that have in the past
been shown to impact donation decisions, such as socioeconomic status and religiosity (Lasby & Barr, 2015).

We found a correlation between amount of money donated and identification of positive emotion as the emotion felt during the donation decision. Greater amounts of money were donated by participants who identified feeling positive emotions such as happiness and pride, compared to those who identified negative emotions such as anger or sadness, those who identified neutrality, or those who identified guilt. There was no difference detected in the amount of money donated between people who identified feeling guilty and those who identified neutrality. This was unexpected, as individuals who feel guilty or anticipate feeling guilty are more likely to attempt to ameliorate those feelings by performing some reparative action such as donating to unrelated charities when they are presented with the opportunity (Chatterjee, Mishra, & Mishra, 2010; Darlington & Macker, 1966; Tangney et al., 1996). However, some recent research has suggested that feelings of guilt might drive people to be reparative only when the offered reparative action is directly and explicitly targeted at the guilt-inducing scenario, and perhaps only when it can be observed by the perceived victims or witnesses of the guilt-inducing behaviour (Cryder, Springer, & Morewedge, 2012; Graton & Ric, 2017). As the donation decision was not clearly directed at any group or charity and made with no observers or acknowledgment of the participants’ responses, it is possible that guilty-feeling individuals did not feel that personal, private sacrifice of money to an unknown charitable entity would successfully ameliorate guilt feelings.

2.4.1 Limitations

One potential limitation of this study is the semantic ambiguity around the word “guilt” in common usage. Often, “guilt” and “shame” might be used interchangeably in casual speech,
despite several differences that have been well characterized in emotion research (Tangney, 1992; Tangney et al., 1996). Potential conflation of terms also occurs, to a lesser extent, between guilt and embarrassment (Tangney et al., 1996; Withers & Sherblom, 2008). These two social emotions often co-occur, resulting in challenges in distinguishing between them in naturalistic settings (Smith & Ellsworth, 1985). In the present task, participants were given the opportunity to choose guilt, shame, or embarrassment as their main or secondary emotions, and trials identified as eliciting either shame or embarrassment were removed from analysis as not-guilt. Despite these measures, it is possible that some contamination between these terms occurred. A future study might instruct participants on the precise definitions of key emotional terms in advance of commencing the study, to ensure that participants are generating the clearest labels for each emotional experience. A second potential limitation is that no measurement of the intensity of emotion experienced was taken after each video. Instead, participants provided an estimate of the average overall strength of the emotions experienced during the videos at the end of the video task. It is therefore not possible to know if the psychophysiological patterns detected were parametrically correlated with the intensity of emotion experienced. Future studies should include intensity measurements following each video or incorporate intensity ratings during the videos. This would help to better understand the relationship between emotional intensity and psychophysiological patterns. The psychophysiological scores were taken as arithmetic means of the physiological response for the identified window of emotion during each video. This represents a relatively conservative estimate of the psychophysiological response. Individuals might not consistently experience the target emotion, might experience fluctuating levels of emotional intensity, or might experience different predominant emotions throughout the video course (Davydov, Zech, & Luminet, 2011). Future studies could examine more granular epochs
to attempt to capture specific psychophysiological responding that might be lost to averaging. A further potential limitation is the amount of demographic information captured, particularly as it might inform patterns observed on the charitable donation item. Past research has shown that age, socioeconomic status, minority group membership, religiosity, gender, and numerous other demographic characteristics contribute to a willingness to donate to charitable causes (Chan, 2020; de Abreu et al., 2015; Gittell & Tebaldi, 2006; Lasby & Barr, 2015; Leslie, Snyder & Glomb, 2013). Future studies interested in the role of guilt in charitable donations would benefit from more comprehensive demographic information collection to provide context for the charitable decision that might interact with guilt proneness or guilt feelings.

2.4.2 Conclusion

This study sought to address the current gap in the literature around the psychophysiological nature of guilt by investigating which autonomic signals are associated with guilt relative to other emotions in healthy adults. Guilt was accompanied with a pattern of SNS and PSNS activations that could separate it from the planned comparison emotions, particularly EGG, swallowing rate and EDA indices. These findings lay the groundwork for future studies exploring excesses or paucities of guilt, such as obsessive-compulsive disorder, PTSD, psychopathy, or frontotemporal dementia. Additional future directions include explorations of autonomic responses in children who are developing guilt, or in populations outside of the North American context who might have different conceptualizations and experiences of guilt.
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Chapter 3: The psychophysiology of guilt in neurodegenerative disorders

3.1 Introduction

Guilt is a negative social emotion, experienced due to the realization that one has brought about a harm to another through one’s action or inaction (Huhmann & Brotherton, 1997; Zeelenberg & Breugelmans, 2008). Guilt is important for normal social functioning in humans as it restrains antisocial behaviour, such as lying and cheating, and encourages prosocial behaviours, such as cooperation and reparation (Breggin, 2015; Donohue & Tully, 2019). Though it is important and normal to experience, guilt can be pathological. This may be due to excessive guilt, as in obsessive-compulsive disorder, or absent guilt, as in psychopathy (Basile et al., 2014; Seara-Cardoso et al., 2016).

3.1.1 Guilt in neurodegenerative conditions

There is evidence that guilt is affected in some neurodegenerative conditions, but the extent to which this occurs across various diagnostic types is unclear. Frontotemporal dementia (FTD) has attracted the most research in this area, as lack of empathy and declines in moral behaviour are among the constellation of symptoms that typify particularly the behavioural variant (bvFTD) of this disease (Mendez et al., 2005). In FTD, there is clear evidence that guilt is often affected early in the disease course and worsens with progression (Rasmussen et al., 2019). Individuals with FTD often commit antisocial acts ranging from being rude to those around them to serious criminal behaviour such as sexual assault (Mendez et al., 2005; Mendez, 2010; Rasmussen et al., 2019; Tanguy et al., 2021). Prosocial sentiments such as guilt and pity are rarely expressed, and while patients may sometimes claim to feel remorse, they tend to show no genuine care for the consequences of their behaviour or the suffering of others, and do not
voluntarily perform reparative behaviours (Diehl-Schmid et al., 2013; Fong et al., 2017; Mendez et al., 2005; Moll et al., 2011). Less research exists surrounding guilt in Alzheimer’s disease (AD), dementia with Lewy bodies (DLB) or Parkinson’s disease (PD). These diseases often display emotional disturbance such as depression, anxiety, and irritability (Aarsland, Marsh, & Schrag, 2009; Burke et al., 2019; Lyketsos & Olin, 2002). However, evidence for effects on social cognition and guilt are mixed. In AD, socially embarrassing behaviour is much less typically seen, and both theory of mind and empathic concern seem to be intact well into the disease course (Fong et al., 2017; Swartz et al., 1997). In LBD and PD, there may be decrements in social functioning and emotional recognition, but whether this is a specific deficit or tied to global cognitive function isn’t known (Alonso-Recio et al., 2020; Freedman & Stuss, 2011; Gossink et al., 2018; Gray & Tickle-Degnen, 2010; Heitz et al., 2016).

3.1.2 The ANS in neurodegenerative conditions

There is also evidence that the autonomic nervous system (ANS) is impacted in neurodegeneration. In FTD, there is blunted reactivity of the ANS to emotional situations, as indexed by skin conductance (Fong et al., 2017; Marshall et al., 2019; Sturm et al., 2013). This under-reactivity has been directly tied to declines in moral behaviour (Marshall et al., 2019; Strikwerda-Brown et al., 2020; Sturm et al., 2018a). Interceptive accuracy, the ability to correctly assess one’s own internal state, may be impaired in this population (Abrevaya et al., 2020; García-Cordero et al., 2016; Marshall et al., 2017). In AD there is no known effect on the ANS in emotion, and normal physiological responses have been observed in AD in emotional distress and fear conditioning (Fong et al., 2017; Hoefer et al., 2008). There is some evidence for interoceptive deficits in AD, but these may relate to cognitive impairment (Abrevaya et al., 2020). Dysautonomia is a very common feature of both DLB and PD (Mendoza-Velásquez et al,
2019; Palma, 2018), affecting regulation of all aspects of the ANS including cardiac, bladder, bowel, sweating, and ocular systems (Thaisetthawatkul et al., 2004). How this may relate to emotions or guilt is not yet known. Interoceptive accuracy is possibly affected in PD (Ricciardi et al., 2016; Santangelo et al., 2018), but it is unknown if it is affected in DLB.

3.1.3 The present study

Taken together, the existing literature suggests that guilt and the ANS are both affected in some neurodegenerative diseases, and that dysfunction in guilt and the ANS may be related. However, little research yet has investigated and compared guilt, the ANS, and the interaction between them across multiple neurodegenerative disorders. The objective of this study is threefold, 1) to identify differences between patients with neurodegenerative disorders and between patients and healthy controls in the autonomic experience of guilt and comparison emotions, 2) to identify the relationship between autonomic reactivity and guilt, and 3) to explore the differences between patient groups and healthy controls in the experience of trait guilt and actual guilt across neurodegenerative dementias. We hypothesized that 1) patients with FTD, DLB, or PD would display altered patterns of ANS responding to emotions in general and guilt in particular relative to healthy controls (HC) and patients with AD, and that this difference would further distinguish between diagnoses; that 2) patients with FTD would show autonomic hyporeactivity to guilt stimuli relative to HCs and other groups, while patients with DLB and PD would show disturbance of guilt correlated with their dysautonomia, and patients with AD would display patterns of activation and experience of guilt similar to HCs; and that 3) patients would show altered interoceptive awareness, and that patients with FTD in particular would report lower trait guilt and display less guilt behaviours, patients with DLB or PD would display some alterations in trait and state guilt, and AD patients would display state and trait guilt similarly to
HCs. To this end, patients and healthy controls were invited to take part in a study in a video task designed to elicit guilt and comparison emotions during the continuous recording of psychophysiological signals.

3.2 Method

3.2.1 Participant Characteristics and Enrollment

Sixty-three participants took part in the study, including 12 patients with Alzheimer’s disease (4 female), 12 patients with frontotemporal dementia (1 female), 10 patients with dementia with Lewy bodies (1 female), 5 patients with Parkinson’s disease (3 female), and 24 age-matched healthy controls with no history of major neurological or psychological disorder (11 female). At time of recruitment, patients with AD met the National Institute on Aging-Alzheimer’s Association criteria for probable AD (DeKosky et al., 2011), patients with DLB met the criteria of the Fourth Consensus Report of the DLB Consortium for probable DLB (McKeith et al., 2017), and PD patients met the Movement Disorder Society’s clinical diagnostic criteria for diagnosis of probable PD (Postuma et al., 2015). In the FTD group, 3 patients met the criteria for the semantic variant and 1 met the criteria for the nonfluent/agrammatic variant (Gorno-Tempini et al., 2011), while the remaining 8 met the international consensus criteria for the behavioural variant of FTD (Rascovsky et al., 2011).

Patients were recruited from the Cognitive Neurology and Alzheimer Research Centre at the Parkwood Institute in London, Ontario, Canada and through advertisements in doctor’s offices in the community. Control participants were recruited from the community through word of mouth, flyers, and volunteer databases at the centre. For the patient groups, inclusion criteria included: age 30 to 90, normal or corrected to normal vision, normal or corrected to normal hearing, and fluency in English. Exclusion criteria included any current major neurological or
psychological disorder that was not accounted for by the neurodegenerative condition of interest, cognitive impairment that precluded comprehension of the task, or the use of beta blockers. For healthy controls, inclusion criteria included: age 50 to 90, normal or corrected to normal vision, normal or corrected to normal hearing, and fluency in English. Exclusion criteria included any current major neurological or psychological disorder, cognitive impairment that precluded comprehension of the task, a score of less than 88 on the ACE-III, or the use of beta blockers. All study procedures were approved by the University of Western Ontario Health Sciences Research Ethics Board. Participants and, where necessary, their substitute decision makers, provided written informed consent prior to undertaking study procedures and were compensated for their time.

3.2.1 Sample size calculations. Using MANOVA procedures, a targeted sample size of N=20 per group is designed to maintain a minimum power (1-ß) of 0.95 and detect an effect size between .57 and .68 with alpha = 0.05. Power calculations were determined using G* Power 3.1.7 (Faul et al., 2007) based on a MANOVA procedures with 4 groups and 10 response variables. The power calculation is based upon estimates from a similar study which detected significant group effects with effect sizes ranging from $d=.48$ to $d=.93$ with similar measures and similar tasks in patient compared to healthy populations (de Wied, van Boxtel, Mathys, & Meeus, 2012).

3.2.2 Stimuli

The task and task procedures are based on those described in study I, though some task procedures have been shortened and simplified, as detailed here, to better account for the attention and memory deficits of the patient populations.
3.2.2.1 *Opinions and behaviour questionnaire*. Participants were asked to complete a computer-based 66-item questionnaire that they were informed would extract their opinions and behaviours on a number of topics, including charitable giving, environmental conservation, and national identity. This questionnaire was developed by the authors based on questionnaires on similar topics created by Statistics Canada (Statistics Canada, 2021). It was derived from the opinions and behaviours questionnaire in study I, but with simplified language and fewer questions. Participants responded using yes/no, a scale from 1 (*not at all*) to 5 (*very much*), multiple choice, or free answer depending on the question (see Appendix B.1 for sample questions and response options). Before beginning the questionnaire, participants were informed that their responses would generate feedback about themselves that they would receive during the video task, and that this feedback would be based on previous survey responses (see below).

3.2.2.2 *Feedback statements*. Prior to each video clip, a short statement purporting to be derived from the opinions and behaviour questionnaire were presented to the participant. Regardless of their responses on the questionnaire, every participant received a standard set of feedback statements (see Appendix B.2). After completing the questionnaire and before undertaking the video task, participants were reminded that they would see the statements, which they were again told would be providing them true feedback about themselves, which would be based on comparisons to Statistics Canada and prior participants. These statements were designed to enhance the emotional experience of each clip by making it relevant to the participant. For example, before a video about starving children in need of donations, a participant might see “You donate less than the average Canadian;” before a video describing the negative environmental impacts of computers: “You waste more energy than average.” All emotional feedback statements were written with the subject put in comparison with the average Canadian
or person, under the assumption that most participants would not know the true average engagement of others in civic or charitable behaviours, or else were broad statements that the average person could accept as true about themselves, such as “You sometimes ignore charity appeals.”

3.2.2.3 Video clips. Thirty-three short video clips from various television shows, movies, charitable agencies, and advertising campaigns were chosen to elicit the target emotions of guilt, amusement, disgust, neutral, pride, and sadness (see Appendix B.3). These emotions were selected to ensure comparisons to emotions closely related to guilt (disgust, sadness), social emotions (pride), and emotion distinct from guilt (amusement), and an unemotional state (neutral). These clips were selected by the authors and tested in a pilot study of 14 people (8 female) to ensure they reliably elicited the target emotions, and to ensure that intensity, arousal, and valence ratings were consistent across emotion categories (see Appendix C). The videos in this study were derived from the list of videos used in study I. To shorten the video task for the patient cohort, seven videos were removed, one each from every emotion category other than guilt, from which two videos were removed, for a total of 8 videos aiming for guilt induction, and 6 each for the other emotions. The videos were selected for removal based on the ability of the videos to elicit the target emotion in the 50+ year old cohort in study I; the least successful video in each emotion category was removed. The time windows in which the emotions occurred most strongly in each video were identified in the pilot study using CARMA video rating software, and only these windows were used in later analysis (Girard, 2014). Clips lasted from 20 seconds to 2 minutes, with an average length of 1 minute.
3.2.2.4 Patient state and trait measures. Patients were asked to complete coordinator- or self-administered paper questionnaires regarding themselves following the conclusion of the video task.

*Addenbrooke’s Cognitive Examination-III English Version A* (ACE-III), a brief coordinator-administered cognitive test with 21 cognitive tasks spread across five subscales: attention, memory, verbal fluency, language, and visuospatial function, designed to comprehensively assess cognitive functioning out of 100 (Hsieh et al., 2013). The ACE-III has been validated for use in dementia (Hsieh et al., 2013).

*The Guilt Inventory*, a 45-item questionnaire, was used as a measure of guilt proneness. Participants rated their level of agreement from 1 (*agree strongly*) to 5 (*disagree strongly*) with a series of statements that are designed to establish their state guilt, trait guilt, and attachment to moral standards and rules (Jones, Schratter, & Kugler, 2000). This inventory has been previously validated in older adult populations (Kugler & Jones, 1992).

*The Empathy Quotient* (EQ), a 60-item questionnaire, was used to assess trait empathy. Participants rated their level of agreement from 1 (*strongly agree*) to 4 (*strongly disagree*) on a series of questions designed to establish their understanding of and connection to the emotions and opinions of others (Baron-Cohen & Wheelwright, 2004). This measure has been previously used in older adults (Bailey, Henry & Von Hippel, 2008).

*The State-Trait Anxiety Inventory* (STAI), a 40-item questionnaire, was used as a measure of participant anxiety during the time of testing and in their daily lives. Participants rated their level of agreement from 1 (*not at all*) to 4 (*very much so*) on a series of statements describing their current level of anxiety, and between 1 (*almost never*) to 4 (*almost always*) on a series of statements describing their usual level of anxiety (Spielberger, Gorsuch, & Lushene, 1970). This
method has been used and validated in older adults and in individuals with dementia (Bergua et al., 2012; Twelftree & Qazi, 2006).

**The Body Perception Questionnaire-Short Form** (BPQ), a 46-item questionnaire, was used to assess awareness of bodily states and autonomic reactivity with three subscales: Body Awareness (sensitivity to internal body feelings and functions), supradiaphragmatic reactivity (responsivity of organs above the diaphragm), and subdiaphragmatic reactivity (responsivity of organs below the diaphragm). Participants rated from 1 (*never*) to 5 (*always*) their level of awareness of their body and how it typically behaved (Cabrera et al., 2018). This questionnaire has been previously validated in older adults and has been used in clinical populations with brain damage in frontal regions (Pearson & Pfeifer, 2020, Wang et al., 2019).

**The Composite Autonomic Symptom Score -31** (COMPASS), a 31-item questionnaire, was used to assess symptoms of autonomic dysfunction with six subscales of symptom types: orthostatic intolerance, vasomotor, secretomotor, gastrointestinal, bladder, and pupillomotor. Participants responded whether 1 (*yes*) they experienced symptoms of autonomic dysfunction or 2 (*no*) they did not. If they were present, participants were able to rate how frequently these symptoms occurred from 1 (*rarely*) to 4 (*almost always*) or 1 (*never*) to 4 (*constantly*) or 1(*never*) to 3 (*a lot of the time*), how severe the symptoms were from 1 (*mild*) to 3 (*severe*), and whether these symptoms were worsening or improving, from 1 (*getting much worse*) to 6 (*completely gone*) (Sletten et al., 2012). This inventory has been validated in older adults and in patients with neurodegeneration (Kim et al., 2017; Lipp, Sandroni, & Ahlskog, 2009; Sletten et al., 2012).

**The Unified Parkinson’s Disease Rating Scale** (UPDRS), a 42-item coordinator- or clinician-administered questionnaire designed to assess symptoms of Parkinsonism with four subscales: mentation, behaviour, and mood; activities of daily living; motor examination, and complications
of therapy. The administrator assessed symptoms such as intellectual impairment, walking, speech, or orthostatic hypotension on a scale from 0 (none, normal) to 4 (severe, marked, complete loss) (Fahn et al., 1987). This questionnaire has been used and validated in PD and DLB (Martínez-Martín et al., 1994; Petrova et al., 2015).

3.2.2.5 Caregiver state and trait measures. Caregivers were asked to complete self-administered paper questionnaires regarding their perspective of the patient and their functioning. The Cambridge Behavioural Inventory Revised (CBI-R), a 45-item questionnaire, was used to assess neurobehavioural and psychiatric symptoms on 10 subscales: memory and orientation, everyday skills, self-care, abnormal behaviour, mood, beliefs, eating habits, sleep, stereotypic and motor behaviours, and motivation. Caregivers rated from 0 (never) to 4 (constantly) the presence of these symptoms in the patient (Wear et al., 2008). The CBI-R has been previously validated for use in dementia groups (Wear et al., 2008).

The Interpersonal Reactivity Index (IRI), a 28-item questionnaire designed to assess the patient’s empathy on 4 subscales: empathic concern (feeling emotional concern for others), perspective taking (ability to take on the perspectives of others), fantasy (emotional identification with fictional characters) and personal distress (negative emotional reactions to the distress of others). Caregivers rated from 1 (does not describe him/her well) to 5 (describes him/her very well) the presence of these empathic facets in the patient’s daily life. (Davis, 1980). The IRI has been previously validated in patient groups (Dermody et al., 2016)

The Revised Self-Monitoring Scale (RSMS), a 13-item questionnaire measures sensitivity and responsiveness to the emotional states of others and the subject’s ability to alter behaviour in the face of those emotions, altered to be from an outside perspective rather than the patient’s own. Caregivers rated from 0 (certainly, always false) to 5 (certainly, always true) their agreement
with how the statements fit with the patient’s current behaviour (Lennox & Wolfe, 1984; Toller et al., 2020). The RSMS has been validated in patient groups (Toller et al., 2020).

The Composite Autonomic Symptom Score-31 Caregiver Version (COMPASS-C), a modified version of the original a 31-item questionnaire, was used to establish the caregiver’s observations of the patient’s autonomic dysfunction, with six subscales of symptom types: orthostatic intolerance, vasomotor, secretomotor, gastrointestinal, bladder, and pupillomotor. Caregivers responded whether 1 (yes) they noticed the patient had symptoms of autonomic dysfunction or 2 (no) they did not observe these symptoms. If they were present, caregivers were able to rate how frequently these symptoms occurred from 1 (rarely) to 4 (almost always) or 1 (never) to 4 (constantly) or 1 (never) to 3 (a lot of the time), how severe the symptoms they observed were from 1 (mild) to 3 (severe), and whether these symptoms were worsening or improving, from 1 (getting much worse) to 6 (completely gone) (Sletten et al., 2012).

3.2.3 Procedure

Following informed consent, and demographic information collection, participants completed the ACE-III to assess cognitive function. Participants were then placed in the psychophysiological monitors to allow them to become comfortable and familiar with the equipment before testing began (see Psychophysiological Assessment, below). Participants were seated in a comfortable chair in front of a computer monitor and asked to complete the opinions and behaviour questionnaire. If they were unable to navigate the computer controls themselves, participants were asked to respond aloud to the questions while a research coordinator completed the questionnaire on their behalf. Following completion of this task the psychophysiological equipment was turned on and participants received the full task instructions. During data collection a research coordinator sat to the side and behind the participant so as to record their
responses, as well as respond to questions, concerns, or emotional distress during the study, while minimizing interruption or distraction for the participant.

