

## Psychopathy, Yawning, and Vigilance

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Psychopathy is characterized by a general antisocial lifestyle with behaviors including being selfish, manipulative, impulsive, fearless, callous, domineering, and particularly lacking in empathy. Contagious yawning in our species has been strongly linked to empathy. One hundred and seventeen students who completed the PPI-R were exposed to a video stimulus of yawns, an in-person yawning stimulus, and a vigilance condition with an in-person yawning stimulus. We found that the vigilance condition extinguished contagious yawning in virtually all participants. We also found that the social-yawning stimulus was not as potent as the video stimulus in evoking yawning. Lastly, we assessed the utility of the Triarchic Psychopathy Measure in this research setting and found that it was not a better measure than the Coldheartedness subscale of the PPI-R in its predictive value of contagious yawning. We provide evidence for a replication of Rundle et al. (2015), a potential negative control for yawning research, and an assessment of an alternative measure to the PPI-R in this research.

Psychopathy, Yawning, and Vigilance

by

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## TABLE OF CONTENTS

LIST OF FIGURES .....	vi
LIST OF TABLES .....	vii
CHAPTER ONE .....	1
Psychopathy .....	1
Neuroanatomy .....	3
Neurochemicals and Psychopathy .....	10
Clinical Findings .....	15
Vigilance .....	17
Neuromodulation .....	18
Anatomy & Pharmacology .....	19
Affect .....	23
Vigilance and Yawning .....	25
Yawning .....	27
Neuroanatomy .....	29
Yawning and Empathy .....	32
Psychopathy and Vigilance .....	34
Synthesis .....	36
Evolution .....	36
Conclusion and Hypothesis.....	37
CHAPTER TWO .....	40
Methods .....	40
Participants.....	40
Materials .....	40
Yawning Paradigms .....	40
<i>Computer Task – Video Stimulus Induced Yawning</i> .....	40
<i>Social-Yawning Task – In-person Yawning Stimulus</i> .....	41
<i>Vigilance Condition – In-person Yawning Stimulus</i> .....	42
Self-Report Measures .....	42
<i>Psychopathic Personality Inventory (Revised)</i> .....	42
<i>Triarchic Psychopathy Measure</i> .....	43
Procedure .....	43
Computer Task.....	44
Vigilance Task .....	44
Social-Yawning Task .....	44
Statistical Analyses .....	45
CHAPTER THREE .....	47
Results.....	47

Participants .....	47
Sex Differences and Caffeine .....	47
Coldheartedness.....	49
Yawning Tasks.....	50
<i>Computer Task</i> .....	51
<i>Vigilance Task</i> .....	51
<i>Social-Yawning Task</i> .....	52
Tri-PM .....	52
CHAPTER FOUR.....	54
Discussion.....	54
Sex Differences .....	54
Coldheartedness and Yawning Tasks.....	55
Computer Task .....	56
Social Yawning Task .....	58
Vigilance Task .....	59
PPI-R vs. Tri-PM .....	60
Conclusion.....	62
REFERENCES .....	64

## LIST OF FIGURES

Figure 1. Uncinate Fasciculus.....	8
Figure 2. FPAN.....	21
Figure 3. Median Split by Task.....	50

## LIST OF TABLES

Table 1. PPI-R Factor Loadings.....	43
Table 2. Means and Standard Deviations of Variables by Sex .....	48
Table 3. Analysis of Variance Between Sex and Yawning Task .....	49
Table 4. ANOVA Between Upper and Lower Quartiles and Yawning Task.....	49
Table 5. Analysis of Variance Between Median Split and Yawning Task.....	50
Table 6. Results of a Step-wise Regression Analysis on Yawning Frequency .....	51
Table 7. Correlations Between the Tri-PM and Model Variables .....	52

## CHAPTER ONE

### Introduction

#### *Psychopathy*

Psychopathy is characterized by a general antisocial lifestyle including being selfish, manipulative, impulsive, fearless, callous, domineering, and particularly lacking in empathy (Hare, 2003; Weber, Habel, Amunts, & Schneider, 2008). The disorder is typically assessed using the Psychopathic Check List-Revised (PCL-R) for incarcerated populations (Hare, 2003) or the Psychopathic Personality Inventory - Revised (PPI-R) for general populations (Lilienfeld & Widows, 2005). Each measure operationalizes two discrete components of psychopathy: a primary (affective) and secondary (behavioral) component (Hare 2003; Levenson, Kiehl, & Fitzpatrick, 1995; Lilienfeld & Widows, 2005). The primary component includes cruelty and lack of affect whereas the secondary component includes impulsivity and aggression. Psychopathy and its close relative Antisocial Personality Disorder (APD) are found overwhelmingly more often in males (Cale & Lillienfeld, 2002). Over the last few decades, research on the systems neuroscience of limbic and cortical structures has attempted to unravel the core biological causes of this specific antisocial disorder.

Over the years, psychopathy has been separately identified from related disorders such as Conduct Disorder (CD) and APD (Abramowitz, Kosson, & Seidenberg, 2004; Rogstad & Rogers, 2008). Psychopathy is distinct from its allied disorders due to its recognizable emotional profile including coldheartedness and a considerable reduction in empathy (Frick, O'Brien, Wootton, & McBurnett, 1994). Psychopaths are not always

aggressive but when they are they employ instrumental aggression, otherwise known as premeditated aggression, more often than impulsive aggression (Frick, Cornell, Barry, Bodin, & Dane, 2003; Cornell et al., 1996), though both types of aggression can be displayed (Blair, 2004). Impulsive aggression is defined by an aggressive act frequently paired with anger that is triggered by a threatening or frustrating event; conversely, instrumental aggression is both goal oriented and therefore reflects purpose (Barratt, Stanford, Dowdy, Liebman, & Kent, 1999; Blair, 2004; Frick et al., 2003). Typical instrumental aggression may include behaviors such as conning (Forouzan & Cooke, 2005) or gaining a victim's possessions through trust (Blair, Peschardt, Budhani, Mitchell, & Pine, 2006). Though psychopaths demonstrate both reactive and instrumental aggression, they show markedly elevated levels of instrumental aggression in pursuit of daily goals.