**3.2.3.1 Video task.** The task was programmed and run in Tobii Pro Lab v1.86.12040 (Tobii Group, Stockholm, Sweden). A single feedback statement appeared on the screen and remained for ten seconds. Participants then viewed the linked video clip. After the video ended, participants were shown a black screen lasting ten seconds, during which they were instructed to think about the video and what the contents of the video made them feel. Participants then reported via selection from a list of the 6 target emotion words the primary emotion they felt while watching the clip (Table 3.1); participants were allowed to select only one word and instructed to pick the emotion that they felt most strongly during the video.

<table>
<thead>
<tr>
<th>Amusement</th>
<th>Neutral</th>
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<tbody>
<tr>
<td>Disgust</td>
<td>Pride</td>
</tr>
<tr>
<td>Guilt</td>
<td>Sadness</td>
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*Table 3.1. Emotion options presented to participants after each video*

Participants were then presented with the same 6 emotion words and asked to select any additional emotions that they felt while watching the video; during this selection they were free to pick as many of the words as they felt described their experience, or none. This was followed by a 20-second white screen which marked a rest period. This repeated in a randomized order in one of four randomly assigned blocks until the participant had watched all 33 videos (Figure 3.1).
3.2.3.3 Charity question. Upon completion of the entire video task, participants were given one opportunity to donate some or all of their remuneration to a charitable organization of their choosing. After deciding whether to donate, participants were prompted to select the total amount out of $50 they wished to give and were able to donate any whole dollar amount between $0 and $50. Finally, participants were asked to identify the primary emotion they felt while making that decision, again selecting a single emotion from the list of 6 emotion words.

3.2.3.4 Interoceptive awareness. Following the charitable donation questions, participants were instructed to count their heartbeats without feeling for their pulses at their throats, wrists, or chests (Ainley, Brass, & Tsakiris, 2014; Barrett et al., 2004; Schandry, 1981). Participants completed this task six times, twice each for intervals of 25, 35, and 45 seconds. Time intervals were randomized, so that participants were not aware of and could not anticipate the length of time they would be asked to count for. Interoceptive accuracy was calculated by dividing the number of counted heartbeats by the number of recorded heartbeats to extract a percent correct.
for each time period and then averaged to create one interoceptive accuracy score. Participants were instructed to report only the heartbeats that they were certain they had actually sensed, rather than to provide an estimate. After instruction, participants were asked to confirm their understanding of the task. If they did not, the task was halted. Throughout the task participants were reminded of the task instructions and of what they were supposed to do to successfully complete the task as needed. If participants were unable to comprehend or adequately perform the task due to attentional or memory deficits, they were marked as did not finish and removed from the analysis. After completion of the task, participants were asked to report if they had estimated or guessed while counting their heartbeat. Any who acknowledged that they had done so were removed from analysis. After this task, all psychophysiological recording equipment was removed.

3.2.3.5 State and Trait Measures. Paper questionnaires (see Patient state and trait measures described above) were completed by the participants on their own or with the assistance of a research coordinator to characterize the state and trait qualities of the sample.

3.2.3.6 Debrief. Following the conclusion of all task activities, a deception check was carried out. Participants were asked to rate on a scale from 1 (agree strongly) to 5 (disagree strongly) whether they believed, on average, that the feedback statements they received were accurate and applied to them. Participants were then debriefed about the nature of the study’s deception and given the opportunity to withdraw their consent to be included in the final analysis.

3.2.4 Psychophysiological Assessment

Psychophysiological data was collected during a baseline 3-minute rest period, the entirety of the video task, the charity question, and the interoceptive awareness task. Psychophysiological data was recorded using a Biopac MP160 system at 1 kHz (Biopac Systems
Inc., Goleta, CA). All psychophysiological data was collected, cleaned, and analyzed in Biopac’s AcqKnowledge 5.0 software. Electrocardiogram (ECG) signals were recorded using a standard three-electrode system, with an Ag-AgCl electrode placed below the right shoulder, one below the left shoulder, and one near the bottom of the rib cage on the left. Electrodermal activity (EDA) was recorded using two Ag-AgCl electrodes placed on the volar surface of the medial phalanges of the index and middle finger of the participant’s right hand. Swallowing electromyography (EMG) was recorded using a three-electrode configuration with two Ag-AgCl electrodes placed on the right side of the larynx and a ground electrode placed on the right shoulder. Electrogastrography (EGG) was recorded using a standard three-electrode system, with one Ag-AgCl electrode placed an inch above the umbilicus, a second approximately six inches away on a 45-degree angle from the first, and a third ground electrode placed above the right hip. Respiration was recorded using the TSD201 Respiratory Effort Transducer, an elasticized belt which was fastened snugly around the participant’s torso at the approximate height of the sternum. Blood pressure was recorded using the Continuous Noninvasive Arterial Pressure (CNAP) 500 Monitor System consisting of a finger cuff sensor placed on the first and second finger of the left hand and a noninvasive blood pressure cuff on the right upper arm for calibration (CNSystems Medizintechnik GmbH, Graz, Austria) (see Appendix B Figure B.1). After psychophysiological equipment was affixed, participants were seated in a comfortable chair and had their hands placed into soft silicone restraints that were attached to the chair arms to prevent fidgeting or removal of the equipment.

3.2.5 Psychophysiological Data Cleaning and Analysis

All data was scored within analysis windows delineated by the onset of the emotion as identified in the pilot study, and the offset of each video. As the EGG has a slow response time,
the 30 seconds immediately post video offset was also included in the analysis window for this signal. All data was examined for movement artifacts, which were confirmed using discreetly recorded videos of participants taken throughout the task. Movement artifacts were removed from the data once identified.

Psychophysiologic analysis measures were largely the same as those presented in study I with some additions to better reflect the known autonomic differences in neurodegenerative disorders, particularly the blood pressure and RMSSD measures. The measures were chosen to reflect standard measurements reported in previous studies of psychophysiology in emotion (Cacioppo, Tassinary, & Berntson, 2017; Kreibig, 2010).

**Respiratory Sinus Arrythmia** (RSA) was chosen as a frequency-domain marker of PSNS-mediated heart rate variability, as RSA has been well validated in the literature as a measurement of parasympathetic cardiac control (Berntson et al., 1997; Berntson et al., 2016). RSA data was cleaned and scored using AcqKnowledge’s automated Multi-epoch HRV and RSA-Spectral analysis software, which measures the minimum and maximum R-R intervals during each cycle of respiration.

**Root Mean Square Successive Difference** (RMSSD) was chosen as a time-series measurement of PSNS-mediated heart rate variability that is capable of parsing total variance in heart rate variability separately from basal heart rate (Berntson et al., 2016; van der Mee et al., 2020). RMSSD was derived from cardiac data using AcqKnowledge’s automated Multi-epoch HRV and RSA-Spectral function.

**Interbeat interval** (IBI) was selected as a measure of heart rate that would accurately reflect changes in autonomic branch activation regardless of baseline IBI, and which is more sensitive to moment-to-moment changes in emotional state in the short term (Berntson et al., 1995;
Berntson et al., 2016; Lohani et al., 2018). IBI data was calculated using AcqKnowledge’s automated Find Rate function. Raw heart rate data was converted to IBI by dividing 60,000 by the identified heart rate (Berntson et al., 2016).

Systolic (SBP) and diastolic blood pressure (DBP) were chosen as measures of sympathetic activation of the heart and circulatory system which are known to be affected in some neurodegenerative disorders (Ahmed et al., 2015; Isonaka et al., 2019). SBP and DBP were both extracted by AcqKnowledge’s automated Arterial Blood Pressure analysis routine. SBP and DBP were both taken as the average blood pressure for the entire analysis window.

Tonic electrodermal activity (EDA) magnitude was selected as a measure of electrodermal activity to account for participants who did not display measurable specific skin conductance responses related to the video stimuli (Boucsein, 2012; Dawson, Schell, & Filion, 2017). EDA data was manually cleaned of artifacts and processed through a low pass filter (0.1 Hz). EDA was calculated as the average value in microsiemens across the filtered signal for each analysis window.

Frequency of non-specific skin conductance response (ns.SCR) was selected as a measure of sympathetic activation that was able to tolerate the length of the recordings and the potential multiple stimulus points created by the video stimuli (Dawson, Schell & Filion, 2017; van der Mee et al., 2020). Specific and non-specific skin conductance responses were identified using AcqKnowledge’s automated Event-Related EDA Analysis routine, which identified any fluctuation of 0.01 microsiemens or greater, but not greater than 2.5 microsiemens. Frequency was calculated as the number of identified ns.SCR responses in an analysis window.

Respiratory rate was selected as a simple and effective marker of respiratory effort that has been validated in previous research (Lorig, 2016). Respiration rate data was rescaled and
processed through a bandpass filter (0.05-1 Hz). Respiration rate was calculated using AcqKnowledge’s automated respiration rate program, which calculates the number of peak-to-peak breath cycles within an identified time window.

**Swallowing rate** was selected as a measurement which has been previously validated in studies of swallowing and emotion (Cuevas et al., 1995; Ritz & Thös, 2006). Swallowing EMG data was cleaned through the removal of movement, breath and speech artifacts. EMG responses were counted as the number of absolute pulses detected in each analysis window.

**Dominant frequency of the EGG signal** was selected as a measurement which has previously been used to identify the dominant power spectra in relation to emotional experience (Levine, 2017; Stern, 2002). EGG data was amplified and filtered offline using a bandpass filter (0.01-0.5 Hz) and cleaned of breath contamination by an adaptive filter set to use the respiration channel as noise. The maximum frequency of each analysis window was extracted using a fast Fourier transform.

### 3.2.6 Analytic approach

All data analysis was carried out in R Studio v1.3.959 (R Core Team, 2018; RStudio Team, 2016). Psychophysiological data for individual videos was averaged across all videos of the same emotion as identified by the participants to create a composite score for each psychophysiological measure in each emotion. All psychophysiological data was examined for outliers, defined as a value that differed from the mean by three or more standard deviations, and outliers were removed from further analysis. Missing data points for individuals who were missing single data points due to brief technical glitches or failures but for whom the rest of the data was usable were imputed using multivariate imputation by chained equations via the *mice* package v3.11.0 (van Buuren & Groothuis-Oudshoorn, 2011). All psychophysioologic measures
were transformed into percent of maximum possible (POMP) scores to account for individual variation and enable comparison between participants (Cohen et al., 1999). To account for non-normally distributed data, small sample sizes, and data that could not be log-transformed due to predominance of 0 values, nonparametric tests and bootstrapping were performed where appropriate using. Bootstrapping was carried out using the boot function in the boot package v1.3-28 (Canty & Ripley, 2021). To correct for multiple comparisons, all relevant p values are Holm-Bonferroni corrected unless otherwise indicated. All graphs were made using the ggplot2 package v3.3.5, and in-graph calculations were performed using the ggpubr package v0.4.0 (Kassambara, 2020; Wickham, 2016).

3.2.6.1 Relationship between emotions and psychophysiological signals

To identify the differences between the diagnostic groups in the six psychophysiological measures across the six emotional categories, psychophysiological data was entered into a repeated-measures multivariate analysis of variance (MANOVA), with age entered as a covariate and gender and diagnostic category entered as between-subjects factors. As the psychophysiological data was non-normally distributed, a semi-parametric repeated measures MANOVA, which allows for resampling to account for non-normal outcomes, was run using multRM function in the MANOVA.RM package v0.5.1 (Friedrich, Konietschke, & Pauly, 2021). Using the repeated measures design, each of the six physiological parameter measures was compared within subjects, between diagnostic groups, and across each of the six emotional experiences to describe the overall pattern of psychophysiological differences between each emotion in each group. For the primary analysis, a MANOVA was performed for the psychophysiological differences between emotion types defined by the intended target emotion for each video, regardless of whether the participant reported feeling that emotion or not. This
was selected a priori as the main approach to analyzing differences between the diagnostic groups, to avoid confounds in emotion endorsement due to poor emotional insight in patients with FTD, as well as other potential difficulties due to cognitive deficits or perseverative responses. To delineate significant effects observed in the MANOVAs, planned contrasts with age and gender as covariates were carried out using the *pairs* and *emmeans* functions in the *emmeans* package v1.6.2-1 (Lenth, 2021).

To explore the relationship between autonomic reactivity— that is, the degree to which autonomic signals change in response to emotional stimuli— and guilt, change scores were calculated for each psychophysiological score by subtracting raw neutral scores from raw guilt scores. These scores were entered into Quade’s ANCOVAs to assess 1) the relationship between trait guilt and physiological reactivity to guilt 2) the interaction between psychophysiological reactivity and diagnosis on trait guilt. Age and gender were entered as covariates and Guilt Inventory score was the outcome using the *aov* function in the *stats* package v4.1.0 (Venables & Ripley, 2002). To explore whether emotional reactivity across various measures can predict diagnostic category, a multinomial logistic regression was carried out for both intended and reported emotion using the *multinom* function in the *nnet* package v7.3-16 (Ripley, Venables, & Ripley 2016).

3.2.6.2 Trait and State measures

As trait and state measures were not normally distributed, Kruskal-Wallis tests were carried out to compare means between the diagnostic categories on all state and trait measurements using the *kruskal.test* function and significant results were followed up with the *pairwise.wilcox.test* function in the *stats* package v4.1.0 (Venables & Ripley, 2002). Bootstrapped bivariate correlations investigated the relationships between the Guilt Inventory,
the EQ, the BPQ, the STAI, and selection of guilt as the primary emotion in the video task. Bivariate correlations were performed using the corr.test function in the psych package v2.1.6 (Revelle, 2021).

3.2.6.3 Interoceptive awareness

To investigate differences in interoceptive awareness between diagnostic categories, a one-way ANOVA was carried out using the aov function and followed up using the pairwise.t.test function in the stats package v4.1.0 (Venables & Ripley, 2002).

To test the hypothesis that higher levels of awareness of bodily signals would be correlated with greater trait guilt, a bivariate correlation was performed to identify the relationship between Guilt Inventory scores and heartbeat accuracy. Bivariate correlations using Kendall’s τ were performed between the Guilt Inventory, IRI, and BPQ subscales using the corr.test function in the psych package v2.1.6 (Revelle, 2021).

3.2.6.4 Charity Donation Decision

To test the association between diagnostic category and amount of money donated, and as amount of money was not normally distributed, a Kruskal-Wallis test was carried out using the kruskal.test function in the stats package v4.1.0 (Venables & Ripley, 2002).

To investigate the relationship between emotion felt while making the charitable decision and diagnostic category, a bootstrapped Chi-squared test was performed using the chisq.test function in the stats package v4.1.0 (Venables & Ripley, 2002). A two-way ANOVA was performed using the aov function in the stats package v4.1.0 (Venables & Ripley, 2002) to identify whether emotion felt during the charity decision task influenced amount given as a factor of diagnostic category.
To explore the relationship between guilt, empathy, and charitable giving, bivariate correlations were performed between amount donated and score on the Guilt Inventory and EQ using the `corr.test` function in the `psych` package v2.1.6 (Revelle, 2021).

### 3.3 Results

#### 3.3.1 Participant demographics.

Due to COVID-19 research restrictions and halts, we were unable to reach our target sample size. 63 participants ranging in age from 50 to 88 (M=69, Med=71) participated in the study. Participants reported attending between 8 and 27 years of formal education (M=15.16, Med=16). Participants were excluded from the main analysis for cognitive testing scores below the cutoff of 88/100 on the ACE-III (2), technical errors in recording of physiological data (3), or noncompliance with task instructions (1). Due to small group sizes and given demographic and disease similarities (Jellinger & Korczyn, 2018), the PD and DLB group were combined into one unit for analysis. See Appendix B Table B.5 for comparison between PD and DLB groups on demographic and testing variables. 57 participants (20 female) were included in the final psychophysiological analysis, 12 AD (4 female), 12 FTD (1 female), 14 DLB/PD (4 female), and 19 HCs (10 female; Table 3.2).

#### 3.3.2 Trait and state ratings.

There were no significant differences in the total scores between groups on the Empathy Quotient, Guilt Inventory, STAI, BPQ Supradiaphragmatic, and no differences between patient groups on the IRI, RSMS, CBI, or Caregiver COMPASS, though both the CBI, \(H(2)=5.51, p=.064\), and Caregiver COMPASS, \(H(2)=5.67, p=.058\), approached significance (Table 3.2). For the CBI-R, this difference was largely driven by the high scores observed for the FTD group (M=70, Med=70.5, SD=21.8) compared to the AD (M=49.3, Med=48, SD=23.8) or DLB/PD
For the Caregiver COMPASS, it was driven by a higher score in the DLB/PD group (M=19.2, Med=19) relative to FTD (M=13.12, Med=13, SD=6.1) or AD (M=8.7, Med=8, SD=8.3).

There were significant differences noted between groups on age, education, the BPQ Bodily Awareness subscale, BPQ Subdiaphragmatic Reactivity subscale, the COMPASS, and the ACE-III (Table 3.2). Age, $H(3)=11.685, p=.008$, was found to be higher in the AD group (M=76.7, Med=78, SD=5.8) relative to the HC group (M=65.42, Med=67, SD=10.6), $p=.004$.

There was no significant difference detected between any other group on age. Education, $H(3)=14.23, p=.003$, was higher in the HC group (M=17, Med=17, SD=3.0) compared to the FTD (M=13, Med=12, SD=4.4), $p=.012$, and the AD (M=13, Med=12, SD=2.7), $p=.015$, groups.

Table 3.2. Means, standard deviations, and ranges for trait and state characteristics.

<table>
<thead>
<tr>
<th>N (female)</th>
<th>AD</th>
<th>FTD</th>
<th>DLB/PD</th>
<th>HC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 (4)</td>
<td>12 (1)</td>
<td>14 (4)</td>
<td>19 (10)</td>
</tr>
<tr>
<td>Age</td>
<td>M</td>
<td>SD</td>
<td>Range</td>
<td>M</td>
</tr>
<tr>
<td>Education</td>
<td>13.3</td>
<td>2.7</td>
<td>10-17</td>
<td>12.8</td>
</tr>
<tr>
<td>Guilt Inventory</td>
<td>110.9</td>
<td>14.7</td>
<td>80-129</td>
<td>125.7</td>
</tr>
<tr>
<td>Empathy Quotient</td>
<td>36.1</td>
<td>15.8</td>
<td>19-62</td>
<td>39.3</td>
</tr>
<tr>
<td>State-Trait Anxiety Inventory</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>26.7</td>
<td>7.8</td>
<td>20-45</td>
<td>25.8</td>
</tr>
<tr>
<td>Trait</td>
<td>30.8</td>
<td>9.1</td>
<td>20-43</td>
<td>34.2</td>
</tr>
<tr>
<td>Body Perception Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Awareness</td>
<td>40.3</td>
<td>14.5</td>
<td>26-69</td>
<td>39.7</td>
</tr>
<tr>
<td>Supradiaphragmatic Reactivity</td>
<td>18.2</td>
<td>4.1</td>
<td>15-29</td>
<td>19.3</td>
</tr>
<tr>
<td>Subdiaphragmatic Reactivity</td>
<td>8.1</td>
<td>2.8</td>
<td>6-14</td>
<td>7.3</td>
</tr>
<tr>
<td>Heartbeat accuracy</td>
<td>0.09</td>
<td>0.22</td>
<td>0-0.61</td>
<td>0.17</td>
</tr>
<tr>
<td>COMPASS</td>
<td>8.7</td>
<td>8.8</td>
<td>0-25</td>
<td>11.3</td>
</tr>
<tr>
<td>ACE-III</td>
<td>62.4</td>
<td>12.5</td>
<td>39-75</td>
<td>63.6</td>
</tr>
<tr>
<td>RSMS</td>
<td>31.8</td>
<td>7.4</td>
<td>19-41</td>
<td>26.5</td>
</tr>
<tr>
<td>IRI</td>
<td>77.6</td>
<td>15.8</td>
<td>45-100</td>
<td>70.3</td>
</tr>
<tr>
<td>CBI-R</td>
<td>49.3</td>
<td>23.8</td>
<td>8-85</td>
<td>70.0</td>
</tr>
<tr>
<td>COMPASS-C</td>
<td>8.9</td>
<td>8.3</td>
<td>0-24</td>
<td>13.3</td>
</tr>
</tbody>
</table>

There were significant differences noted between groups on age, education, the BPQ Bodily Awareness subscale, BPQ Subdiaphragmatic Reactivity subscale, the COMPASS, and the ACE-III (Table 3.2). Age, $H(3)=11.685, p=.008$, was found to be higher in the AD group (M=76.7, Med=78, SD=5.8) relative to the HC group (M=65.42, Med=67, SD=10.6), $p=.004$.

There was no significant difference detected between any other group on age. Education, $H(3)=14.23, p=.003$, was higher in the HC group (M=17, Med=17, SD=3.0) compared to the FTD (M=13, Med=12, SD=4.4), $p=.012$, and the AD (M=13, Med=12, SD=2.7), $p=.015$, groups.
No other significant differences were noted on education. On the BPQ Bodily Awareness subscale, $H(3)=10.90, p=.012$, scores were significantly lower in the FTD group ($M=39.7, Med=39, SD=7.0$) relative to HCs ($M=48.8, Med=49.0, SD=10.1$), $p=.047$, and significantly higher in the DLB/PD ($M=58.1, Med=54.0, SD=17.8$) group relative to AD ($M=40.3, Med=35.5, SD=14.5$), $p=.023$ and FTD, $p=.008$. On the BPQ Subdiaphragmatic Reactivity subscale, $H(3)=12.43, p=.006$, the difference was driven by low scores in FTD ($M=7.3, Med=7, SD=1.7$) and higher scores in DLB/PD ($M=10.4, Med=10.0, SD=2.5$), $p=.009$. No other significant differences were noted. On the COMPASS, $H(3)=17.5, p<.001$ scores were higher in the DLB/PD group ($M=23.7, Med=25, SD=8.9$) compared to the AD ($M=8.7, Med=6, SD=8.8$), $p=.005$, FTD ($M=11.3, Med=12, SD=6.9$), $p=.007$, and HC groups ($M=13.7, Med=14, SD=7.9$), $p=.012$. There were no other significant differences between groups. On the ACE-III, $H(3)=34.76, p<.001$, the difference was driven by the higher scores in the HC group ($M=94.2, Med=95, SD=3.6$) relative to the AD ($M=62.4, Med=67.5, SD=12.5$), $p<.001$, FTD ($M=63.6$, Med=63, SD=16.9), $p<.001$, and DLB/PD groups ($M=70.5, Med=71.0, SD=15.7$), $p<.001$. There were no significant differences between patient groups on the ACE-III.

### 3.3.3 Psychophysiology Results

#### 3.3.3.1 MANOVA

Using the Wild Bootstrapping modified ANOVA-type statistic (WildBS MATS), there was a significant effect of emotion on psychophysiological signals, $F(5, 257)=22.184, p=.002$, $\eta^2_p=.068$, and an interaction of emotion and diagnosis, $F(15,855)=24.123, p=.048$, $\eta^2_p=.061$. There was no main effect of diagnosis, $F(3,171)=6.002, p=.339$, $\eta^2_p=.010$.

#### 3.3.3.2 Planned Contrasts
All planned contrasts are computed with age and gender as covariates and corrected using Tukey’s method for multiple comparisons. See Appendix B.6 for full tables of results.

**Swallowing Electromyography**

In the DLB/PD group there was a significant difference in swallowing rate between guilt (M=12.73, SD=12.76) and disgust (M=34.52, SD=19.06), $t(276)=-3.26$, $p=.016$, $g=1.344$, and between guilt and sadness (M=32.86, SD=27.58), $t(276)=-3.29$, $p=.014$, $g=.937$. In the HC group the difference in swallowing rate between guilt (M=19.64, SD=13.00) and disgust (M=33.61, SD=17.04) was significant $t(276)=-2.976$, $p=.037$, $g=.922$, while the difference between guilt and sadness (M=31.90, SD=18.87) approached significance $t(276)=-2.385$, $p=.071$, $g=.757$. No other significant differences were noted for any group in any comparison to guilt (Figure 3.2).

There were no significant differences in swallowing rate within diagnostic groups for guilt compared to any other emotion.

![Swallowing electromyography in all emotions across all patient groups showing significant comparisons between guilt and disgust in the HC group, and both guilt and disgust and sadness and disgust in the DLB/PD group. *$=$significant at the $p=.05$ level](image)

**Fig 3.2.** Swallowing electromyography in all emotions across all patient groups showing significant comparisons between guilt and disgust in the HC group, and both guilt and disgust and sadness and disgust in the DLB/PD group. *$=$significant at the $p=.05$ level
Skin Conductance Level Magnitude

During the experience of guilt, there was a significant difference between the HC (M=29.26, SD=17.89) and FTD (M=53.7, SD=15.35), t(276)\(=-3.59, p=.002, g=1.435\), the HC and AD (M=46.4, SD=17.68) groups, t(276)\(=-2.69, p=.038, g=.963\), and the FTD and DLB/PD (M=39.7, SD=32.25) groups, t(276)=2.72, p=.035, g=.539 (Figure 3.3). There were no significant differences within diagnostic groups for guilt compared to any other emotion.

![EDA magnitude in all emotions across all patient groups showing significant comparisons during guilt between the HC and AD and HC and FTD groups, as well as between the FTD and DLB/PD groups. *=significant at p=.05, **=significant at p=.01](image)

Diastolic Blood Pressure

In the FTD group, the difference in diastolic blood pressure between guilt (M=49.59, SD=19.32) and amusement (M=40.47, SD=19.54) approached significance, t(276)=2.694, p=.080, g=0.469. There were no other significant differences within diagnostic groups for guilt compared to any other emotion, nor were there any significant differences between diagnostic groups during the experience of guilt.
Non-specific skin conductance response

There were no significant differences in ns.SCRs between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.

Electrogastrography

There were no significant differences in EGG signal between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.

Interbeat Interval

There were no significant differences in IBI between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.

Respiratory Sinus Arrhythmia

There were no significant differences in RSA between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.

Root Mean Square Successive Differences

There were no significant differences in RMSSD between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.

Respiration Rate

There were no significant differences in respiration rate between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.

Systolic Blood Pressure

There were no significant differences in systolic blood pressure between diagnostic groups during the experience of guilt, or within diagnostic groups for guilt in comparison to any other emotion.
3.3.3.3 Emotional reactivity results.

Controlling for age and gender, neither change in physiological signals $F(1,57)=.001, p=.972$, diagnosis, $F(3,171)=.994, p=.403$, nor interaction between the change in physiological signals and diagnosis, $F(3,171)=2.074, p=.116$, was associated with scores on the Guilt Inventory.

A multinomial logistic regression was conducted to explore whether the pattern of psychophysiological responses predicted diagnosis. With age and gender included as covariates, this regression was statistically significant $\chi^2(30) = 59.570, p=.001$. The model identified differences between the HC group and the patient groups on a number of psychophysiological measures (Table 3.3). In the HC group respiration increased ($M=3.69, SD=20.21$), while it declined in all patient groups. This difference was significant in the AD group ($M=38.65, SD=36.53$), $\beta=-.061, CI [-.10, -.02]$, and the FTD group ($M=-31.31, SD=34.97$), $\beta=-.059, CI [-.10, -.02]$, and approached significance in the DLB/PD group ($M=-22.30, SD=40.75$), $\beta=-.038, CI [-.08, .001]$. In the HC group EDA magnitude increased ($M=3.13, SD=14.41$), while in the FTD ($M=-15.23, SD=14.24$) $\beta=-0.21, CI [-.03, -.07]$ and DLB/PD groups ($M=-5.07, SD=10.16$) $\beta=-.10, CI [-.20, -.001]$ it decreased. In the HC group, IBI decreased significantly ($M=-4.81, SD=15.34$), while in the DLB/PD group it did not ($M=-0.77, SD=.34$) $\beta=.006, CI [.004, .20]$. 
<table>
<thead>
<tr>
<th></th>
<th>AD</th>
<th></th>
<th>FTD</th>
<th></th>
<th>DLB/PD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeffs.</td>
<td>SE</td>
<td>Odds Ratio</td>
<td>CI 95%</td>
<td>Coeffs.</td>
<td>SE</td>
</tr>
<tr>
<td>EGG</td>
<td>0.036</td>
<td>0.040</td>
<td>1.037</td>
<td>-0.04 – 0.11</td>
<td>0.060</td>
<td>0.050</td>
</tr>
<tr>
<td>IBI</td>
<td>0.060</td>
<td>0.050</td>
<td>1.062</td>
<td>-0.04 – 0.16</td>
<td>0.082</td>
<td>0.056</td>
</tr>
<tr>
<td>Respiration</td>
<td>-0.061</td>
<td>0.021</td>
<td>0.941**</td>
<td>-0.10 – -0.02</td>
<td>-0.059</td>
<td>0.022</td>
</tr>
<tr>
<td>Swallowing</td>
<td>0.028</td>
<td>0.043</td>
<td>1.028•</td>
<td>-0.06 – 0.11</td>
<td>-0.018</td>
<td>0.046</td>
</tr>
<tr>
<td>RSA</td>
<td>-0.039</td>
<td>0.062</td>
<td>0.962</td>
<td>-0.16 – 0.08</td>
<td>-0.094</td>
<td>0.065</td>
</tr>
<tr>
<td>RMSSD</td>
<td>-0.034</td>
<td>0.055</td>
<td>0.967</td>
<td>-0.14 – 0.08</td>
<td>0.010</td>
<td>0.052</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>0.065</td>
<td>0.044</td>
<td>1.068</td>
<td>-0.02 – 0.15</td>
<td>0.040</td>
<td>0.051</td>
</tr>
<tr>
<td>Diastolic BP</td>
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<td>0.044</td>
<td>1.026</td>
<td>-0.06 – 0.11</td>
<td>0.002</td>
<td>0.040</td>
</tr>
<tr>
<td>ns.SCR</td>
<td>0.009</td>
<td>0.025</td>
<td>1.009</td>
<td>-0.04 – 0.06</td>
<td>0.020</td>
<td>0.028</td>
</tr>
<tr>
<td>EDA</td>
<td>-0.019</td>
<td>0.056</td>
<td>0.989</td>
<td>-0.13 – 0.09</td>
<td>-0.205</td>
<td>0.069</td>
</tr>
</tbody>
</table>

Table 3.3. Coefficients, standard errors, odds ratios and 95% confidence intervals for the patient groups as compared to healthy controls •=significant at \( p=.1 \), *=significant at \( p=.05 \), **=significant at \( p=.01 \).
3.3.4 Trait guilt, state guilt, and anxiety results

After Holm-Bonferroni corrections for multiple comparisons, there was a positive correlation between the Guilt Inventory and selection of guilt as the primary emotion during the video task for the AD cohort, $\tau_b = .567$, 95% BCa CI [-.092, .953], $p = .049$, but this correlation was not found for any other cohort. There was a correlation between the Guilt Inventory and amount donated for the DLB/PD cohort $\tau_b = .833$, 95% BCa CI [.242, .795], $p = .034$, but this correlation was not noted for any other group. There was a correlation between the state anxiety and the Guilt Inventory in AD, $\tau_b = .589$, 95% BCa CI [.035, .963], $p = .032$, and between trait anxiety and the Guilt Inventory in the HC group $\tau_b = .361$, 95% BCa CI [-.035, .963], $p = .040$, but no significant SAI or TAI correlations occurred for any other group.

Using a Kruskal-Wallis test, there was no significant difference detected between the diagnostic groups in terms of the number of times that guilt was endorsed as the primary emotion felt during the video task, $H(3) = 6.345$, $p = .100$ (Figure 3.4)

**Fig 3.4.** Number of times that guilt was selected as the primary emotion felt during the video task by each diagnostic group
3.3.5 Interoceptive awareness results

Two participants from the AD group and two from the FTD group were excluded from the interoceptive accuracy analysis due to failure to comprehend task instructions or perform the task correctly (3) or attempting to use a strategy to complete the task (1). Thus, data from 53 participants was included in the analysis.

**Interoceptive Accuracy.** A one-way ANOVA confirmed that significant differences existed between the diagnostic groups on interoceptive accuracy, $F(3,50)=3.135, p=.033$ (Fig 3). Follow-up t-tests identified the primary driver of this difference as Alzheimer’s disease, as patients with AD performed significantly worse than healthy controls, $t(52)=1.735, p=.039$. No other significant differences were noted between groups (Figure 3.5).

![Heartbeat accuracy across all patient groups displaying a significant difference between the HC and AD groups.](image)

**Fig 3.5.** Heartbeat accuracy across all patient groups displaying a significant difference between the HC and AD groups.
Attention to bodily signals. No significant correlation was detected between the Guilt Inventory score and heartbeat accuracy for AD, \( r(8)=-.05, p=.901 \), FTD, \( r(8)=-.39, p=.902 \), DLB/PD, \( r(12)=-.18, p=.531 \), or HC, \( r(17)=.15, p=.529 \).

Amongst the patient groups, no significant correlation was detected between the Guilt Inventory or IRI and any BPQ subscales, while and neither HCs nor patients showed any significant correlation between the Guilt Inventory and the BPQ subscales.

3.3.6 Charitable giving and guilt

57 participants responded to the charity question and were included in the analysis.

Amount donated. The average amount of money donated by the AD group was $33.08 (SD=21.46), by the FTD group was $33.33 (SD=22.19), by the DLB/PD group was $23.57 (SD=24.37), and by the HC group was $18.86 (SD=23.80). There was no significant difference detected between diagnostic categories on amount of money donated, \( H(3)=4.996, p=.172 \).

Emotion identified. There was no association identified between diagnostic category and emotion endorsed during the charity decision, \( \chi^2(15)=16.475, p=.351 \). An ANOVA found no effect on charitable giving of emotion identified during the task, \( H(5)=9.661, p=.085 \).

Trait and state factors. No correlation was identified between the EQ and amount donated for AD, \( r(8)=-.481, p=.093 \), FTD, \( r(8)=.447, p=.233 \), DLB/PD, \( r(12)=-.065, p=.800 \) or HC, \( r(17)=-.035, p=.860 \).There was no significant correlation between Guilt Inventory score and amount donated for the AD group, \( r(8)=.552, p=.098 \), DLB/PD, \( r(12)=.247, p=.395 \), HC, \( r(17)=-.188, p=.441 \) or for the FTD group, \( r(8)=-.0188, p=.959 \).

3.4 General Discussion

The ANS is known to be responsive to emotion, and neurodegenerative conditions are known to cause dysfunction in the ANS, in emotion, or in both (Kreibig, 2010; Mendoza-
Velásquez et al, 2019; Sturm et al., 2018b). While guilt is a deeply visceral emotion that is often affected in some neurodegenerative disorders, little research has explored the way guilt and the ANS interact in multiple neurodegenerative conditions. We sought to identify the role of the pattern of activation of the ANS in guilt and comparison emotions in neurodegenerative dementias relative to each other and to healthy controls. We also sought to explore whether changes in the reactivity of the ANS to the experience of guilt underlies changes in the experience of trait or state guilt. Finally, we sought to explore how trait and state features related to guilt differ between neurodegenerative conditions and healthy controls. This study is the first, to our knowledge, to investigate the comparative patterns of ANS response to emotion in neurodegeneration beyond skin conductance and cardiac signals, the first to investigate specifically guilt induction instead of empathic concern, and the first to include patients with DLB and PD.

3.4.1 Psychophysiology in neurodegeneration

The results establish that there are differences between healthy controls and the three neurodegenerative conditions of interest in terms of psychophysiology generally, and that psychophysiological differences occur between emotions in neurodegeneration. For a majority of the psychophysiological signals under consideration, we were unable to find a significant difference between the response of the ANS to guilt in any of the diagnostic categories, nor a difference within diagnostic groups between emotions. However, watching emotional videos was associated with some significant psychophysiological differences between diagnostic groups and between emotions, though these differences must be interpreted with some caution due to group size (Field, 2018).
Swallowing rate was the most successful at distinguishing between guilt and other emotions within the diagnostic groups. In the DLB/PD group, swallowing rate was lower in guilt compared to either disgust or sadness. In the HC group, the difference between guilt and disgust was significant while the difference between guilt and sadness approached significance. This pattern is very similar to that observed in study I, where swallowing rate was found to be lower in guilt relative to either disgust or sadness. This pattern of significant relative changes in swallowing rate in guilt was not observed in either the FTD or AD groups. This suggests that while the DLB/PD group shows an emotional swallowing response comparable to that seen in healthy controls, this response may be less marked or completely absent in FTD or AD. This may represent an alteration in the bodily response to guilt, or to disgust or sadness, or to all three, in these disorders. This response was partially anticipated, as we hypothesized that the FTD group in particular would display altered patterns of ANS reactivity. However, we hypothesized that the AD group would more closely resemble the HC group, while the DLB/PD group would display disturbance of the ANS. The reason for this unexpected finding is unclear. It may suggest an underlying difference in the guilt experience in these dementias, or it may reflect poor comprehension or attentional deficits in these dementias relative to the HC and DLB/PD groups. It invites future research into emotional swallowing as it relates to guilt in particular, and how it may be altered in neurodegeneration.

Differences were also noted during the experience of guilt in skin conductance magnitude between HCs and both FTD and AD, as well as between the FTD and DLB/PD groups. As in the swallowing response noted above, participants with FTD and AD resembled one another, while the HC and DLD/PD group were more similar to each other. As before, this finding was unexpected, given the hypothesized similarity between the HC and AD groups and the FTD and
DLD/PD groups in terms of ANS disturbance. Also unexpected was the direction of this result, as both the FTD and AD group displayed higher absolute EDA magnitude during guilt than HCs or the DLB/PD group. Prior research has associated FTD with blunting of skin conductance responses to situations that might induce feelings of guilt or empathy (Fong et al., 2017; Marshall et al., 2019; Sturm et al., 2013). By contrast, individuals with AD are typically observed to show similar responses to HCs in terms of electrodermal activity (Fong et al., 2017).

Given the finding in study I of decreased EDA magnitude during the experience of guilt, this finding may suggest that a higher absolute EDA magnitude in these populations is an abnormal response to guilt stimuli. Given the low endorsement of guilt in both of these groups, it may also reflect lack of engagement or poor comprehension of the guilt stimuli in patients with AD or FTD. More research is needed to expand on and explore this specific finding in both health and neurodegeneration.

Taken together, these findings support and build on those of study I. Specifically, they emphasize that swallowing rate may be a key physiological response to differentiate guilt from other related emotions, and which may be impacted in disease. Further, it suggests that lower EDA magnitude may be related to the experience of guilt in health, and heightened EDA magnitude may be observed in neurodegeneration.

Emotional reactivity. Exploring the change in psychophysiological scores between guilt and neutral showed that emotional ANS reactivity was not able to predict an individual’s Guilt Inventory score. This suggests that while viscerality of guilt may be important to the overall experience of the emotion, it is secondary to cognitive processes. That is, that visceral changes, or the absence thereof, do not directly relate to an individual’s state or trait experience of guilt in either health or neurodegeneration. However, these results must be interpreted with caution given
the small sample sizes and non-normal distribution of the data. Also, self-reporting of emotions and guilt are likely to be impaired particularly in FTD. Inclusion of a caregiver or study partner’s assessment specifically of guilt may help to strengthen these associations in future research.

However, change in psychophysiological signals during guilt trials was able to predict diagnostic category membership when comparing the neurodegenerative conditions to healthy controls. AD was differentiated from HC only by respiration, with the HC group’s respiration generally increasing while the AD group’s did not, suggesting more SNS activation in HCs and more PSNS activation in AD. During guilt, FTD was distinguished from HC by respiration, as the FTD group’s respiration pattern resembled that of the AD group; and EDA magnitude, which increased in HCs, indicative of engagement of the SNS, and declined in FTD, indicative of SNS disengagement. During guilt, DLB/PD was differentiated from HCs by IBI, which increased in patients while it decreased in HCs, indicative of SNS engagement in HCs and PSNS engagement in DLB/PD. Similarly, they also showed reductions in EDA magnitude relative to controls, though this reduction was less extreme than that observed in the FTD group. Both respiration, which displayed a similar pattern to the other patient groups, and RMSSD, which increased in patients and decreased in HCs, approached significance in this group. Both the respiration decline and RMSSD increase suggest PSNS engagement during the experience of guilt in patients. Overall, these findings are suggestive of inappropriate engagement of the PSNS and under-reactivity of the SNS in patients to stimuli that triggered an autonomic response in their healthy peers.

These results support that there are changes in the amount of autonomic reactivity displayed by patients relative to healthy controls when faced with emotionally arousing stimuli regardless of final emotion identified. These results are supportive of previous findings
specifically in FTD. These studies have found that individuals with FTD often do not show expected SNS engagement to emotionally or socially relevant stimuli, particularly as indexed by the skin conductance response (Fong et al., 2017). Taken together with the above results in terms of absolute EDA magnitude, they suggest that while EDA may be higher in FTD in guilt relative to HCs in general, the degree to which EDA changes between neutral stimuli and guilt stimuli is impacted. The present results expand on these findings and suggest that similar patterns of unusual ANS activation or under-activation may be present in AD and DLB/PD as well. These findings suggest that the ANS response to the experience of emotions may be altered in neurodegenerative conditions beyond FTD. Particularly, DLB and PD are both known to feature dysautonomia, but the connection of this to emotion has not been made. AD has previously been assumed to show relatively little ANS alteration, but these results suggest there may be subtle changes that could be linked to emotion.

3.4.2 Trait and State Guilt in Neurodegeneration

Overall, there was no clear differences amongst the diagnostic groups on any of trait measures related to guilt proneness or empathy measured either by self-report or informant report. As well, no coherent picture of associations between the guilt inventory and measures of empathy, anxiety, or guilty feelings emerged between any of the patient groups on the self- or caregiver-rated questionnaires. HCs also did not show many of the correlations that were expected due to the findings in study I. The reason for this is unclear and may reflect various methodological issues. There may be an issue with the tasks or measures in use and their capacity to capture trait and state information in patient groups or in older controls. It also may be that the mixed profile of bvFTD and PPA cases in the FTD group muddied the distinctions between the patient groups. It is also possible that the limited sample sizes, made even smaller by
separating by diagnosis, rendered the groups too small to successfully perform correlational analyses (Bujang & Baharum, 2016; Gatsonis & Sampson, 1989).

There was also no effect of diagnostic category on the number of times that a participant reported feeling guilt. One possible reason for this finding is that the videos were not successful at eliciting guilt from this population. Just over 40% of participants reported feeling no guilt at all, with almost equal representation from the HC and all patient groups besides DLB/PD, the majority of whom reported at least one instance of guilt. Perhaps with different or more personalized stimuli, or stimuli that required less attention and cognitive effort, it would be possible to more successfully elicit guilt in these populations.

Taken together, these findings present an unexpected picture of similarity across groups in terms of state and trait guilt and related emotion and personality characteristics. This may be due to the difficulty of obtaining reliable responses on questionnaires that can be long or difficult to comprehend for patients. It is also possible that the small, heterogeneous sample played a role in this unexpected finding.

3.4.3 Interoceptive Awareness in Neurodegeneration

**Interoceptive accuracy.** While a difference was noted between groups in terms of the heartbeat accuracy task, this was largely driven by the difference between the relatively good performance of the HC group, and the very poor performance of the AD group. This may be reflective less of a decline in actual interoceptive ability in the AD population than a reflection of their cognitive difficulties hampering task performance. No significant differences were noted for FTD or DLB/PD either from HCs or other patient groups.

**Attention to bodily signals.** There was no correlation found between scores on the Guilt Inventory and heartbeat accuracy for any of the groups. This stands contrary to the prediction
that increased attention to bodily signals would correspond to increased guilt-proneness, as well as to the findings in study I of a negative association between these variables. This finding and the one above is likely reflective of the difficulty that patient groups had with the performance of this task, as 30 participants (5 HCs) failed to detect a single heartbeat, while in the first study only one person failed to sense their heartbeat. This may be due to cognitive impairment, poor attention, unwillingness to make the effort to complete the task, or another issue related to participant characteristics, such as poor insight.

We were also unable to detect associations between the Guilt Inventory or IRI and the BPQ subscales for body perception or reactivity for any diagnostic group. This lack of association stands in contrast to the findings described in study I, where associations between the Guilt Inventory and body awareness and reactivity were noted. The reason for this is unclear but may be related to difficulties in assessing these factors in patients, as well as the small and heterogenous sample.

3.4.4 Guilt and the Charity Donation

*Donation decision.* There was no difference between the groups on the amount of money that the participants chose to donate to charity. Patient groups on average gave about half or more of their total remuneration to charity, while the healthy controls gave a little over a third. Relative to study I, this reflects the general trend observed in charitable giving, in which increasing age is associated with increasing willingness to donate (Gittell & Tebaldi, 2006). There was also no difference between the groups based on the emotions that they reported while making the donation decision, and the emotion reported did not significantly drive their donation decision. Participants very rarely reported feeling guilt during the decision to donate, with only 5 (2 HC, 2 DLB/PD, 1 AD) identifying it as their current emotion. Neutral and pride predominated instead,
accounting for 26 (13 HC) and 17 (2 HC) participants, respectively. On the whole, this finding supports the positivity bias found in the donation trends of older adults (Bjälkebring et al., 2016), and suggests that guilt does not drive donation decisions in older adults or in neurodegeneration.

**Trait and state factors.** As in the cohort in study one, we found no association either between the EQ or the Guilt Inventory and the amount donated for any groups. This suggests that, as in the previous study, the decision to donate is likely driven by more factors than empathy or guilt-proneness alone, such as religiosity or socioeconomic status (Lasby & Barr, 2015). This decision may also be driven in this cohort by social pressure to give, as the participant had to verbally report to the research coordinator whether they would like to donate or not, and how much they wished to donate (Andreoni, Rao, & Trachtman, 2017).

**3.4.5 Limitations**

One limitation of this study is the size of the sample. Due to COVID-19 restrictions and shutdowns, recruitment for this study was limited and ultimately halted. As such, patient groups were much smaller than initially intended, rendering the study underpowered and having negative effects on the statistical inferences able to be drawn, particularly when participants had to be removed from various analyses. This also resulted in a more heterogeneous sample as described above, with a few PPA patients and a few bvFTD making up the FTD group, and PD and DLB patients making up the DLB/PD group. As these patients may differ in terms of their experience of guilt or ANS dysfunction or both, this could have impacted the results greatly. Relatedly, our patient sample was gender imbalanced in favour of male participants, which may have heighted or eliminated gender differences in the ANS or guilt that exist in these groups. Future studies should include more participants per group and, where possible, consider ensuring gender balance, as well as a more homogenous sample of FTD subtypes, or include multiple
FTD subtypes as their own diagnostic group in the analysis. In this way, the risk for contamination by intra-group differences would be lessened. A second potential limitation is that participants were required to respond to the post-video questions verbally to the research coordinator. This was done to ensure that participants would be able to be closely monitored and kept on track by the coordinator, and also to account for the way that participant’s arms would be restrained and unable to operate a mouse. As the research coordinator was visibly and audibly present in the room and the participant needed to interact with them regularly, their presence may have influenced responding in a number of ways. Needing to verbally admit to fault by declaring themselves to feel guilty may have made some participants uncomfortable and caused them to identify a different emotion as their primary during the video task. Similarly, this may have driven some people to choose to donate when they otherwise might not have done so. Future studies could better separate the participant and the research coordinator, or else program an experiment that is able to respond to voice commands, so as to eliminate the obvious presence of another person in the room. Another limitation was the lack of a caregiver questionnaire specifically designed to assess guilt proneness or state and trait guilt in the patient groups. Though we included caregiver questionnaires designed to capture empathy or neuropsychiatric behaviours, nothing was able to directly assess guilt. As patients often lack insight into their social and moral deficits, having a caregiver report may have aided in the elucidation of the relationship between trait guilt and the psychophysiological scores or other measures. A future study should develop and use an informant report of trait guilt in order to ensure that this information is successfully captured. Another limitation is that emotional labels were provided without intensity ratings for each video. Due to this, it is impossible to know whether the psychophysiological signals identified represent a strong or a weak instance of the emotional
experience. Thus, it cannot be known whether or how psychophysiology is impacted by emotional intensity in this study. In future, studies should include ratings of intensity at the end of the video or incorporate them throughout to better capture potential fluctuations in emotion or emotional intensity during video viewing. The psychophysiological scores in this study were calculated as the arithmetic mean of the physiological signal throughout a single video’s analysis window, and then averaged across all instances of the target emotion. This represents a relatively conservative estimate of the psychophysiological response, as individuals may experience different emotions throughout a video, or fluctuations in the intensity of that emotion.

Individuals might not consistently experience the target emotion, might experience fluctuating levels of emotional intensity, or might experience different predominant emotions throughout the video course (Davydov, Zech, & Luminet, 2011). Future studies could examine more granular epochs to attempt to capture specific psychophysiological responding that might be lost to averaging.

### 3.4.6 Conclusion

This study sought to address the current gap in the literature around the cognitive and psychophysiological experience of guilt and emotions in Alzheimer’s disease, frontotemporal dementia, and dementia with Lewy bodies. We identified differences in psychophysiology, emotion, and the psychophysiological experience of guilt across these neurodegenerative diseases and between them and healthy controls. In particular, we identified psychophysiological factors underlying the difference in ANS activity in neurodegeneration compared to healthy controls, as well as identifying under-reactivity in guilt for patients relative to healthy controls. Our findings for the cognitive and behavioural experience of guilt were less clear. These findings lay the groundwork for future studies not only of ANS function and dysfunction in
neurodegeneration, but also for more exploration of the way that guilt and other complex social emotions are affected in neurodegeneration. Future research could also investigate ANS responding in children who are developing guilt, in populations beyond the North American context, and in other patient populations with pathological levels of guilt such as obsessive-compulsive disorder or psychopathy.
3.5 References


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Chapter 4: The nonverbal expression of guilt in healthy adults

4.1 Introduction

Guilt is the emotional consequence of realizing that through one’s action or inaction one is or could be responsible for an actual harm occurring to another person (Huhmann & Brotherton, 1997; Zeelenberg & Breugelmans, 2008). It is an emotion that, as a function of its nature, must be expressed to observers (Rosenstock & O’Connor, 2018; Shore & Parkinson, 2018; Smith Anderson, & Straussberger, 2018). Guilt serves two social functions: to discourage antisocial behaviour and encourage prosocial behaviours (Murrar et al., 2019; Roseman, Wiest, & Swartz, 1994; Tangney, Stuewig, & Mashek, 2007). It is the prosocial action of apology and acknowledging guilt that necessitates guilt’s successful, genuine conveyance to observers (Eisenberg, Garvey, & Wells, 1998; MacLin et al., 2009; Robinson, Smith-Lovin, & Tsoudis, 1994; Smith, et al., 2018). Conveyance of sincere feelings of guilt typically require nonverbal expression (Khalil & Feltovich, 2018; Okimoto, Wenzel, & Hornsey, 2015). However, little is known about the ways in which guilt is communicated nonverbally.

4.1.1 Nonverbal expressions of emotion

Emotion is conveyed by language and non-language qualities of the voice, but the expression of emotion is enhanced by nonverbal behaviours, which are universal in humans, though precise expressions are culturally bound (Archer, 1997; Gendron et al., 2014; Jack et al., 2009; Jack et al., 2012; Matsumoto & Hwang, 2013). The pattern of nonverbal activity that signifies different emotional states has attracted a great deal of scrutiny not only from the scientific community, but also from law enforcement, the media, public relations, and computer scientists, among many others (Granhag & Strömwall, 2002; Roth et al., 2016; Sandlin &
Gracyalny, 2018; Stephens, Waller, & Sohrab, 2019; Warnick et al., 2021). Four channels of nonverbal behaviour have been particularly studied in this area. The first and most frequently studied is facial expression, the movement of the muscles of the face alone and in concert to create emotionally meaningful positions, such as a smile, which typically signifies happiness (Ekman & Oster, 1979; Gunnery & Hall, 2014). Gestures, the action of parts of the body alone or together which can create or enhance emotional messages to the observer, as in for example giving a thumbs up to indicate that all is well, are a second category of nonverbal behaviour (Kipp & Martin, 2009). Closely related is posture, the position of the body or part of the body, which can convey gross emotional states, as in for example leaning and turning the upper body and head away from an observer to convey discomfort (Gregersen, 2005; Mondloch, Nelson, & Horner, 2013). Finally, gaze, the direction of the eyes at or away from an observer or the stimulus, which can be used to signal approach or avoidance intention (Adams & Kleck, 2003; Bayliss et al., 2007). Working together, all of these signals produce an experience of a person’s internal life and emotional experience better than any individual signal on its own is capable of (Adams & Kleck, 2003; Castellano, Kessous & Caridakis, 2008; Dael, Goudbeek, & Scherer, 2013).

4.1.2 Nonverbal expressions of guilt

Guilt drives reparative behaviour, that is, actions that seek to fix the harm caused, and one of the primary reparative actions is apology (Howell, Turowski, & Buro, 2012; Rosenstock & O’Connor, 2018). In order for an apology to successfully repair a harm, it must be perceived by the recipient as sincere and driven by genuine intentions to right the wrong and to not behave similarly in future (Rosenstock & O’Connor, 2018; Shore et al., 2018; Smith & Parkinson, 2018). Expressing guilt has been shown to be very successful in convincing the observer that the
apology is authentic and backed by intention to not cause harm again (Hareli & Eiskovits, 2006; Hornsey et al., 2020; Shnable et al., 2015). However, expressions of guilt that occur purely verbally or textually are often viewed as insincere or manipulative, necessitating secondary signifiers to affirm that the guilt expressed is sincere (Khalil & Feltovich, 2018; Okimoto, Wenzel, & Hornsey, 2015). This is most often done through the use of nonverbal behaviours such as tears, negative facial expressions, and postural changes. The presence of these actions has been associated with increased judgements of sincerity of the emotion expressed, and more positive evaluations of the transgressor (MacLin et al., 2009; Hornsey et al., 2020).

Existing studies of the nonverbal expression of guilt are rare. Of the two studies that have investigated guilt expressed by the face, one did not identify a unique facial expression of guilt (Keltner & Buswell, 1996). The other identified lowering of the brow as important both for expressors of guilt and for observers to read guilt in expressors, while stretching of the lips was observed in expressors but not fundamental to observers (Julle-Danière et al., 2020). The study by Julle-Danière et al. also identified three specific gestures, touching the neck with a single hand, nodding, and turning the head away, as key to the guilt expression (2020). No studies have investigated posture specific to guilt, though the two related emotions of embarrassment and shame have attracted some research. These studies have suggested that a collapsed, diminished posture, with the shoulders shrunken down and towards the midline of the chest and the head tilted downwards, is common to embarrassment and shame (Haidt & Keltner 1999; Keltner & Anderson, 2000; Tracy & Matsumoto, 2008). Aversion of gaze has been associated with guilt in some studies, though results are mixed (Keltner 1995; Pivetti et al., 2016; Yu, Duan, & Zhou, 2017).
4.1.3 The present study

Though expressing guilt is a fundamental aspect of its purpose as an emotion, no studies to date have comprehensively investigated the nonverbal behaviours associated with feeling guilty. The present study sought to fill this gap by identifying whether there is a distinct nonverbal expression associated with the real-time experience of guilt in healthy adults. We hypothesized that there would be a unique nonverbal signature of guilt that was distinct from other emotions.

Based on the existing literature around guilt, as well as shame and embarrassment, we predicted that, overall, the pattern of behaviours elicited in the participants during the experience of guilt would convey submission and contrition to an observer through a pattern of discrete gestural, postural, and facial variables. That is, that the face would display a negative aspect, gestures would be contained and involve the touching of the head or neck area and aversion of the head, posture would be slumped and diminished, and gaze would be averted. To this end, healthy adults were recruited to take part in a video task designed to elicit guilt and comparison emotions while continuous discreet recordings were made of their faces and upper bodies.

4.2 Method

The participants enrolled, task and task procedures are the same as those described in study I.

4.2.1 Participant Characteristics and Enrollment

The sample was comprised of healthy adults recruited from the community. Participants were recruited through word of mouth, as well as flyers and advertisements placed throughout the community and on local public transit which invited interested participants to take part in research on emotion. Inclusion criteria included: age 18 to 80, normal or corrected to normal vision, normal or corrected to normal hearing, and fluency in English. Exclusion criteria included
any current major neurological or psychological disorder. All study procedures were approved by the University of Western Ontario Research Ethics Board. Participants provided written informed consent prior to undertaking study procedures and were compensated for their time.

**4.2.1.1 Sample size calculations.** Sample size calculations were performed for study I (section 2.2.1.1). Using linear regression procedures, a targeted sample size of N=79 was retrospectively identified as sufficient to maintain a minimum power (1-ß) of 0.95 and detect a medium effect size between .30 and .36 with alpha = 0.05. Power calculations were determined using G* Power 3.1.9.7 (Faul et al., 2007) with 1 group and 10 response variables. The power calculation was based upon estimates from a similar study which detected significant group effects with effect size between $f^2=.30$ and $f^2=.36$ when investigating the postural and gestural expression of shame relative to pride (Tracy & Matsumoto, 2008).

**4.2.2 Stimuli**

**4.2.2.1 Opinions and behaviour questionnaire.** Participants were asked to complete a computer-based 103-item questionnaire that they were informed would extract their opinions and behaviours on a number of topics, including charitable giving, environmental conservation, and national identity. This questionnaire was developed by the authors based on questionnaires on similar topics created by Statistics Canada (Statistics Canada, 2021). Participants responded using yes/no, a scale from 1 (*not at all*) to 5 (*very much*), multiple choice, or free answer depending on the question (see Appendix A.1 for sample questions and response options). Before beginning the questionnaire, participants were informed that their responses would generate feedback about themselves that they would receive during the video task, and that this feedback would be based on previous survey responses (see below).
4.2.2.2 Feedback statements. Prior to each video clip, a short statement purporting to be derived from the opinions and behaviour questionnaire were presented to the participant. Regardless of their responses on the questionnaire, every participant received a standard set of feedback statements (see Appendix A.2). After completing the questionnaire and before undertaking the video task, participants were reminded that they would see the statements, which they were again told would be providing them true feedback about themselves, which would be based on comparisons to Statistics Canada and prior participants. These statements were designed to enhance the emotional experience of each clip by making it relevant to the participant’s past and present actions and opinions. For example, before a video about starving children in need of donations, a participant might see “You donate less than the average Canadian;” before a video describing the negative environmental impacts of laundry: “Your laundry habits waste more water than two-thirds of Canadians.” All emotional feedback statements were written with the subject put in comparison with the average Canadian or person, under the assumption that most participants would not know the true average engagement of others in civic or charitable behaviours, or else were broad statements that the average person could accept as true about themselves, such as “You sometimes ignore charity appeals.”

4.2.2.3 Video clips. Forty short video clips from various television shows, movies, charitable agencies, and advertising campaigns were chosen to elicit the target emotions of guilt, amusement, disgust, neutral, pride, and sadness (see Appendix A.3). These emotions were selected to ensure comparisons to emotions closely related to guilt (disgust, sadness), social emotions (pride), an emotion distinct from guilt (amusement), and a baseline unemotional state (neutral). 10 videos were selected to elicit guilt, while 6 videos were chosen to elicit each of the comparison emotions. These clips were selected by the authors and tested in a pilot study of 14
people (8 female) to ensure they reliably elicited the target emotions, and to ensure that intensity, arousal, and valence ratings were consistent across emotion categories (see Appendix C). The time window in which the emotions occurred most strongly in each video were identified in the pilot study using CARMA video rating software, and only these windows were used in later analysis (Girard, 2014). Clips lasted from 20 seconds to 2 minutes, with an average length of 1 minute.

4.2.3 Procedure

Following informed consent and demographic information collection, participants were seated in a comfortable chair in front of a computer monitor and asked to complete the opinions and behaviour questionnaire by themselves. Following completion of this task, the webcam was turned on and adjusted to ensure that the participant’s entire head and upper chest were visible in frame, and the participant received the full task instructions. During data collection a research coordinator was separated from the participant by a standing screen. This allowed the coordinator to respond to questions, concerns, or emotional distress during the study, while reducing distraction for the participant.

4.2.3.1 Video task. The task was programmed and run in E-Prime version 3.0 (Psychology Software Tools., Pittsburgh, PA). A single feedback statement appeared on the screen and remained until the participant clicked to acknowledge it. Participants then viewed the linked video clip. After the video ended, participants were shown a black screen lasting ten seconds, during which they were instructed to think about the video and what the contents of the video made them feel. Participants then reported via selection from a list of 12 emotion words the primary emotion they felt while watching the clip (Table 4.1); participants were allowed to select only one word and instructed to pick the emotion that they felt most strongly during the video.
This emotion words list contained the six target emotions as well as additional words potentially related to guilt (anger, contempt, embarrassment, shame), and the remaining basic emotions (fear, happiness).

<table>
<thead>
<tr>
<th>Amusement</th>
<th>Embarrassment</th>
<th>Neutral</th>
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<tbody>
<tr>
<td>Anger</td>
<td>Fear</td>
<td>Pride</td>
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<tr>
<td>Contempt</td>
<td>Guilt</td>
<td>Sadness</td>
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<tr>
<td>Disgust</td>
<td>Happiness</td>
<td>Shame</td>
</tr>
</tbody>
</table>

*Table 4.1. Emotion options presented to participants after each video*

Participants were then presented with the same 12 emotion words and asked to select any additional emotions that they felt while watching the video; during this selection they were free to pick as many of the words as they felt described their experience, or none. This was followed by a 20-second white screen which marked a rest period. This repeated in an individually randomized order until the participant had watched all 40 videos (Figure 4.1).

*Fig 4.1. Schematic of the trial design, depicting context statement, emotional video, and post-video questions.*

*4.2.3.2 Debrief.* Following the conclusion of all task activities, a deception check was carried out. Participants were asked to rate on a scale from 1 (*agree strongly*) to 5 (*disagree strongly*)
whether they believed, on average, that the feedback statements they received were accurate and applied to them. Participants were then debriefed about the nature of the study’s deception and given the opportunity to withdraw their consent to be included in the final analysis.

4.2.4 Video Recording, Data Cleaning, and Analysis

The entire task was filmed using an MWay 720p webcam which was mounted unobtrusively atop the computer monitor on which participant stimuli was displayed. The recording was captured using Biopac’s AcqKnowledge linked media recording function (Biopac Systems Inc., Goleta, CA). Participants were instructed to maintain a forward facing attitude to ensure minimal rotation and ensure good quality recordings of facial movements. The section of peak emotion identified by the pilot study for each video was clipped from the total recording using OpenShot Video Editor v2.5.1 (Thomas et al., 2021) and precise timepoints provided by AcqKnowledge.

4.2.4.1 Action Unit analysis. Recordings with a resolution of 640x480 at 33 frames per second were saved as MP4 files and analyzed frame by frame by FaceReader 8.1 (Noldus Information Technology, Wageningen, The Netherlands). FaceReader was set to detect each of the twenty most common facial AUs, which were reported on a scale between 0 (not present) and 1 (maximally present). Frame by frame AU data was averaged across the entire analysis window, and averages for individual videos were averaged across all videos of the same emotion as identified by the participants to create a composite score for each AU for each emotion.

From the 20 available AUs produced by FaceReader, six were selected a priori based on existing studies that identified facial expressions of emotion in embarrassment, shame, and guilt, as well as related emotions such as anxiety (Table 4.2). AUs 12- Lip Corner Puller, 14-Dimpler, 15- Lip Corner Depressor, and 24- Lip Pressor were selected as all have been associated with the
display of embarrassment and shame (Keltner, 1995; Velusamy et al., 2011). AU 4- Brow Lowerer and AU 20- Lip Stretcher are the only facial AUs that have been previously associated with the expression of guilt specifically (Julle-Danière et al., 2020).

<table>
<thead>
<tr>
<th>Expression</th>
<th>Example Image</th>
<th>Emotions</th>
<th>Reference</th>
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<tbody>
<tr>
<td>AU 4 Brow Lowerer</td>
<td>![Image]( AU 4 Brow Lowerer )</td>
<td>Anger, Anxiety Sadness, Disgust, Confusion, Frustration, Guilt</td>
<td>Velusamy et al., 2011; Julle-Danière et al., 2020</td>
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<td>Happiness, Contempt, Embarrassment</td>
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<tr>
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<td>Keltner, 1995; Velusamy et al., 2011</td>
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<tr>
<td>AU 15 Lip Corner Depressor</td>
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<td>Sadness, Disgust, Embarrassment</td>
<td>Keltner, 1995</td>
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<td>AU 20 Lip Stretcher</td>
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<td>Fear, Guilt</td>
<td>Julle-Daniere et al., 2020</td>
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<tr>
<td>AU 24 Lip Pressor</td>
<td>![Image]( AU 24 Lip Pressor )</td>
<td>Anger, Anxiety, Embarrassment</td>
<td>Keltner, 1995</td>
</tr>
<tr>
<td>Head tilt down</td>
<td>Shame, Embarrassment</td>
<td>Keltner, 1995; Tracy, Robins, &amp; Schriber, 2009</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------</td>
<td>---------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Head turn</td>
<td>Guilt, Embarrassment</td>
<td>Julle-Daniere et al., 2020; Keltner, 1995</td>
<td></td>
</tr>
<tr>
<td>Nod</td>
<td>Guilt</td>
<td>Julle-Daniere et al., 2020</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2 Facial, postural, and gestural expressions with representative images, related emotions, and citations to papers that had previously identified the expression with guilt or a related emotion.

4.2.4.2 Postural and Gestural analysis. Gestural data was recorded using the Body Action and Posture Coding System (Dael, Mortillaro, & Scherer, 2012). Six body postures and gestures were chosen a priori from the 141 available postures and gestures from the Body Action and Posture Coding System based on existing research (Table 4.2). Lowering or tilting downwards of the head; slumping, diminishment or collapsing of the upper body; and touching of the face have all
been associated with shame and embarrassment (Keltner, 1995; Haidt & Keltner, 1999; Keltner & Anderson, 2000; Tracy & Matsumoto, 2008; Tracy, Robins, & Schriber, 2009). Turning of the head, nodding, and touching of the neck has been specifically associated with guilt (Julle-Danière et al., 2020). Gestures and postures were scored by three independent raters blinded to the emotional condition of each video. Following rating of the initial 15 participants, Cohen’s kappa confirmed inter-rater reliability (k>0.75). After retraining and consensus scoring on points of discrepancy, raters completed postural and gestural ratings for all participants. All postures and gestures were scored in 5 second increments, with postures coded as present/absent and gestures coded in terms of the number of times that they occurred. Postures were scored as percentage of time spent in the posture, while gestures were scored for number of occurrences.

4.2.4.3 Gaze analysis. FaceReader recorded gaze direction as forward, left, or right in relation to the screen for each video frame. Aversion of gaze has been associated in many studies with shame, embarrassment, and guilt (Keltner, 1995; Velusamy et al., 2011; Yu, Duan, & Zhou, 2017; Julle-Danière et al., 2020). Forward gaze was coded as 1 while left and right were both coded as 0. The codes were averaged across the analysis window to create a percentage of time spent looking at the screen between 0 and 100 for each video, and this percentage was averaged across all videos of the same emotion as identified by the participants to create a composite score for percentage of time that gaze was directed at the screen for each emotion.

4.2.5 Analytic approach

All data analysis was carried out in R Studio v1.3.959 (R Core Team, 2018; RStudio Team, 2016). Data for individuals who were missing single data points due to recording glitches or failures, but for whom the rest of the data was usable, were imputed using multivariate imputation by chained equations via the mice function mice package version 3.11.0 (van Buuren
All AU, gaze, postural, and gestural measures were transformed into percent of maximum possible (POMP) to account for individual variation and enable comparison between participants (Cohen et al., 1999).

In order to identify the variables that contributed to the distinction between emotion categories with guilt as the reference group, available AUs, gaze direction, gestures, and postures were entered into a linear mixed effects model as predictor variables using the *lmer* function in the *lme4* package v1.1-27.1 (Bates et al., 2015). To account for the repeated measures nature of the data, participant ID was entered into the model as a random effect, while gender and age were entered as fixed effects. Confidence intervals for the model were calculated using the *confint* function in the *stats* package v4.1.0 (Venables & Ripley, 2002). Planned contrasts were carried out to investigate the specific differences between guilt and the comparison emotions for each postural, gestural and facial variable using Quade’s ANCOVA via the *aov* and the *summary.lm* functions in the *stats* package v4.1.0 (Venables & Ripley, 2002). All graphs were made using the *ggplot2* package v3.3.5, and in-graph calculations were performed using the *ggpubr* package v0.4.0 (Kassambara, 2020; Wickham, 2016).

### 4.3 Results

#### 4.3.1 Participant demographics.

108 participants ranging in age from 18 to 77 (M=39, Med=31) participated in the study. Participants reported attending between 6 and 23 years of formal education (M=15.963, Med=16). Participants were excluded from the main analysis for failure to endorse feeling guilt as the primary emotion for any video during the video task (7); technical errors in recording or analysis of video data such as videos that were too dark for the face to be clearly seen, videos in which the participant moved their face out of the frame after recording began, videos which
recorded at too low of a frame rate to be analyzed, or video files which were corrupted during
data transfer (20); and incomplete or absent video recordings due to power or equipment failure
(4). Thus, 77 participants (37 female) were included in the final video data analysis.

4.3.2 Video data results

4.3.2.1 Linear mixed effect model. Of the variables of interest, slumping or collapsing of the
upper body, touching of the neck, and nodding occurred so infrequently that they could not be
included in the ethogram. As such, AUs 4-Brow Lowerer, 12-Lip Corner Puller, 14-Dimpler, 15-
Lip Corner Depressor, 20-Lip Stretcher, 24-Lip Pressor, tilt down of the head, turning of the
head, touching of the face, and gaze direction were entered into a linear mixed effects model
with both age and gender included as fixed effects in the model (Table 4.3). Overall, this model
was statistically significant \( \chi^2(10) = 36.251 \ p < .001 \).

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Brow Lowerer</td>
<td>-0.013</td>
<td>0.004</td>
<td>-3.181</td>
<td>0.002**</td>
<td>-0.021 – -0.005</td>
</tr>
<tr>
<td>12 Lip Corner Puller</td>
<td>0.014</td>
<td>0.005</td>
<td>2.581</td>
<td>0.010*</td>
<td>0.003 – 0.024</td>
</tr>
<tr>
<td>14 Dimpler</td>
<td>0.003</td>
<td>0.012</td>
<td>0.242</td>
<td>0.809</td>
<td>-0.020 – 0.026</td>
</tr>
<tr>
<td>15 Lip Corner Depressor</td>
<td>0.007</td>
<td>0.009</td>
<td>0.716</td>
<td>0.474</td>
<td>-0.011 – 0.024</td>
</tr>
<tr>
<td>20 Lip Stretcher</td>
<td>-0.005</td>
<td>0.007</td>
<td>-0.669</td>
<td>0.504</td>
<td>-0.018 – 0.009</td>
</tr>
<tr>
<td>24 Lip Pressor</td>
<td>0.007</td>
<td>0.005</td>
<td>1.384</td>
<td>0.167</td>
<td>-0.003 - 0.017</td>
</tr>
<tr>
<td>Tilt Down</td>
<td>0.018</td>
<td>0.006</td>
<td>3.116</td>
<td>0.002**</td>
<td>0.007 – 0.030</td>
</tr>
<tr>
<td>Turn Head</td>
<td>-0.015</td>
<td>0.006</td>
<td>-2.495</td>
<td>0.013*</td>
<td>-0.027 – -0.003</td>
</tr>
<tr>
<td>Touch Face</td>
<td>-0.012</td>
<td>0.005</td>
<td>-2.281</td>
<td>0.023*</td>
<td>-0.022 – -0.002</td>
</tr>
<tr>
<td>Gaze</td>
<td>0.003</td>
<td>0.003</td>
<td>0.790</td>
<td>0.430</td>
<td>-0.004 – 0.009</td>
</tr>
</tbody>
</table>

Table 4.3. Results of linear mixed effect model with \( p \) values reported for ease of interpretation.

Using emotion as the outcome variable, expression of guilt as opposed to at least one of the
comparison emotions was significantly predicted by level of display of 4-Brow Lowerer,
\[ t(447)=-3.181, \ p=.002, \ CI[-.021,-.005], \] 12-Lip Corner Puller \( t(447)=2.581, \ p=.010, \)
\[ CI[.003,.024], \] head tilt down \( t(447)=3.116, \ p=.002, \ CI[.007,.030], \) turn head \( t(447)=-2.495, \)
\[ p=.013, \ CI[-.027,-.003], \] and touching the face \( t(447)=-2.281, \ p=.023, \ CI[-.022,-.002]. \]
### 4.3.2.2 Planned contrasts

To investigate the specific relationships between these variables, planned contrasts were carried out between guilt and all comparison emotions for each of the variables identified as significant in the mixed effects model (table 4.4).

![Table 4.4](https://example.com/table4.4.png)

<table>
<thead>
<tr>
<th></th>
<th>4-Brow Lowerer</th>
<th>12-Lip Corner Puller</th>
<th>Tilt Head Down</th>
<th>Turn Head</th>
<th>Touch Face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t$</td>
<td>$p$</td>
<td>$t$</td>
<td>$p$</td>
<td>$t$</td>
</tr>
<tr>
<td>Amusement</td>
<td>-.485</td>
<td>.628</td>
<td>7.773</td>
<td>&lt;.001***</td>
<td>6.076</td>
</tr>
<tr>
<td>Disgust</td>
<td>2.383</td>
<td>.018*</td>
<td>5.626</td>
<td>&lt;.001***</td>
<td>8.218</td>
</tr>
<tr>
<td>Neutral</td>
<td>.388</td>
<td>.698</td>
<td>1.851</td>
<td>.065</td>
<td>4.829</td>
</tr>
<tr>
<td>Pride</td>
<td>-1.556</td>
<td>.120</td>
<td>1.614</td>
<td>.107</td>
<td>5.251</td>
</tr>
<tr>
<td>Sadness</td>
<td>.465</td>
<td>.642</td>
<td>2.409</td>
<td>.016*</td>
<td>5.324</td>
</tr>
</tbody>
</table>

Table 4.4. Summary of contrasts between guilt and comparison emotions.

These contrasts identified head tilt down as the most significantly different posture or gesture ($p$<.001 for all emotion comparisons). Participants were less likely to tilt their heads down during the guilt condition relative to any other emotion (Figure 4.2). Turning of the head separated guilt from amusement, disgust, and sadness, and participants were less likely to turn their heads relative to those emotions (Figure 4.3). 4-Brow Lowerer (Figure 4.4) was less common in guilt than in disgust, while 12-Lip Corner Puller (Figure 4.5) was less common in guilt than in amusement, disgust, or sadness.
**Fig 4.2.** Comparison of presence of downwards head tilt across emotions. During guilt (M=.52), participants were less likely to tilt their heads down than in amusement (M=11.6), \( p < .001 \), disgust (M=21.2), \( p < .001 \), neutral (M=9.3), \( p < .001 \), pride (M=15.0), \( p < .001 \), or sadness (M=11.2), \( p < .001 \).

**Fig 4.3.** Comparison of head turning across emotions. During guilt (M=0), participants were less likely to turn their heads away than in amusement (M=7.7), \( p = .006 \), disgust (M=19.1), \( p < .001 \), or sadness (M=8.5), \( p = .002 \).
Fig 4.4. Comparison of brow lowerer across emotions. During guilt (M=21.9), participants were less likely to lower their brow than in disgust (M=27.0), *p*=.018.

Fig 4.5. Comparison of lip corner puller across emotions. During guilt (M=7.2), participants were less likely to display upturned lips than in amusement (M=19.2), ****p<.001, disgust (M=16.5), ****p<.001, or sadness (M=8.7), *p*=.016.
4.4 General Discussion

Emotions are commonly displayed on the face and by the body. While the expression of social emotions is often more complicated than basic emotions, there is clear evidence that social emotions can be read through the face and the body (App et al., 2011; Tracy & Matsumoto, 2008). Though there have been some limited studies of the facial expression of guilt and related emotions, little to date has explore the embodiment of guilt (Julle-Danière et al., 2020; Keltner 1995; Keltner & Buswell, 1996). We sought to investigate the facial and particularly the bodily expressions of guilt in healthy adults, and to delineate the features that are key to the nonverbal expression of guilt. This study has provided the first combined exploration of postures, gestures, gaze, and facial expression in guilt without direct social interaction.

We identified differences between guilt and the comparison emotions on several facial, postural, and gestural variables. In particular, head tilt down, turning of the head, Lip Corner Puller, and Brow Lowerer were found to be significantly different in guilt relative to at least one other emotion. While touching of the face was identified by the omnibus test as a potential feature of guilt relative to the other emotions, these differences did not survive in the follow up contrasts. The other facial expression variables under consideration, AUs Dimpler, Lip Corner Depressor, Lip Stretcher, and Lip Pressor did not contribute significantly to the ethogram. Direction of gaze to or away from the screen also did not contribute significantly.

Amongst the significant variables, both Brow Lowerer and Lip Corner Puller were less commonly observed in guilt than the comparison emotions they distinguished it from. Brow Lowerer initiates a furrowed brow commonly seen in negative emotions like disgust, sadness, or frustration (Dirupo et al., 2020; Grafsgaard et al., Kohler et al., 2004). This AU was engaged during guilt about the same proportion of time as it was during all other emotions except disgust.
During the display of disgust, the brow was significantly more engaged than it was in other emotions. This difference likely indicates a difference either in the expression of disgust compared to other emotions or the intensity of the underlying feeling of disgust, rather than a difference between guilt and other emotions. Lip Corner Puller creates a smile and is often seen in embarrassment as an aspect of the appeasement display, during which the embarrassed individual attempts to lighten the experience (Ambadar, Cohn, & Reed, 2009; Keltner, 1995; Keltner & Buswell, 1997). Similar to Brow Lowerer, this facial display was less common in guilt compared to amusement, disgust, and sadness. The engagement of Lip Corner Puller during amusement is likely reflective of a smile or laughter induced by enjoyment of the videos. During disgust and sadness, the pulling upwards of the lips may possibly reflect grimacing, nervous laughter or smiling, genuine amusement at disgusting stimuli, or an attempt to distance the self from distressing feelings using smiles or laughter (Ansfield, 2007; Deckman & Skolnick, 2020; Hemenover & Schimmack, 2007; Keltner & Bonanno, 1997; Kunz, Prkachin, & Lautenbacher, 2009). However, the exact reason for display of this AU in these emotions is not clear. Again, this may be reflective of a difference in those emotions, rather than a distinguishing feature of guilt. However, it is interesting that individuals did not engage in these coping behaviours in the negative experience of guilt while they did in disgust or sadness. This potential difference between guilt, sadness, and disgust should be investigated more in future studies. Tilting downwards of the head distinguished guilt from all other emotions; participants were less likely to tilt their heads down than in any other emotion. This is a finding was unexpected and in contrast to previous studies, in which a downwards-facing head posture is one of the most common aspects of the display of embarrassment and shame (Keltner, 1995). Similarly, turning away of the head was significantly less common in guilt compared to amusement, disgust, and
sadness, with similar trends in comparison to neutral and pride, despite being previously identified as key for guilt in a feigned wrongdoing scenario (Julle-Danière et al., 2020). In disgust and sadness, this gesture may reflect simple efforts at evasion of noxious stimuli. In the current task, participants were encouraged to turn away from stimuli that distressed them, and a common reaction to objects of disgust and sadness is to turn away to evade them (Hanich, 2009; Nabi, 2002). For amusement, turning away may be secondary to the tossing or movement of the head during laughter, though the exact reason for this difference is as yet unclear.

There are a few possible explanations for the unexpected findings in this study. One possibility is that these findings are reflective of the intensely social nature of guilt. Both tilting and turning of the head were less common in guilt relative to other emotions, while aversion of the gaze was consistent between guilt and the comparison emotions. All of these gestures have been previously strongly associated with the display of guilt in tasks that involved in-person interaction during feigned wrongdoing in a laboratory setting, an interactive game with a confederate, and observing the social behaviour of others (Julle-Danière et al., 2020; Keltner & Buswell, 1996; Yu, Duan, & Zhou, 2017). The absence of these gestures in this study may indicate that the commission of these movements is in fact a purely social gesture, that is, they make up an appeasement or evasion display intended to enhance an apology, convey remorse, offer submission, evade the emotional consequences of looking into the eyes of a wronged party, or some other social motive. In the absence of victim or observer who is aware of the performer’s guilty feelings, as in the video task, the drive to immediately enact these behaviours disappears. This likely also holds true for the lack of engagement of facial AUs. While it is difficult to avoid the instinctive crumpling of the face when feeling disgust, to control a smile while laughing, or to eliminate the upward movement of the brow during surprise, our results
indicate there may be no clear instinctual drive to make a guilty face in the absence of an observer to acknowledge and attempt to ameliorate one’s guilt to.

Another possibility is that the relatively level, forward facing, direct posture of the head and direct gaze reflects attentional capture by the guilt-inducing stimuli. Often, attention is captured by arousing stimuli, even if the arousing stimulus is negative in nature (Miyazawa & Iwasaki, 2009; Strauss & Allen, 2009). The guilt stimuli were also rendered personal by the context statements presented at the beginning of each video, which directly related the content of the video to the participant. While this was common across all film clips, the guilt film clips in particular were often the most self-focused, as they were intended to directly appeal to the actions, behaviours, or opinions of the viewer. Thus, while some videos in other emotion categories addressed themselves to the viewer (to appeal to the individual to purchase something, to avoid certain behaviours), a majority of the guilt videos specifically addressed the participant and invited them to reflect upon themselves. Previous research has consistently found that attention is easily captured and held by self-focused stimuli (Alexopoulos et al., 2012; Humphreys & Sui, 2016; Schäfer et al., 2016; Sui & Rotshtein, 2019). As the guilt videos started personal and remained so consistently throughout, they may have directed attention more strongly to the video than other emotions.

4.4.1 Limitations.

One potential limitation of this study is that no measurement of emotional intensity or arousal was taken for each video. It is therefore not possible to know whether the observed changes in the facial, postural, gestural, or gaze variables are reflective of a difference in the expression of the emotions as a whole, or of the general arousal level, or some combination thereof. With the current design it is also not possible to explore whether intensity of the
emotional experience parametrically correlates with intensity of nonverbal expressions. This is especially important as past research has indicated that in guilt specifically there are variations in guilt expression dependent on intensity of guilt feelings (Julle-Danière et al., 2020). Future studies should include measurements of the general arousal level and the intensity of emotion during or after each video so as to better characterize the specific feelings underlying the expressions. Another limitation was that the variables were taken as the arithmetic mean of the variable in question throughout the entire analysis window, and then averaged across all videos of that emotion type. This results in a very conservative estimate of many of the nonverbal expressions, as the consistency or intensity of the emotion, or even the predominant emotion being experienced, may change throughout the course of even a very short video (Davydov, Zech, & Luminet, 2011). More granular epochs of examination may enable the capture of subtle expressional elements that may otherwise be lost to averaging.

### 4.4.2 Conclusion

This study sought to address the current gap in the literature around the nonverbal expression of guilt in healthy adults. We found an unexpected pattern of under-reactivity to guilt relative to other emotions that is potentially reflective of guilt’s deeply social nature, or its unique capacity to capture and hold attention. These findings suggest directions for future studies to address the lack of knowledge surrounding the nonverbal expression of guilt. In particular, future studies may include a social aspect to the paradigm, perhaps including an observer for some participants but not others to more fully expand on the possibility of the guilt expression being entirely bound to social pressures. Additional future directions include explorations of guilt expressions in children who are developing guilt, or in populations outside of the North
American context who might have different conceptualizations and experiences of guilt, or culturally bound expressions of guilt not common to North America.
4.5 References


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Chapter 5: General Discussion

5.1 Introduction

Guilt is an emotional experience that is necessary for normal social functioning, though in its excess or absence it can cause great difficulties both for the individual and for society (Pletti et al., 2017; Tilghman-Osborne, Cole, & Felton, 2012). Though it is an important and universal emotion, little is known about the way that guilt is expressed in health, or how this expression is altered in disease. Existing knowledge about guilt suggests that it is expressed internally via autonomic activation and deactivation, and externally via nonverbal cues (Boden & Eatough, 2019; Day & Bobocel, 2013; Julle-Danière et al., 2020). However, the exact patterns of these expressions are unknown in health, and therefore changes are difficult to ascertain in disease. Given these gaps in knowledge, this thesis seeks to establish the autonomic and nonverbal expression of guilt and explore the ways in which the autonomic signal of guilt may be altered in neurodegeneration. The central hypothesis of this thesis was that guilt is an emotion that is uniquely expressed relative to other emotions in health, and the expression of guilt is affected in neurodegenerative disease with ANS dysfunction, or frontal, insular or amygdala pathology.

Study I delineated the experience of guilt in healthy adults. Consistent with existing studies of the ANS in emotion (Pace-Schott et al., 2019), we found that there are distinguishing autonomic features that occur during the cognitive and affective experience of several primary and secondary emotions. Of particular interest, we were able to confirm that this alteration of the ANS also occurs during the cognitive experience of guilt. We were further able to identify specific autonomic signals that are key to the guilt experience. Contrary to expectations, our
findings presented a more mixed picture of SNS and PSNS activation and deactivation, suggesting that guilt is not defined purely by SNS activation in healthy adults. Of particular note, we found that activity of the EGG controlled by the SNS or PSNS, swallowing rate controlled by the SNS, and heart activity mediated by the PSNS were particularly associated with guilt. Addressing the third objective, identified an association between trait guilt, attention to the body, and reactivity of the subdiaphragmatic organs. This supports the potential link suggested by previous research between bodily signals and guilt (Mul et al., 2018; Stoica & Depue, 2020). However, this finding did not extend to heartbeat accuracy. Overall, these findings confirm our hypothesis that guilt is expressed at least in part by the ANS and that trait attention to the body may be linked to trait guilt.

Study II expanded the findings of study I to investigate the way that the ANS is affected in neurodegenerative diseases featuring pathology in the ANS or in CNS regions implicated in guilt, and the connection between these effects and potential changes in trait and state guilt. Consistent with study I and expectations, we identified differences between emotions in the groups. We also found that psychophysiological scores distinguished between the diagnostic categories, confirming that there are differences between the groups in ANS responding. We were not able to identify differing patterns of either state or trait guilt between the diagnostic categories, however we were able to do so using autonomic reactivity scores. Using autonomic reactivity scores, we were able to identify specifically some disengagement of the SNS and over-engagement of the PSNS in patients, particularly FTD, relative to controls. We did not find a deficit in interoceptive awareness that could not otherwise be attributed to cognitive impairment. Taken together, these results confirm that there are changes in these neurodegenerative diseases that are reflected in the ANS response to emotional stimuli. It further suggests that there may be
specific changes in the experience of guilt that may be indexed via the alterations in reactivity to guilt-inducing stimuli, though more research is necessary to confirm and explore those findings in detail.

In study III, the external, nonverbal expression of guilt was explored in healthy adults. We identified features that distinguished guilt from the comparison emotions, particularly movements of the brow and lip, as well as movements of the head. However, these movements largely did not reflect our expectations, as participants were less likely to tilt or turn their head away, or to move their faces into more negatively valenced postures. We took these findings to suggest that the nonverbal expression of guilt is in large part dependent on the existence of an audience to whom the feeling of guilt is being conveyed. Without this audience, the need to perform guilt-signaling behaviours is absent. More research is needed to investigate the presence or absence of others in the expression of guilt.

5.2 The Visceral Experience of Guilt in Health and Disease

There is a great deal of evidence that the ANS is responsive to emotional states, and that it generates patterns that are detectable and able to distinguish between emotions to some degree (Kreibig, 2010; Pace-Schott et al., 2019). The results of study I confirm these findings, as we were able to identify psychophysiological differences between all of our comparison emotions. We were able to extend these findings further to suggest that ANS activity occurs not only for basic emotions such as anger and disgust, but also for more complex secondary emotions like pride and, crucially, guilt. Study I identified mixed SNS and PSNS responding during the experience of guilt and identified effectors throughout the body as key to the experience of guilt. This finding lends further support to the small body of literature that indicates that ANS responding to emotions is not purely constrained to activity of either the SNS or PSNS.
depending on whether the emotion spurs behaviour or not. Rather, there is an interplay of autonomic activity that varies between effectors. In guilt particularly, we found that the movement of the stomach muscles was the psychophysiological signal most successful at distinguishing guilt from the comparison emotions. This signal had been previously investigated in disgust and in relationship to vividness of emotions, but never in guilt (Meissner, Muth, & Herbert, 2011; Vianna & Tranel, 2006; Vianna et al., 2009). Our findings lend credence to the growing interest in the activity of the gut as it relates to cognitive and emotional functioning (Proctor et al., 2017; Van Oudenhove et al., 2011). Swallowing rate decline, driven by SNS activation, and RSA increase, driven by PSNS activation, were also key features of guilt that suggest further areas of research.

The finding of differential ANS activation in emotion was also supported by study II, where distinctions between emotions was observable even in patient groups. Particularly, this study suggested that the findings in study I related to swallowing rate and EDA magnitude were important components of the guilt response. This study also confirmed existing observations of autonomic disturbance linked with emotional disturbance in FTD (Balconi et al., 2015; Fong et al., 2017; Sturm et al., 2018). It extended these findings to indicate that autonomic responding to emotions may also be affected in DLB, PD, and to a lesser extent in AD. Specifically, we found that alterations in the reactivity of the ANS to guilt stimuli occur in all patient groups. In FTD particularly we found that under-reactivity of skin conductance responses occurs during guilt videos, which has previously been identified in other studies exploring empathy and moral behaviour in FTD. We also identified that for all patient groups the respiration rate declined, relative to healthy controls. In AD and FTD this decline was significant, while in DLB/PD it approached significance. To our knowledge this is the first study to identify respiration rate
during emotion processing as particularly altered in these neurodegenerative diseases. This may suggest future areas of focus for research in the ANS in neurodegeneration.

Existing literature has firmly established a link between body awareness and empathy or emotional awareness (Craig, 2002; Grynberg & Pollatos, 2015; Mul et al., 2018; Stoica & Depue, 2020; Terasawa et al., 2014). In study I, we supported and extended this finding by identifying a correlation between trait guilt proneness and trait bodily attention. This suggests that monitoring of altered bodily signals caused by the ANS is linked to guilt proneness, highlighting the importance of the interrelationship between the cognitive and embodied experience of the emotion. We also identified reactivity of the subdiaphragmatic organs, but not of the superdiaphragmatic organs, as correlated with trait guilt. This aligns neatly with the finding of the centrality of the EGG in guilt. Study II was less able to coherently identify a relationship between bodily awareness and guilt, which may suggest methodological issues, or else an alteration in this connection with age. In neither study I nor study II were we able to find a clear association between guilt proneness and heartbeat accuracy, a measure of interoceptive awareness. Future studies are needed to explore and confirm potential links between awareness of the body and guilt, and how it may be altered in disease.

5.3 Guilt in Neurodegeneration

It is well known that in FTD perturbations of empathy and guilt are some of the most common and enduring symptoms (Daigmorte et al., 2019; Moll et al., 2011). These deficits have been linked with changes in the ANS, as discussed above. However, for diseases such as DLB or PD where perturbation of the ANS is clear and commonly noted, whether or how this may be associated with guilt or other emotions remains unclear. In study II, we did not identify changes in trait guilt, as indexed by the Guilt Inventory and the IRI, nor in state guilt, indexed by the
number of times that guilt was selected as the emotion felt during the task and by the charity donation decision. This was unexpected, given existing literature in the experience of guilt and performance of moral or social behaviours in FTD (Cipriani et al., 2013; Mendez, 2010; Strikwerda-Brown et al., 2020). These unexpected findings may reflect methodological issues such as the small, heterogenous sample, reliance on patient’s self-report, or the questionnaires in use. Future studies using larger, more homogenous samples and questionnaires more easily applied to cognitively impaired populations would help to better elucidate the changes in guilt in FTD and other neurodegenerative conditions.

5.4 The Nonverbal Expression of Guilt

The findings of study III provide greater insight into the way that guilt is expressed in healthy adults. We investigated behaviours that had previously been observed in guilt, as well as in the related but distinct emotions of shame and embarrassment (Haidt & Keltner, 1999; Julle-Danière et al., 2020; Keltner, 1995; Velusamy et al., 2011). Though we did find that many of those behaviours were highlighted in our ethogram, the changes occurred in the opposite direction to those observed in previous studies (Julle-Danière et al., 2020). These results were unexpected and could be taken to suggest that there are no meaningful nonverbal signals of guilt. However, it is possible instead that these findings highlight one of the key aspects of guilt: its social utility. In study III, there was no person present to whom guiltiness needed to be signalled, either so that the participant could communicate that they knew they had erred or so that they could initiate actions to repair the harm they caused or the appearance of being a bad person that they had incurred. Without this social pressure to perform guiltiness, we failed to observe expected guilt behaviours that had been previously observed by Julle-Danière et al. during feigned wrongdoing in the presence of an allegedly wronged party (2020). This suggests that as
the primary end to the expression of guilt is to convey guilt to others and make efforts towards repairing one’s moral self in the eyes of observers, there is no need to perform guilt behaviours when one is unobserved.

Relatedly, in both study I and II the participants were given the option to donate some or all of the money they were receiving to charity. In study I, the participants performed this choice unobserved, and gave an average of just over $13. In study I the 50+ cohort, the average amount donated was $17. In study II this decision was made in the presence of a research coordinator, and the choice had to be vocalised to the coordinator. In this instance, the average amount donated was almost $26, significantly more than either the study I group as a whole, or the 50+ cohort of study I. This supports the idea that the presence of another person may affect the way that guilt is expressed, or the way that behaviour may be performed when guilt is a potential risk.

5.5 Limitations and Future Directions

Across all three studies, a number of limitations exist that could be addressed in future studies in order to expand on these findings. In all three studies, one limitation was the lack of an emotional intensity measurement. The intensity of emotions felt can vary widely between emotional experiences, and even within that experience. Based on existing research, intensity is likely to have an effect on the ANS and on nonverbal expressions (Vianna et al., 2009; Julle-Danière et al., 2020). Without an intensity or arousal measurement either during each video or immediately after it is viewed, it is not possible to ascertain how intensely the emotion identified was felt. Thus, in these studies it cannot be known how either the ANS or nonverbal expressions of emotion vary along with subjective emotional intensity, and whether the signals may correlate with the intensity ratings. Relatedly, it is possible that throughout the videos individuals experienced more than one emotion or a blend of emotions, and that there were periods in which
an emotion other than the emotion they ultimately identified as their primary emotion
predominated. Thus, there may be fluctuations in the ANS or in nonverbal behaviours that are
misinterpreted as belonging to the guilt response when instead they reflect some other emotion or
combination of emotions. Though we included the ability to identify secondary emotions felt
following the conclusion of the videos, these responses were not time-locked, and it is
impossible to know whether they occurred with guilt, or separately, or both. In future studies, an
ideal solution would be to include continuous affect and intensity ratings throughout videos, to
ensure that the full emotional experience is captured, and that the underlying emotions are
correctly matched with their observable physiological or behavioural expressions.

In study II in particular, a major limitation was the sample size. Though efforts were
made to reach the sample sizes calculated to detect the differences under the investigation, due to
pandemic restrictions halting study visits, study II fell short of the enrollment target. It was
therefore also unbalanced in regard to gender, and unable to ensure homogeneity in terms of
patient symptom profiles that may have affected the results. We therefore consider the results for
study II to be preliminary, and at present the results must be interpreted with great caution due to
the potential negative effect of a small and unbalanced sample on the statistical methods in use.
In future studies, a larger sample size would enable more certainty around the statistical
inferences being drawn and may allow for the detection of differences that were not observable
with this sample size. A more gender balanced group with more homogeneity of disease
subtypes may allow for more clarity around diagnostic group differences than were possible to
obtain in this study.

Another limitation is that the psychophysiological and nonverbal behaviour scores were
all captured as arithmetic means across the whole analysis window, and these means were further
averaged to create a single score for each physiological signal within each emotion. Though this method has been utilized in previous studies, it is a relatively conservative measure of the observed signals and may not take into account fluctuations in intensity or in emotion as discussed above, as well as potentially eliminating elements of the signals that may evolve over time (Davydov, Zech, & Luminet, 2011). Future studies could investigate more granular epochs and capture time series data. In this way, they may capture the finer grained details of responding that might otherwise be lost to averaging and composite scoring.

Another potential limitation is the semantic ambiguity that exists around the word “guilt” in normal conversation. Though “guilt” and “shame” have been completely and clearly separated in research, this distinction does not typically exist in daily life (Niedenthal, Tangney, & Gavanski, 1994; Tangney, Wagner, & Gramzow, 1992; Tangney et al., 1996). The terms are often used interchangeably, and commonly thought to represent the same general concept. Along with embarrassment, they may also co-occur, occasioning even more muddling of the terms (Smith & Ellsworth, 1985; Withers & Sherblom, 2008). In both studies I and III participants were given the opportunity to identify guilt, shame, or embarrassment, and either shame or embarrassment were discarded as not-guilt. In study II this was not done, to avoid confusing participants unnecessarily. Even with this attempt to eliminate crossover between the terms, it is possible that contamination occurred, either in the sense that participants felt a combination of these emotions, or that they identified themselves as feeling one when under the research definition they would have likely been classified as feeling another. To address this issue, future studies could clearly instruct participants on the intended definitions in use for each emotional term to ensure that participants are producing the most correct label for their experience.
Additional future directions building on this research could explore alterations of guilt via physiological manipulations. We know that it is possible to, for example, affect disgust feelings by eliciting or soothing physiological signals (Liuzza et al., 2019; Nord et al., 2020; Tracy, Steckler, & Heltzel, 2019). Eliciting the emotional experience of guilt via the body may suggest treatment targets to alter maladaptive levels of guilt in some diseases. Relatedly, alterations in the physiological and nonverbal expressions of guilt could be investigated in disorders other than neurodegenerative, such as posttraumatic stress disorder, psychopathy, or obsessive-compulsive disorders. This may help to establish groups that might respond to alterations of guilt, or else suggest other targets for modulation. The introduction of a social observer or target for social behaviours may help to further elucidate the elements of the guilt expression that are tied to being observed. As it is likely that the nonverbal guilt performance is triggered by the presence of an observer, it is possible that the autonomic experience also may be altered by a similar social pressure. Guilt expression should also be investigated outside of the Western, educated, industrialized, rich, and democratic context (Henrich, Hein, & Norenzayan, 2010). While guilt may be an almost universal emotion at the most fundamental level (Anolli & Pascucci, 2005; Bear et al., 2009; Bedford, 2004; Breugelmans & Poortinga, 2006; Fontaine et al., 2006; Johnson et al., 1987; Osei-Tutu et al., 2021; Patel, 2018), its conceptualization and expression are unlikely to be completely consistent between cultures (Anolli & Pascucci, 2005; Bierbauer, 1992; Furukawa, Tangney, & Higashibara, 2012; Matsumoto et al., 1988; Silfver, 2007; Stompe et al., 2001). Understanding different expressions of guilt may allow for more advancements in the area of diagnosis or treatment, as well as increasing knowledge about cross-cultural expressions. Finally, investigating the development of autonomic and nonverbal expressions of guilt in young
children may enable further understanding about the way that guilt develops and changes with maturation and a growing understanding of the thoughts and feelings of others.

5.6 Conclusions

Guilt is a deeply important emotional experience, but one about which much yet remains unknown. The results presented in this thesis advance our knowledge of the way that guilt is embodied and expressed, and how elements of this expression may be altered in neurodegenerative disorders. We identified aspects of the autonomic and nonverbal expression of guilt that could be used to distinguish guilt from comparison emotions. In particular, we established the autonomic signals that distinguish guilt from other emotions in healthy adults. Through this study, we were able to confirm that the ANS is responsive in complex secondary emotions like guilt, and that guilt and body perceptions are linked. Further, we demonstrated that the ANS expression of guilt and other emotions are altered in three neurodegenerative conditions, though we could not confirm that neurodegenerative conditions are associated with specific alterations in the cognitive experience of guilt. In terms of the nonverbal expression of emotion, our findings suggested some features that can distinguish between guilt and other emotions, and that the nonverbal expression of guilt may be driven by the presence of an observer. Taken together, these findings present novel insight into the way that guilt is experienced and how it is felt and conveyed by the guilty individual. Guilt is a complex emotional experience that can be driven by numerous external and internal factors, and that can drive complex behaviours. This study lays the groundwork for additional research into the way that guilt is experienced, how it may be altered or affected, and how it is expressed in health and disease.
5.7 References


Appendices

Appendix A: Chapters 2 & 4 (Study I & III) Supplementary Material

A.1 Sample questions and response options for opinions and behaviour questionnaire

Do you think that it is important to help the poor or underprivileged?
1. Yes
2. No
3. Don’t know

In the past 12 months have you engaged in formal or informal unpaid activities aimed at conservation or preservation of the environment or wildlife?
1. Yes
   a. How much time on average per week, in hours? ______
2. No
3. Don’t know

In the past 12 months, have you sped while driving, passed without adequate space, or otherwise driven unsafely?
1. Yes, frequently
2. Yes, on a few occasions
3. Yes, rarely
4. No

On a scale from 1 to 5, how important is finding a cure for cancer to you?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not important at all</td>
<td></td>
<td></td>
<td></td>
<td>Very important</td>
</tr>
</tbody>
</table>

Do you think that having new things is important?
1. Yes
2. No

On a scale from 1 to 5, how important is it to you to carry on Canadian traditions, customs, and holidays?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not important at all</td>
<td></td>
<td></td>
<td></td>
<td>Very important</td>
</tr>
</tbody>
</table>

Do you usually use a dryer, or do you air dry clothing where possible?
1. Usually use a dryer in both summer and winter
2. Usually use a dryer in winter, but not in summer
3. Do not have/do not use a dryer
### A.2 Feedback Statements

<table>
<thead>
<tr>
<th>Video</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Friday</td>
<td>You like to have new things</td>
</tr>
<tr>
<td>One Child</td>
<td>You donate less than the average Canadian to international relief efforts</td>
</tr>
<tr>
<td>Don't Almost Give- Jack</td>
<td>You could do more to help people in Canada</td>
</tr>
<tr>
<td>Africare-Shoeboxes</td>
<td>You don’t want to be repeatedly asked to donate money</td>
</tr>
<tr>
<td>Without...</td>
<td>You sometimes ignore charity appeals</td>
</tr>
<tr>
<td>Strawberry Wasted</td>
<td>You waste much more food than average</td>
</tr>
<tr>
<td>WWF Laptop</td>
<td>You waste more energy than average</td>
</tr>
<tr>
<td>WWF T-Shirt</td>
<td>Your laundry habits waste more water than two thirds of respondents</td>
</tr>
<tr>
<td>60 Seconds Blood Donation</td>
<td>You think blood and organ donation is as important as most Canadians</td>
</tr>
<tr>
<td>French</td>
<td>You find humourous ads more memorable than the average Canadian</td>
</tr>
<tr>
<td>Sinking</td>
<td>You can always learn a new language</td>
</tr>
<tr>
<td>Charlie Sheen</td>
<td>You are as influenced by celebrity endorsement as most Canadians</td>
</tr>
<tr>
<td>Dad Makes Cookies</td>
<td>You bake less than the average Canadian</td>
</tr>
<tr>
<td>Go First</td>
<td>You are as influenced by ads as most people</td>
</tr>
<tr>
<td>Haircut</td>
<td>Your opinion of adoption is shared by half of Canadians</td>
</tr>
<tr>
<td>Rotting Chicken</td>
<td>You worry about rotted food as much as the average person</td>
</tr>
<tr>
<td>Drinking 6000 Blended Maggots</td>
<td>You feel as sick about maggots as the average person</td>
</tr>
<tr>
<td>Rotting Meat</td>
<td>You would never eat rotted meat</td>
</tr>
<tr>
<td>The Poop Lady</td>
<td>You should not eat contaminated food</td>
</tr>
<tr>
<td>Toxic Food Environment</td>
<td>You are as anxious about vomiting as the average person</td>
</tr>
<tr>
<td>Custard</td>
<td>You would not eat food contaminated with bodily fluids</td>
</tr>
<tr>
<td>Cotton</td>
<td>You will see a video about cotton thread</td>
</tr>
<tr>
<td>Rubber Gloves</td>
<td>You will see a video about rubber gloves</td>
</tr>
<tr>
<td>Fibre Optics</td>
<td>You will see a video about fibre optics</td>
</tr>
<tr>
<td>Erasers</td>
<td>You will see a video about erasers</td>
</tr>
<tr>
<td>Playing Cards</td>
<td>You will see a video about playing cards</td>
</tr>
<tr>
<td>Stickers</td>
<td>You will see a video about stickets</td>
</tr>
<tr>
<td>I Am Canadian</td>
<td>You are in Canada</td>
</tr>
<tr>
<td>Made From Canada</td>
<td>Your sense of Canadian identity is as strong as average</td>
</tr>
<tr>
<td>Anthem</td>
<td>Your sense of connection to the world is stronger than average</td>
</tr>
<tr>
<td>Peacekeeping</td>
<td>You think peacekeeping is as important as most Canadians</td>
</tr>
<tr>
<td>Fly the Flag</td>
<td>You feel connected to Canada</td>
</tr>
<tr>
<td>Greatest Human Achievements</td>
<td>You are proud of humanity’s achievements</td>
</tr>
<tr>
<td>----------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Dying Wife</td>
<td>You get sad about as easily as other people</td>
</tr>
<tr>
<td>SickKids vs Cancer</td>
<td>You think fighting cancer is important</td>
</tr>
<tr>
<td>Last Minutes with Oden</td>
<td>You feel sorry for people who have recently lost a pet</td>
</tr>
<tr>
<td>12 Days of Christmas</td>
<td>You should not drive unsafely</td>
</tr>
<tr>
<td>Notification</td>
<td>You feel sorry for people who have recently lost a child</td>
</tr>
<tr>
<td>Madly in love</td>
<td>You feel sad when someone else is sad about as often as other people</td>
</tr>
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*Table A.1. Feedback statements and associated video titles*
<table>
<thead>
<tr>
<th>Video Name</th>
<th>Target Emotion</th>
<th>Length</th>
<th>Topic</th>
<th>Source Agency/Film</th>
<th>Source Country</th>
</tr>
</thead>
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<td>Guilt</td>
<td>60s</td>
<td>Blood Donation</td>
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<td>Canada</td>
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<td>30s</td>
<td>Poverty/3rd World</td>
<td>Africare</td>
<td>USA</td>
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<td>30s</td>
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<td>Salvation Army</td>
<td>Canada</td>
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<td>USA</td>
</tr>
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<td>1m50s</td>
<td>Environment/Climate Change</td>
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<td>USA</td>
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<td>30s</td>
<td>Poverty/Canada</td>
<td>Ad Council</td>
<td>USA</td>
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<td>Let Them Figure It Out</td>
<td>Guilt</td>
<td>60s</td>
<td>Environment/Climate Change</td>
<td>Government of Ontario</td>
<td>Canada</td>
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<td>Fly the Flag</td>
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<td>60s</td>
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<td>Greatest Human Achievements</td>
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<td>1m55s</td>
<td>World unity/human excellence</td>
<td>Questar Video</td>
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<td>1m</td>
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<td>Molson Canadian</td>
<td>Canada</td>
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<td>Made From Canada</td>
<td>Pride</td>
<td>45s</td>
<td>Canadian identity</td>
<td>Molson Canadian</td>
<td>Canada</td>
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<td>Peacekeeping</td>
<td>Pride</td>
<td>1m10s</td>
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<td>The Anthem</td>
<td>Pride</td>
<td>1m30s</td>
<td>World unity</td>
<td>Samsung Mobile</td>
<td>USA</td>
</tr>
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<td>12 Days of Christmas</td>
<td>Sadness</td>
<td>1m30s</td>
<td>Anti-drunk driving</td>
<td>Transport Accident Commission</td>
<td>Australia</td>
</tr>
<tr>
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*Table A.2. Video stimuli names, target emotions, length, topics, source agency and source country*
A.4 Psychophysiological recording

Fig A.1. Diagram of the electrode (red circles), leads (red lines), respiration belt (blue rectangle), and modules (red squares) placement for swallowing electromyography, electrocardiogram, respiration, electrogastrogram, and electrodermal activity recording on a standard participant
Appendix B: Chapter 3 (Study II) Supplementary Material

B.1 Sample questions and response options for opinions and behaviour questionnaire

Do you think that it is important to help the poor?
   1. Yes
   2. No
   3. Don’t know

Do you think that you could do more to help the poor in other countries?
   1. Yes
   2. No
   3. Don’t know

Do you recycle?
   1. Yes- everything that I can
   2. Almost always
   3. Sometimes
   4. No

How many computers do you use regularly? ____

On a scale from 1 to 5, how strongly do you feel sorry for people whose child has recently died?

<table>
<thead>
<tr>
<th></th>
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<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not very strongly</td>
<td>Very strongly</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On a scale from 1 to 5, how important is being Canadian to you?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td></td>
<td>Not important at all</td>
<td>Very important</td>
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### B.2 Feedback Statements

<table>
<thead>
<tr>
<th>Video</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Friday</td>
<td>You like to have new things</td>
</tr>
<tr>
<td>One Child</td>
<td>You donate less than the average Canadian to international relief efforts</td>
</tr>
<tr>
<td>Don’t Almost Give- Jack</td>
<td>You could do more to help people in Canada</td>
</tr>
<tr>
<td>Africare-Shoeboxes</td>
<td>You don’t want to be repeatedly asked to donate money</td>
</tr>
<tr>
<td>Without...</td>
<td>You sometimes ignore charity appeals</td>
</tr>
<tr>
<td>Strawberry Wasted</td>
<td>You waste much more food than average</td>
</tr>
<tr>
<td>WWF Laptop</td>
<td>You waste more energy than average</td>
</tr>
<tr>
<td>WWF T-Shirt</td>
<td>Your laundry habits waste more water than two thirds of respondents</td>
</tr>
<tr>
<td>French</td>
<td>You find humourous ads more memorable than the average Canadian</td>
</tr>
<tr>
<td>Sinking</td>
<td>You can always learn a new language</td>
</tr>
<tr>
<td>Charlie Sheen</td>
<td>You are as influenced by celebrity endorsement as most Canadians</td>
</tr>
<tr>
<td>Dad Makes Cookies</td>
<td>You bake less than the average Canadian</td>
</tr>
<tr>
<td>Go First</td>
<td>You are as influenced by ads as most people</td>
</tr>
<tr>
<td>Rotting Chicken</td>
<td>You worry about rotted food as much as the average person</td>
</tr>
<tr>
<td>Drinking 6000 Blended Maggots</td>
<td>You feel as sick about maggots as the average person</td>
</tr>
<tr>
<td>Rotting Meat</td>
<td>You would never eat rotted meat</td>
</tr>
<tr>
<td>The Poop Lady</td>
<td>You should not eat contaminated food</td>
</tr>
<tr>
<td>Toxic Food Environment</td>
<td>You are as anxious about vomiting as the average person</td>
</tr>
<tr>
<td>Cotton</td>
<td>You will see a video about cotton thread</td>
</tr>
<tr>
<td>Rubber Gloves</td>
<td>You will see a video about rubber gloves</td>
</tr>
<tr>
<td>Fibre Optics</td>
<td>You will see a video about fibre optics</td>
</tr>
<tr>
<td>Erasers</td>
<td>You will see a video about erasers</td>
</tr>
<tr>
<td>Playing Cards</td>
<td>You will see a video about playing cards</td>
</tr>
<tr>
<td>I Am Canadian</td>
<td>You are in Canada</td>
</tr>
<tr>
<td>Made From Canada</td>
<td>Your sense of Canadian identity is as strong as average</td>
</tr>
<tr>
<td>Anthem</td>
<td>Your sense of connection to the world is stronger than average</td>
</tr>
<tr>
<td>Peacekeeping</td>
<td>You think peacekeeping is as important as most Canadians</td>
</tr>
<tr>
<td>Fly the Flag</td>
<td>You feel connected to Canada</td>
</tr>
<tr>
<td>Dying Wife</td>
<td>You get sad about as easily as other people</td>
</tr>
<tr>
<td>SickKids vs Cancer</td>
<td>You think fighting cancer is important</td>
</tr>
<tr>
<td>Last Minutes with Oden</td>
<td>You feel sorry for people who have recently lost a pet</td>
</tr>
<tr>
<td>12 Days of Christmas</td>
<td>You should not drive unsafely</td>
</tr>
<tr>
<td>Notification</td>
<td>You feel sorry for people who have recently lost a child</td>
</tr>
</tbody>
</table>

Table B.1. Feedback statements and associated video titles
### B.3 Video clip details

<table>
<thead>
<tr>
<th>Video Name</th>
<th>Target Emotion</th>
<th>Length</th>
<th>Topic</th>
<th>Source Agency/Film</th>
<th>Source Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 Seconds Blood Donation</td>
<td>Guilt</td>
<td>60s</td>
<td>Blood Donation</td>
<td>Canadian Blood Services</td>
<td>Canada</td>
</tr>
<tr>
<td>Africare - Shoeboxes</td>
<td>Guilt</td>
<td>30s</td>
<td>Poverty/3rd World</td>
<td>Africare</td>
<td>USA</td>
</tr>
<tr>
<td>Black Friday</td>
<td>Guilt</td>
<td>30s</td>
<td>Poverty/Canada</td>
<td>Salvation Army</td>
<td>Canada</td>
</tr>
<tr>
<td>WWF Laptop</td>
<td>Guilt</td>
<td>2m15s</td>
<td>Environment/Climate Change</td>
<td>World Wildlife Fund</td>
<td>USA</td>
</tr>
<tr>
<td>WWF T-Shirt</td>
<td>Guilt</td>
<td>1m50s</td>
<td>Environment/Climate Change</td>
<td>World Wildlife Fund</td>
<td>USA</td>
</tr>
<tr>
<td>Don't Almost Give-Jack</td>
<td>Guilt</td>
<td>30s</td>
<td>Poverty/Canada</td>
<td>Ad Council</td>
<td>USA</td>
</tr>
<tr>
<td>Let Them Figure It Out</td>
<td>Guilt</td>
<td>60s</td>
<td>Environment/Climate Change</td>
<td>Government of Ontario</td>
<td>Canada</td>
</tr>
<tr>
<td>One Child</td>
<td>Guilt</td>
<td>1m40s</td>
<td>Poverty/3rd World</td>
<td>Save the Children</td>
<td>UK</td>
</tr>
<tr>
<td>Strawberry Wasted</td>
<td>Guilt</td>
<td>60s</td>
<td>Food Waste</td>
<td>Ad Council</td>
<td>USA</td>
</tr>
<tr>
<td>Without...</td>
<td>Guilt</td>
<td>1m15s</td>
<td>Poverty/3rd World</td>
<td>Save the Children</td>
<td>USA</td>
</tr>
<tr>
<td>Go First</td>
<td>Amusement</td>
<td>30s</td>
<td>Advertisement</td>
<td>Cars.com</td>
<td>USA</td>
</tr>
<tr>
<td>Dad Makes Cookies</td>
<td>Amusement</td>
<td>30s</td>
<td>Adoption</td>
<td>Ad Council</td>
<td>USA</td>
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<tr>
<td>Charlie Sheen</td>
<td>Amusement</td>
<td>30s</td>
<td>Advertisement</td>
<td>DirecTV</td>
<td>USA</td>
</tr>
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<td>French</td>
<td>Amusement</td>
<td>45s</td>
<td>Adoption</td>
<td>Ad Council</td>
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<td>Haircut</td>
<td>Amusement</td>
<td>30s</td>
<td>Adoption</td>
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<td>Amusement</td>
<td>40s</td>
<td>Advertisement</td>
<td>Berlitz</td>
<td>USA</td>
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<td>Drinking 6000 Blended Maggots</td>
<td>Disgust</td>
<td>45s</td>
<td>Home Video</td>
<td>Where's My Challenge</td>
<td>UK</td>
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<td>Custard</td>
<td>Disgust</td>
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<td>Food contamination</td>
<td>Braindead</td>
<td>New Zealand</td>
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<td>The Poop Lady</td>
<td>Disgust</td>
<td>55s</td>
<td>Food contamination</td>
<td>Hoarders</td>
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<td>Rotting Chicken</td>
<td>Disgust</td>
<td>1m16s</td>
<td>Rotting food</td>
<td>Home video/David0101010</td>
<td>Unknown</td>
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<td>Disgust</td>
<td>1m36s</td>
<td>Rotting food</td>
<td>Home video/agnozja</td>
<td>Unknown</td>
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<tr>
<td>Toxic Food Environment</td>
<td>Disgust</td>
<td>20s</td>
<td>Vomiting</td>
<td>Supersize Me</td>
<td>USA</td>
</tr>
<tr>
<td>Cotton</td>
<td>Neutral</td>
<td>1m</td>
<td>Informational</td>
<td>How It's Made</td>
<td>Canada</td>
</tr>
<tr>
<td>Erasers</td>
<td>Neutral</td>
<td>45s</td>
<td>Informational</td>
<td>How It's Made</td>
<td>Canada</td>
</tr>
<tr>
<td>Fibre Optics</td>
<td>Neutral</td>
<td>40s</td>
<td>Informational</td>
<td>How It's Made</td>
<td>Canada</td>
</tr>
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<td>Playing Cards</td>
<td>Neutral</td>
<td>35s</td>
<td>Informational</td>
<td>How It's Made</td>
<td>Canada</td>
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<td>Rubber Gloves</td>
<td>Neutral</td>
<td>40s</td>
<td>Informational</td>
<td>How It's Made</td>
<td>Canada</td>
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<td>35s</td>
<td>Informational</td>
<td>How It's Made</td>
<td>Canada</td>
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<td>Video Stimuli</td>
<td>Target Emotion</td>
<td>Length</td>
<td>Topic</td>
<td>Source Agency</td>
<td>Source Country</td>
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<td>------------------------------------------------------------</td>
<td>--------------------------------------</td>
<td>----------------</td>
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<td>Fly the Flag</td>
<td>Pride</td>
<td>60s</td>
<td>Canadian identity</td>
<td>Air Canada</td>
<td>Canada</td>
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<td>Greatest Human</td>
<td>Pride</td>
<td>1m55s</td>
<td>World unity/human excellence</td>
<td>Questar Video</td>
<td>UK</td>
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<td>I Am Canadian</td>
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<td>1m</td>
<td>Canadian identity</td>
<td>Molson Canadian</td>
<td>Canada</td>
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<tr>
<td>Made From Canada</td>
<td>Pride</td>
<td>45s</td>
<td>Canadian identity</td>
<td>Molson Canadian</td>
<td>Canada</td>
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<td>Peacekeeping</td>
<td>Pride</td>
<td>1m10s</td>
<td>Canadian Peacekeeping</td>
<td>Royal Canadian Mounted Police</td>
<td>Canada</td>
</tr>
<tr>
<td>The Anthem</td>
<td>Pride</td>
<td>1m30s</td>
<td>World unity</td>
<td>Samsung Mobile</td>
<td>USA</td>
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<td>12 Days of Christmas</td>
<td>Sadness</td>
<td>1m30s</td>
<td>Anti-drunk driving</td>
<td>Transport Accident Commission</td>
<td>Australia</td>
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<td>Dying Wife</td>
<td>Sadness</td>
<td>1m20s</td>
<td>Death of a loved one</td>
<td>Home video/Erin Solari</td>
<td>USA</td>
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<td>Madly in love</td>
<td>Sadness</td>
<td>1m45s</td>
<td>Loss of a loved one to dementia</td>
<td>Human Kind</td>
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<td>Last Minutes with Oden</td>
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<td>1m10s</td>
<td>Death of a pet</td>
<td>Phos Pictures</td>
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<td>Sadness</td>
<td>45s</td>
<td>Death of a loved one</td>
<td>The Messenger</td>
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<td>SickKids vs Cancer</td>
<td>Sadness</td>
<td>40s</td>
<td>Childhood cancer</td>
<td>SickKids</td>
<td>Canada</td>
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</tbody>
</table>

Table B.2. Video stimuli names, target emotions, length, topics, source agency and source country
B.4 Psychophysiological recording

Fig B.1. Diagram of the electrode (red circles), leads (red lines), respiration belt (blue rectangle), modules (red squares), and CNAP finger cuff and module (green rectangles) placement for swallowing electromyography, electrocardiogram, respiration, electrogastrogram, electrodermal activity, and continuous blood pressure recording on a standard participant.
### B.5 Comparison between DLB and PD groups

<table>
<thead>
<tr>
<th>N (female)</th>
<th>Dementia with Lewy Bodies</th>
<th>Parkinson’s Disease</th>
<th>Comparisons</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>Range</td>
</tr>
<tr>
<td>Age</td>
<td>71.56</td>
<td>8.83</td>
<td>60-85</td>
</tr>
<tr>
<td>Education</td>
<td>15.11</td>
<td>2.26</td>
<td>12-19</td>
</tr>
<tr>
<td>Guilt Inventory</td>
<td>133.22</td>
<td>21.49</td>
<td>105-174</td>
</tr>
<tr>
<td>Empathy Quotient</td>
<td>36.89</td>
<td>9.97</td>
<td>24-49</td>
</tr>
<tr>
<td>State-Trait Anxiety Inventory</td>
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<td></td>
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<tr>
<td>State</td>
<td>33.33</td>
<td>8.94</td>
<td>23-45</td>
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<tr>
<td>Trait</td>
<td>26.44</td>
<td>9.63</td>
<td>21-50</td>
</tr>
<tr>
<td>Body Perception Questionnaire</td>
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<td></td>
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</tr>
<tr>
<td>Body Awareness</td>
<td>61.67</td>
<td>17.33</td>
<td>41-94</td>
</tr>
<tr>
<td>Supradiaphragmatic reactivity</td>
<td>22.44</td>
<td>3.97</td>
<td>18-30</td>
</tr>
<tr>
<td>Subdiaphragmatic reactivity</td>
<td>9.89</td>
<td>2.03</td>
<td>6-13</td>
</tr>
<tr>
<td>Heartbeat accuracy</td>
<td>0.32</td>
<td>0.38</td>
<td>0-0.83</td>
</tr>
<tr>
<td>COMPASS</td>
<td>25.33</td>
<td>9.96</td>
<td>8-40</td>
</tr>
<tr>
<td>ACE-III</td>
<td>69.89</td>
<td>16.98</td>
<td>38-89</td>
</tr>
<tr>
<td>RSMS</td>
<td>34.71</td>
<td>9.43</td>
<td>21-51</td>
</tr>
<tr>
<td>IRI</td>
<td>80.57</td>
<td>14.58</td>
<td>71-112</td>
</tr>
<tr>
<td>CBI-R</td>
<td>56.00</td>
<td>24.01</td>
<td>18-88</td>
</tr>
<tr>
<td>COMPASS-C</td>
<td>19.40</td>
<td>7.27</td>
<td>8-27</td>
</tr>
<tr>
<td>UPDRS</td>
<td>48.57</td>
<td>12.70</td>
<td>30-65</td>
</tr>
</tbody>
</table>

Table B.3. Comparison between DLB and PD groups in terms of state, trait, and demographic information showing no significant differences between the groups using an independent 2-group Mann Whitney U test in R.
### B.6 Planned contrast tables

#### Swallowing Electromyography Results

<table>
<thead>
<tr>
<th>Guilt Comparison</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-AD</td>
<td>5.402</td>
<td>8.39</td>
<td>0.644</td>
<td>0.918</td>
<td>-16.3 – 27.1</td>
</tr>
<tr>
<td>HC-FTD</td>
<td>0.568</td>
<td>9.20</td>
<td>0.062</td>
<td>0.999</td>
<td>-23.2 – 24.3</td>
</tr>
<tr>
<td>HC-DLB/PD</td>
<td>7.582</td>
<td>6.08</td>
<td>1.247</td>
<td>0.598</td>
<td>-8.1 – 23.3</td>
</tr>
<tr>
<td>AD-FTD</td>
<td>-4.834</td>
<td>11.21</td>
<td>-0.431</td>
<td>0.973</td>
<td>-33.8 – 24.1</td>
</tr>
<tr>
<td>AD-DLB/PD</td>
<td>2.180</td>
<td>8.84</td>
<td>-0.247</td>
<td>0.995</td>
<td>-20.7 – 25.0</td>
</tr>
<tr>
<td>FTD-DLB/PD</td>
<td>7.014</td>
<td>9.60</td>
<td>0.730</td>
<td>0.885</td>
<td>-17.8 – 31.8</td>
</tr>
</tbody>
</table>

Table B.4. Swallowing electromyography during guilt compared across each diagnostic category.

<table>
<thead>
<tr>
<th>Guilt Comparison</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC Amusement</td>
<td>1.605</td>
<td>5.42</td>
<td>0.296</td>
<td>0.997</td>
<td>-13.9 – 17.2</td>
</tr>
<tr>
<td>Disgust</td>
<td>-16.123</td>
<td>5.42</td>
<td>-2.976</td>
<td>0.037</td>
<td>-31.7 – -0.6</td>
</tr>
<tr>
<td>Neutral</td>
<td>-1.529</td>
<td>5.42</td>
<td>-0.282</td>
<td>0.999</td>
<td>-17.1 – 14.0</td>
</tr>
<tr>
<td>Pride</td>
<td>-1.844</td>
<td>5.42</td>
<td>-0.340</td>
<td>0.999</td>
<td>-17.4 – 13.7</td>
</tr>
<tr>
<td>Sadness</td>
<td>-12.920</td>
<td>5.42</td>
<td>-2.385</td>
<td>0.071</td>
<td>-28.5 – 2.6</td>
</tr>
<tr>
<td>AD Amusement</td>
<td>-17.091</td>
<td>10.56</td>
<td>-1.618</td>
<td>0.587</td>
<td>-47.4 – 13.2</td>
</tr>
<tr>
<td>Disgust</td>
<td>-15.457</td>
<td>10.56</td>
<td>-1.463</td>
<td>0.688</td>
<td>-45.8 – 14.9</td>
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<tr>
<td>Neutral</td>
<td>2.407</td>
<td>10.56</td>
<td>0.228</td>
<td>0.999</td>
<td>-27.9 – 32.7</td>
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<tr>
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<td>10.56</td>
<td>-0.165</td>
<td>1.000</td>
<td>-32.1 – 28.6</td>
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<td>Sadness</td>
<td>-8.172</td>
<td>10.56</td>
<td>-0.774</td>
<td>0.972</td>
<td>-38.5 – 22.1</td>
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<tr>
<td>FTD Amusement</td>
<td>11.053</td>
<td>11.82</td>
<td>0.935</td>
<td>0.937</td>
<td>-22.9 – 44.9</td>
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<tr>
<td>Disgust</td>
<td>-16.810</td>
<td>11.82</td>
<td>-1.422</td>
<td>0.714</td>
<td>-50.7 – 17.1</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.353</td>
<td>11.82</td>
<td>0.030</td>
<td>1.000</td>
<td>-33.6 – 34.3</td>
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<tr>
<td>Pride</td>
<td>-4.451</td>
<td>11.82</td>
<td>-0.376</td>
<td>0.999</td>
<td>-38.4 – 29.5</td>
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<tr>
<td>Sadness</td>
<td>-3.057</td>
<td>11.82</td>
<td>-0.259</td>
<td>0.999</td>
<td>-36.9 – 30.9</td>
</tr>
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Table B.5. Swallowing electromyography in each diagnostic category for guilt in comparison to other emotions.
### Skin Conductance Level Magnitude Results

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Table B.6 Skin conductance magnitude during guilt compared across each diagnostic category

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Table B.7 Skin conductance magnitude in each diagnostic category for guilt in comparison to other emotions.
### Non-specific skin conductance response results

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Table B.8 Non-specific skin conductance responses during guilt compared across each diagnostic category.

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Table B.9 Non-specific skin conductance responses in each diagnostic category for guilt in comparison to other emotions.
### Electrogastrography results

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Table B.10 Electrogastrography responses during guilt compared across each diagnostic category

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<td>-0.921</td>
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<td>0.885</td>
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<td>1.758</td>
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Table B.11 Electrogastrography responses in each diagnostic category for guilt in comparison to other emotions.
### Interbeat interval results

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<th>95% CI</th>
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<td>0.933</td>
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**Table B.12** Heart period during guilt compared across each diagnostic category

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<th>Std. Error</th>
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<td>5.64</td>
<td>0.561</td>
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<td>5.64</td>
<td>1.272</td>
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<td>1.537</td>
<td>0.641</td>
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</tr>
<tr>
<td>Amusement</td>
<td>11.999</td>
<td>11.00</td>
<td>1.091</td>
<td>0.885</td>
<td>-19.6 – 43.6</td>
</tr>
<tr>
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<td>11.00</td>
<td>0.548</td>
<td>0.994</td>
<td>-25.5 – 37.6</td>
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<tr>
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<td>-0.032</td>
<td>1.000</td>
<td>-31.9 – 31.2</td>
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<td>-0.679</td>
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<td>0.989</td>
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<td>0.080</td>
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<td>6.96</td>
<td>-0.440</td>
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**Table B.13** Heart period in each diagnostic category for guilt in comparison to other emotions.
### Respiratory Sinus Arrhythmia Results

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Table B.14 RSA during guilt compared across each diagnostic category

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<td>-22.4 – 11.9</td>
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<td>5.97</td>
<td>-1.308</td>
<td>0.781</td>
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<td>Amusement</td>
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<td>11.64</td>
<td>0.407</td>
<td>0.999</td>
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<tr>
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<td>11.64</td>
<td>-0.176</td>
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Table B.15 RSA in each diagnostic category for guilt in comparison to other emotions.
### Root Mean Square Successive Differences Results

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<tr>
<td><strong>HC-AD</strong></td>
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<td>9.25</td>
<td>0.089</td>
<td>0.999</td>
<td>-23.1 – 24.7</td>
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<td><strong>HC-FTD</strong></td>
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<td>10.13</td>
<td>-0.344</td>
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<td>0.811</td>
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<td>-36.2 – 27.6</td>
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<td>9.74</td>
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<td>0.953</td>
<td>-20.0 – 30.3</td>
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Table B.16 RMSSD during guilt compared across each diagnostic category

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</tr>
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<td>5.97</td>
<td>-0.885</td>
<td>0.949</td>
<td>-22.4 – 11.6</td>
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<tr>
<td>Disgust</td>
<td>-7.806</td>
<td>5.97</td>
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<tr>
<td>Sadness</td>
<td>6.306</td>
<td>11.64</td>
<td>0.542</td>
<td>0.994</td>
<td>-27.1 – 39.7</td>
</tr>
<tr>
<td><strong>FTD</strong></td>
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<tr>
<td>Amusement</td>
<td>-7.006</td>
<td>13.02</td>
<td>-0.538</td>
<td>0.995</td>
<td>-44.4 – 30.4</td>
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<tr>
<td>Disgust</td>
<td>0.424</td>
<td>13.02</td>
<td>0.033</td>
<td>1.000</td>
<td>-37.0 – 37.8</td>
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<tr>
<td>Neutral</td>
<td>10.062</td>
<td>13.02</td>
<td>0.773</td>
<td>0.972</td>
<td>-27.3 – 47.4</td>
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<tr>
<td>Pride</td>
<td>-7.879</td>
<td>13.02</td>
<td>-0.605</td>
<td>0.991</td>
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</tr>
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<td>Sadness</td>
<td>-5.912</td>
<td>13.02</td>
<td>-0.454</td>
<td>0.998</td>
<td>-43.4 – 31.5</td>
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<td><strong>DLB/PD</strong></td>
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<td>Amusement</td>
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<td>7.36</td>
<td>-1.072</td>
<td>0.892</td>
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</tr>
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<td>Disgust</td>
<td>-13.151</td>
<td>7.36</td>
<td>-1.787</td>
<td>0.476</td>
<td>-34.3 – 8.0</td>
</tr>
<tr>
<td>Neutral</td>
<td>-3.982</td>
<td>7.36</td>
<td>-0.541</td>
<td>0.994</td>
<td>-25.1 – 17.1</td>
</tr>
<tr>
<td>Pride</td>
<td>-7.413</td>
<td>7.36</td>
<td>-1.007</td>
<td>0.915</td>
<td>-28.5 – 13.7</td>
</tr>
<tr>
<td>Sadness</td>
<td>-6.927</td>
<td>7.36</td>
<td>-0.941</td>
<td>0.366</td>
<td>-28.0 – 14.2</td>
</tr>
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Table B.17 RMSSD in each diagnostic category for guilt in comparison to other emotions.
<table>
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<tr>
<th>Guilt Comparison</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amusement</td>
<td>-4.360</td>
<td>4.76</td>
<td>-0.916</td>
<td>0.942</td>
<td>-18.0 – 9.3</td>
</tr>
<tr>
<td>Disgust</td>
<td>6.721</td>
<td>4.76</td>
<td>1.412</td>
<td>0.720</td>
<td>-6.9 – 20.4</td>
</tr>
<tr>
<td>Neutral</td>
<td>-2.284</td>
<td>4.76</td>
<td>-0.480</td>
<td>0.996</td>
<td>-15.9 – 11.4</td>
</tr>
<tr>
<td>Pride</td>
<td>-3.839</td>
<td>4.76</td>
<td>-0.806</td>
<td>0.966</td>
<td>-17.5 – 9.8</td>
</tr>
<tr>
<td>Sadness</td>
<td>-4.108</td>
<td>4.76</td>
<td>-0.863</td>
<td>0.955</td>
<td>-17.8 – 9.6</td>
</tr>
<tr>
<td>Amusement</td>
<td>13.467</td>
<td>9.28</td>
<td>1.451</td>
<td>0.696</td>
<td>-13.2 – 40.1</td>
</tr>
<tr>
<td>Disgust</td>
<td>6.750</td>
<td>9.28</td>
<td>0.727</td>
<td>0.978</td>
<td>-19.9 – 33.4</td>
</tr>
<tr>
<td>Neutral</td>
<td>9.063</td>
<td>9.28</td>
<td>0.977</td>
<td>0.925</td>
<td>-17.6 – 35.7</td>
</tr>
<tr>
<td>Pride</td>
<td>3.809</td>
<td>9.28</td>
<td>0.410</td>
<td>0.999</td>
<td>-22.8 – 30.4</td>
</tr>
<tr>
<td>Sadness</td>
<td>4.223</td>
<td>9.28</td>
<td>0.455</td>
<td>0.998</td>
<td>-22.4 – 30.9</td>
</tr>
<tr>
<td>Amusement</td>
<td>10.436</td>
<td>10.39</td>
<td>1.005</td>
<td>0.916</td>
<td>-19.4 – 40.3</td>
</tr>
<tr>
<td>Disgust</td>
<td>3.111</td>
<td>10.39</td>
<td>0.300</td>
<td>0.999</td>
<td>-26.7 – 32.9</td>
</tr>
<tr>
<td>Neutral</td>
<td>14.958</td>
<td>10.39</td>
<td>1.440</td>
<td>0.703</td>
<td>-14.9 – 44.8</td>
</tr>
<tr>
<td>Pride</td>
<td>3.386</td>
<td>10.39</td>
<td>0.326</td>
<td>0.999</td>
<td>-26.4 – 33.2</td>
</tr>
<tr>
<td>Sadness</td>
<td>8.009</td>
<td>10.39</td>
<td>0.771</td>
<td>0.972</td>
<td>-21.8 – 37.8</td>
</tr>
<tr>
<td>Amusement</td>
<td>4.594</td>
<td>5.87</td>
<td>0.783</td>
<td>0.970</td>
<td>-12.3 – 21.4</td>
</tr>
<tr>
<td>Disgust</td>
<td>8.413</td>
<td>5.87</td>
<td>1.433</td>
<td>0.707</td>
<td>-8.4 – 25.3</td>
</tr>
<tr>
<td>Neutral</td>
<td>9.375</td>
<td>5.87</td>
<td>1.597</td>
<td>0.601</td>
<td>-7.5 – 26.2</td>
</tr>
<tr>
<td>Pride</td>
<td>-2.677</td>
<td>5.87</td>
<td>-0.456</td>
<td>0.998</td>
<td>-19.5 – 14.2</td>
</tr>
<tr>
<td>Sadness</td>
<td>5.473</td>
<td>5.87</td>
<td>0.932</td>
<td>0.938</td>
<td>-11.4 – 22.3</td>
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</tbody>
</table>

Table B.19 Respiration rate in each diagnostic category for guilt in comparison to other emotions.
### Systolic Blood Pressure Results

<table>
<thead>
<tr>
<th>Guilt Comparison</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-AD</td>
<td>7.32</td>
<td>10.32</td>
<td>0.709</td>
<td>0.893</td>
<td>-19.4 – 34.0</td>
</tr>
<tr>
<td>HC-FTD</td>
<td>17.06</td>
<td>11.31</td>
<td>1.508</td>
<td>0.434</td>
<td>-12.2 – 46.3</td>
</tr>
<tr>
<td>HC-DLB/PD</td>
<td>-1.37</td>
<td>7.48</td>
<td>-0.183</td>
<td>0.998</td>
<td>-20.7 – 18.0</td>
</tr>
<tr>
<td>AD-FTD</td>
<td>9.74</td>
<td>13.78</td>
<td>0.706</td>
<td>0.895</td>
<td>-25.9 – 45.4</td>
</tr>
<tr>
<td>AD-DLB/PD</td>
<td>-8.69</td>
<td>10.9</td>
<td>-0.800</td>
<td>0.855</td>
<td>-36.8 – 19.4</td>
</tr>
<tr>
<td>FTD-DLB/PD</td>
<td>-18.42</td>
<td>11.8</td>
<td>-1.560</td>
<td>0.403</td>
<td>-48.9 – 12.1</td>
</tr>
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</table>

Table B.20 Systolic blood pressure during guilt compared across each diagnostic category.

<table>
<thead>
<tr>
<th>Guilt Comparison</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC-AD</td>
<td>-3.189</td>
<td>6.66</td>
<td>-0.479</td>
<td>0.997</td>
<td>-22.3 – 15.9</td>
</tr>
<tr>
<td>Disgust</td>
<td>-5.486</td>
<td>6.66</td>
<td>-0.824</td>
<td>0.963</td>
<td>-24.6 – 13.6</td>
</tr>
<tr>
<td>Neutral</td>
<td>1.373</td>
<td>6.66</td>
<td>0.206</td>
<td>0.999</td>
<td>-17.7 – 20.5</td>
</tr>
<tr>
<td>Pride</td>
<td>-5.461</td>
<td>6.66</td>
<td>-0.820</td>
<td>0.999</td>
<td>-24.6 – 13.7</td>
</tr>
<tr>
<td>Sadness</td>
<td>-3.617</td>
<td>6.66</td>
<td>-0.543</td>
<td>0.994</td>
<td>-22.7 – 15.5</td>
</tr>
<tr>
<td>AD-FTD</td>
<td>3.465</td>
<td>12.99</td>
<td>0.267</td>
<td>0.999</td>
<td>-33.8 – 40.7</td>
</tr>
<tr>
<td>Disgust</td>
<td>-4.574</td>
<td>12.99</td>
<td>-0.352</td>
<td>0.999</td>
<td>-41.8 – 32.7</td>
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<tr>
<td>Neutral</td>
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<td>12.99</td>
<td>-0.254</td>
<td>1.000</td>
<td>-40.6 – 34.0</td>
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<tr>
<td>Pride</td>
<td>-4.466</td>
<td>12.99</td>
<td>-0.344</td>
<td>0.999</td>
<td>-41.7 – 32.8</td>
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<tr>
<td>Sadness</td>
<td>-5.870</td>
<td>12.99</td>
<td>-0.452</td>
<td>0.998</td>
<td>-43.1 – 31.4</td>
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<tr>
<td>FTD</td>
<td>-31.368</td>
<td>14.54</td>
<td>-2.158</td>
<td>0.261</td>
<td>-73.1 – 10.4</td>
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<td>Disgust</td>
<td>-3.333</td>
<td>14.54</td>
<td>-0.229</td>
<td>0.999</td>
<td>-45.1 – 38.4</td>
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<tr>
<td>Neutral</td>
<td>-30.033</td>
<td>14.54</td>
<td>-2.066</td>
<td>0.308</td>
<td>-71.8 – 11.7</td>
</tr>
<tr>
<td>Pride</td>
<td>-4.980</td>
<td>14.54</td>
<td>-0.343</td>
<td>0.999</td>
<td>-46.7 – 36.7</td>
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<td>-1.467</td>
<td>14.54</td>
<td>-0.101</td>
<td>1.000</td>
<td>-43.2 – 40.3</td>
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Table B.21 Systolic blood pressure in each diagnostic category for guilt in comparison to other emotions.
### Diastolic Blood Pressure Results

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<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HC-AD</strong></td>
<td>1.876</td>
<td>9.63</td>
<td>0.195</td>
<td>0.997</td>
<td>-23.0 – 26.8</td>
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<td><strong>HC-FTD</strong></td>
<td>-15.993</td>
<td>10.55</td>
<td>-1.516</td>
<td>0.429</td>
<td>-43.3 – 11.3</td>
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<td><strong>HC-DLB/PD</strong></td>
<td>5.239</td>
<td>6.98</td>
<td>0.751</td>
<td>0.876</td>
<td>-12.8 – 23.3</td>
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<tr>
<td><strong>AD-FTD</strong></td>
<td>-17.870</td>
<td>12.86</td>
<td>-1.389</td>
<td>0.507</td>
<td>-51.1 – 15.4</td>
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<tr>
<td><strong>AD-DLB/PD</strong></td>
<td>3.362</td>
<td>10.14</td>
<td>0.332</td>
<td>0.9874</td>
<td>-22.9 – 29.6</td>
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<td><strong>FTD-DLB/PD</strong></td>
<td>21.232</td>
<td>11.02</td>
<td>1.927</td>
<td>0.219</td>
<td>-7.25 – 49.7</td>
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Table B.22 Diastolic blood pressure during guilt compared across each diagnostic category

<table>
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<th>Guilt Comparison</th>
<th>Estimate</th>
<th>Std. Error</th>
<th>t</th>
<th>p</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HC</strong></td>
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<td>6.22</td>
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<td>-20.8 – 14.9</td>
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<td>Disgust</td>
<td>0.470</td>
<td>6.22</td>
<td>0.076</td>
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<td>6.22</td>
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<td>-1.665</td>
<td>6.22</td>
<td>0.026</td>
<td>0.999</td>
<td>-19.5 – 16.2</td>
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<tr>
<td><strong>AD</strong></td>
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<td>Amusement</td>
<td>6.423</td>
<td>12.12</td>
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<td>36.550</td>
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<td>2.694</td>
<td>0.080</td>
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<td>0.999</td>
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<td>13.57</td>
<td>0.329</td>
<td>0.999</td>
<td>-34.5 – 43.4</td>
</tr>
<tr>
<td>Sadness</td>
<td>4.650</td>
<td>13.57</td>
<td>0.343</td>
<td>0.999</td>
<td>-34.3 – 43.6</td>
</tr>
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<td><strong>DLB/PD</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Amusement</td>
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<td>7.67</td>
<td>0.339</td>
<td>0.999</td>
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<td>-0.806</td>
<td>0.966</td>
<td>-28.2 – 15.8</td>
</tr>
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<td>7.67</td>
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<td>0.997</td>
<td>-18.4 – 25.6</td>
</tr>
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<td>Pride</td>
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<td>7.67</td>
<td>0.441</td>
<td>0.998</td>
<td>-18.6 – 25.4</td>
</tr>
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<td>Sadness</td>
<td>1.414</td>
<td>7.67</td>
<td>0.184</td>
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<td>-20.6 – 23.4</td>
</tr>
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</table>

Table B.23 Diastolic blood pressure in each diagnostic category for guilt in comparison to other emotions.
## Appendix C: Video Pilot Study Information for Study I, II, & III

<table>
<thead>
<tr>
<th>Video Title</th>
<th>Intended Emotion</th>
<th>Negative (1) - Positive (9)</th>
<th>Calm (1) - Aroused (9)</th>
<th>Dominated (1) - Dominating (9)</th>
<th>Identified Emotion(s) (# of responses)</th>
<th>Strength of emotion</th>
<th>Other Emotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africare - Shoeboxes</td>
<td>Guilt</td>
<td>2.50</td>
<td>5.00</td>
<td>3.25</td>
<td>Guilt (3), Other (5)</td>
<td>6.7 5.8</td>
<td>Sadness; Guilt</td>
</tr>
<tr>
<td>WWF T-Shirt</td>
<td>Guilt</td>
<td>4.90</td>
<td>4.60</td>
<td>5.50</td>
<td>Guilt (3), Other (7)</td>
<td>6.0 4.9</td>
<td>Guilt</td>
</tr>
<tr>
<td>WWF Laptop</td>
<td>Guilt</td>
<td>4.50</td>
<td>3.63</td>
<td>5.00</td>
<td>Guilt (3), Other (5)</td>
<td>4.3 6.6</td>
<td>Shame</td>
</tr>
<tr>
<td>Don’t Almost Give – Jack</td>
<td>Guilt</td>
<td>4.50</td>
<td>3.25</td>
<td>5.25</td>
<td>Guilt (1), Other (8)</td>
<td>6.0 5.3</td>
<td>Guilt; Shame</td>
</tr>
<tr>
<td>Strawberry Wasted</td>
<td>Guilt</td>
<td>4.40</td>
<td>3.90</td>
<td>4.70</td>
<td>Guilt (2), Other(8)</td>
<td>4.5 6.6</td>
<td>Amusement; Guilt; Contempt</td>
</tr>
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<td>60 Seconds Blood Donation</td>
<td>Guilt</td>
<td>5.29</td>
<td>3.57</td>
<td>5.29</td>
<td>Guilt (2), Other (5)</td>
<td>5.0 5.8</td>
<td>Happiness; Sadness</td>
</tr>
<tr>
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<td>Guilt</td>
<td>3.70</td>
<td>3.50</td>
<td>4.40</td>
<td>Guilt (2), Other (8)</td>
<td>6.5 3.9</td>
<td>Guilt; Shame</td>
</tr>
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<td>Let Them Figure It Out</td>
<td>Guilt</td>
<td>4.75</td>
<td>3.13</td>
<td>4.75</td>
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<td>7.0 3.0</td>
<td>Neutral; Contemplative</td>
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<td>Guilt</td>
<td>4.00</td>
<td>3.63</td>
<td>4.50</td>
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<td>4.50</td>
<td>3.40</td>
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<td>Guilt; Shame</td>
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<td>Amusement</td>
<td>6.71</td>
<td>5.43</td>
<td>5.86</td>
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<td>5.9</td>
<td>Happiness; Pride</td>
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<td>Item</td>
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<td>Other</td>
<td>Neutral</td>
<td>Other</td>
<td>Neutral</td>
<td>Other</td>
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</tr>
<tr>
<td>Go First</td>
<td>6.10</td>
<td>3.90</td>
<td>5.20</td>
<td>4.9</td>
<td>6.0</td>
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<td>Other (1)</td>
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<td>3.88</td>
<td>5.50</td>
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<td>6.30</td>
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<td>5.5</td>
<td>6.0</td>
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<td>Other (4)</td>
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<td>Drinking 6000 Blended Maggots</td>
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<td>3.50</td>
<td>5.90</td>
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<td>Poop Lady</td>
<td>Disgust</td>
<td>2.71</td>
<td>5.57</td>
<td>4.71</td>
<td>6.3</td>
<td>Disgust</td>
<td>6.3</td>
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<td>Toxic Food Environment</td>
<td>Disgust</td>
<td>3.86</td>
<td>3.71</td>
<td>3.86</td>
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<td>Custard</td>
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<td>3.38</td>
<td>5.13</td>
<td>4.13</td>
<td>6.7</td>
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<td>Rotting Meat</td>
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<td>3.63</td>
<td>4.38</td>
<td>4.50</td>
<td>6.6</td>
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<td>Other (3)</td>
</tr>
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<td>Rotting Chicken</td>
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<td>3.57</td>
<td>4.86</td>
<td>4.29</td>
<td>4.4</td>
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<td>Other (2)</td>
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<td>5.00</td>
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<td>Other (1)</td>
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<td>2.63</td>
<td>5.13</td>
<td>6.9</td>
<td>Neutral (7)</td>
<td>Other (1)</td>
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<td>Wool</td>
<td>Neutral</td>
<td>5.00</td>
<td>3.20</td>
<td>4.50</td>
<td>6.7</td>
<td>Neutral (9)</td>
<td>Other (1)</td>
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</tbody>
</table>

Additional Emotions:
- Neutral; Amusement; Humourous
- Humour; Happy
- Confusion; Amused; Satisfaction; Pride
- Happy; Pride
- Disgust; Amused
- Sadness
- Unsettled; disgust
- Curious
- None
- Curious
- Bored, curious
<table>
<thead>
<tr>
<th>Table C.1 Information about pilot study with target emotion, ratings from 1 to 9 on the negative-positive, calm-aroused, dominated-dominating scales, emotions identified and number of participants who identified it, strength</th>
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<tbody>
<tr>
<td>Erasers</td>
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<tr>
<td>I am Canadian</td>
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<tr>
<td>The Anthem</td>
</tr>
<tr>
<td>Made From Canada</td>
</tr>
<tr>
<td>Greatest Human Achievements</td>
</tr>
<tr>
<td>Peacekeeping</td>
</tr>
<tr>
<td>Fly the Flag</td>
</tr>
<tr>
<td>Last Minutes with Oden</td>
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<tr>
<td>Notification</td>
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<tr>
<td>Madly in Love</td>
</tr>
<tr>
<td>Dying Wife</td>
</tr>
<tr>
<td>SickKids vs Cancer</td>
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<td>12 Days of Christmas</td>
</tr>
</tbody>
</table>

Table C.1 Information about pilot study with target emotion, ratings from 1 to 9 on the negative-positive, calm-aroused, dominated-dominating scales, emotions identified and number of participants who identified it, strength
Appendix D: Research Ethics Approval for Study I and III

Western University Health Science Research Ethics Board
HSREB Full Board Initial Approval Notice

Principal Investigator: Dr. Elizabeth Finger
Department & Institution: Schulich School of Medicine and Dentistry/Clinical Neurological Sciences, London Health Sciences Centre

Review Type: Full Board
HSREB File Number: 109071
Study Title: The psychophysiology of emotions

HSREB Initial Approval Date: June 01, 2017
HSREB Expiry Date: June 01, 2018

Documents Approved and/or Received for Information:

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Comments</th>
<th>Version Date</th>
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<tbody>
<tr>
<td>Revised Western University Protocol</td>
<td>Received May 18, 2017</td>
<td></td>
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<tr>
<td>Revised Letter of Information &amp; Consent</td>
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<td>Other</td>
<td>Debrief and Recomment</td>
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<td>Recruitment Items</td>
<td>Telephone Script and Reminder Call Script</td>
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<td>Advertisement</td>
<td>Recruitment ad</td>
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<tr>
<td>Other</td>
<td>Email Scripts</td>
<td>2017/03/31</td>
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<td>Instruments</td>
<td>Final Questionnaire</td>
<td>2017/03/31</td>
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<td>Instruments</td>
<td>Guilt Inventory instructions and scoring</td>
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<td>Instruments</td>
<td>Empathy Quotient</td>
<td>2017/04/10</td>
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<tr>
<td>Instruments</td>
<td>The Guilt Inventory</td>
<td>2017/04/10</td>
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<tr>
<td>Instruments</td>
<td>Context statements that will precede videos</td>
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<tr>
<td>Instruments</td>
<td>Questions following each film</td>
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</table>

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCP52), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000000.
Dear Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations, Part 4 of the Natural Health Products Regulations, Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wrotynski, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Date: 15 May 2019

Tie Elizabeth Finger

Project ID: 109071

Study Title: The psychophysiology of emotions

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

REB Meeting Date: 21/May/2019

Date Approval Issued: 15/May/2019

REB Approval Expiry Date: 01/Jan/2020

Dear Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation: Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 0000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyrzykowski, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSRB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Date: 5 June 2020

To: Elizabeth Finger

Project ID: 109071

Study Title: The psychophysiology of emotions

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

REB Meeting Date: 16 Jan 2020

Date Approval Issued: 05 Jun 2020

REB Approval Expiry Date: 01 Jan 2021

Dear Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation: Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000540.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSRUB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Date: 27 May 2021

To: Elizabeth Finger

Project ID: 109071

Study Title: The psychophysiology of emotions

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

REB Meeting Date: 08 June 2021

Date Approval Issued: 27 May 2021

REB Approval Expiry Date: 01 Jan 2022

Dear Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation: Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

The Office of Human Research Ethics

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Appendix E: Research Ethics Approval for Study II

Date: 1 June 2018

To Dr. Elizabeth Finger

Project ID: 111170

Study Title: The psychophysiology of emotion in neurodegenerative diseases

Application Type: HSREB Initial Application

Review Type: Full Board

Meeting Date: March 6, 2018

Date Approval Issued: 01/Jan/2018

REB Approval Expiry Date: 01/Jan/2019

Dear Dr. Elizabeth Finger

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

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<thead>
<tr>
<th>Document Name</th>
<th>Document Type</th>
<th>Document Date</th>
</tr>
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<td>Paper Survey</td>
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<td>BodyPerceptionQuestionnaire_short</td>
<td>Paper Survey</td>
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<tr>
<td>Cambridge Behavioural Inventory</td>
<td>Paper Survey</td>
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<td>CAMPASSS1</td>
<td>Paper Survey</td>
<td>27/Feb/2018</td>
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<tr>
<td>ConsentCaregiver</td>
<td>Written Consent/Assent</td>
<td>06/Feb/2018</td>
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<tr>
<td>ConsentHealthy</td>
<td>Written Consent/Assent</td>
<td>08/May/2018</td>
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<td>ConsentPatient</td>
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<td>08/May/2018</td>
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<td>Consent instruments</td>
<td>Other Data Collection Instruments</td>
<td>02/Feb/2018</td>
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<td>Debriefing and Document</td>
<td>Debriefing Letter</td>
<td>10/May/2018</td>
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<td>Email Script</td>
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<tr>
<td>Emotivity Question</td>
<td>Paper Survey</td>
<td>10/Apr/2017</td>
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<td>Interpersonal Reactivity Index</td>
<td>Paper Survey</td>
<td>02/Feb/2018</td>
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<tr>
<td>Multidimensional Assessment of Introspective Awareness</td>
<td>Paper Survey</td>
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<td>Opinions and Behaviour Questionnaire</td>
<td>Other Data Collection Instruments</td>
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<td>Post Video Response Sheet</td>
<td>Other Data Collection Instruments</td>
<td>16/Jan/2017</td>
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<td>Recruitment Ad for Healthy Controls</td>
<td>Recruitment Materials</td>
<td>02/Feb/2018</td>
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<td>Recruitment Ad for Patients</td>
<td>Recruitment Materials</td>
<td>12/Feb/2018</td>
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<tr>
<td>Research Protocol</td>
<td>Protocol</td>
<td>27/Feb/2018</td>
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<tr>
<td>Revised SelfMonitoring Scale</td>
<td>Paper Survey</td>
<td>02/Feb/2018</td>
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<td>State-Task Anxiety Inventory</td>
<td>Paper Survey</td>
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<td>Telephone Script</td>
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<td>03/Feb/2018</td>
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<td>The Ghit Inventory</td>
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<td>Video link list</td>
<td>Other Data Collection Instruments</td>
<td>03/Feb/2018</td>
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No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000040.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

*Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).*
Dear Dr. Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation: Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyrzyński, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Dear Dr. Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation: Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Dr. Joseph Gilbert, HSUEB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Dear Dr. Elizabeth Finger,

The Western University Research Ethics Board has reviewed the application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

Western University REB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation: Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations, Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The REB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

The Office of Human Research Ethics

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Curriculum Vitae

Personal Information
Chloe Stewart  
PhDc Year 5  
Supervisor: Dr. Elizabeth Finger

Education
University of Western Ontario
Candidate for PhD in Neuroscience  
Thesis title: *The expression of guilt*  
Thesis Advisor: Dr. Elizabeth Finger

University College London
Masters of Science in Cognitive Neuroscience  
Dissertation: *Working memory, inhibitory control, and cognitive flexibility in term and preterm infants at 12 months of age*  
Dissertation Advisor: Dr Michelle de Haan

University of Toronto
Honours Bachelor of Science  
Double Major in Psychology & Criminology and Sociolegal Studies

Recognitions
Best Poster Presentation - Mental Health, Parkwood Institute Research Day  
April 2021

Lawson Cognitive Vitality Travel Award, $2,170  
October 2020

Lawson Internal Research Fund Studentship, $15,000  
July 2017

Dean’s List, University of Toronto  
2012, 2013, 2014

Related Work Experience
Trial Drug Coordinator, FOXY Study  
Present  
*Western University*

Teaching Assistant, NEURO3000  
January 2017- April 2020  
*Western University*, Dr. Rhodri Cusack, Dr. Rob Bartha, Dr. Tim Bussey

Publications


**Conference Presentations**

**Oral Presentations**


**Poster Presentations**


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