There are disagreements on how to characterize psychopathy as a personality trait or disorder. This may be a result of the various lifestyles of those who score high on trait psychopathy may lead. Thus, identification of psychopaths can be difficult (Lilienfeld, Watts, & Smith, 2015). The first line assessment for non-incarcerated populations is the PPI-R, which scales the psychopathic trait on a continuum. Thus, the average member of society falls within 10 percentile points of the 50<sup>th</sup> percentile, based on standardized national averages. Psychopaths are also categorized into general groups based on personal efficacy: successful and unsuccessful (Lilienfeld et al., 2015). The distinction is based on the relative life success, criminal history, and ability to follow social interaction norms, but has yet to be firmly established in the literature. Unsuccessful psychopaths are generally defined as having a life history of arrest, relationship difficulties, and clearly

demonstrating their antisocial disorder (Raine et al., 2004). In contrast, successful psychopaths range from non-incarcerated individuals to highly successful individuals in positions of authority such as corporate CEOs (Lilienfeld, Watts, & Smith, 2015). Regardless of how psychopathy is conceptualized, it is becoming more apparent that the trait is best understood on a continuous spectrum rather than discretely.

### *Neuroanatomy*

There is a long history of seeking neuroanatomical correlates for psychopathic behavior, as lack of diagnosis does not mean absence of a trait. Outlining these anatomical underpinnings offers the potential of a better understanding into the root causes of the behaviors. At the general level, we now know that psychopathy likely involves brain abnormalities of both the amygdala and prefrontal cortex (PFC; Gao, Glenn, Schug, Yang, & Rain, 2009). Unfortunately, these abnormalities are not consistent within the psychopathic spectrum, making diagnosis difficult based on neuroimaging alone (Moul, Killcross, & Dadds, 2012). For instance, the results are mixed in terms of over- or under- activation of amygdalae (Birbaumer et al., 2005; Müller et al., 2003). However, it may be more clear in children, where those with callous unemotionality and conduct disorder (traits considered the developmental precursors to psychopathy) are observed to have underactive amygdalae as well as abnormalities in amygdala-mediated tasks like fear recognition (Marsh et al., 2009; Jones, Laurens, Herba, Barker, & Viding, 2009).

A hallmark trait of psychopathy includes the failure to condition to aversive stimuli in paradigms such as fear conditioning (Lykken, 1955; Hare, 1965; Hare, 1968; Hare & Quinn, 1971). In a foundational study by Lykken (1955), shocks were

administered via electrodes on the non-dominant hands of psychopathic inmates and skin-conductance responses were assessed as a measure of anxiety. Inmates were introduced to unconditioned stimuli: two buzzers. Then, shocks were conditioned to buzzer 1 and not buzzer 2. This was followed by extinction trials. The results showed that psychopathic inmates failed to adequately condition to the unconditioned stimulus (buzzer 1) and generalize to buzzer 2 compared to controls. Additionally, their galvanic skin response to the buzzer stimuli was attenuated when compared to non-psychopathic inmates. This study was the first to demonstrate the attenuated physio-emotional response of psychopathic persons and led to a body of research regarding psychopathy and emotional processing spanning over sixty years.

Failure to condition to aversive stimuli may be a consequence of smaller amygdala volume (Weber, Habel, Amunts, & Schneider, 2008) as well as reduced or absent amygdalar activity during fear conditioning tasks (Birbaumer et al., 2005). Within psychopathic populations, Yang and colleagues (2010) found differential amygdalar pathologies in successful compared to unsuccessful psychopaths. The basolateral and superficial amygdalar nuclei are structurally more abnormal in unsuccessful psychopaths. Successful psychopaths have more normal amygdalae, which may contribute to their relative success in society. While of value, incomplete and sometimes inconsistent findings still leave us with a difficult problem, which is that we are far from having a complete understanding of psychopathy based on fundamental neuroscience.

The neurofunctional underpinnings of trait psychopathy and the interpersonal interaction styles of psychopaths have been examined with the aim of shedding light on the social deficits seen in persons high on trait psychopathy. Using fMRIs, Glenn, Raine,

and Schug (2009) produced findings suggesting that individuals with higher psychopathic traits had marked amygdalar impairment compared to controls during a moral decision-making task, indicating that high trait psychopathy was associated with abnormal moral decision-making. The authors theorize that because the amygdala's function is disrupted during decision-making tasks (by virtue of less activity) it is less likely to respond as it does in normal individuals when thinking of causing harm to others. Therefore, the behavior is not inhibited. The researchers also found a more widespread dysregularity of the PFC, posterior cingulate, and angular gyrus during the same tasks in psychopaths. These areas have previously been shown to be involved in moral decision-making (Raine & Yang, 2006) and their abnormal functioning may shed light on the behaviors exhibited by psychopaths, such as conning and manipulation. Similarly, Rilling et al. (2007) found that psychopaths were less likely to socially cooperate, demonstrating difficulty participating in reciprocal altruism. Using fMRI imaging, the authors found that high psychopathic trait males were less likely to cooperate by defecting from the prisoner's dilemma task<sup>1</sup>, and were even less likely to continue to cooperate after establishing trust with a paired partner. fMRI showed hypoactivation of the orbito-frontal cortex during cooperation while hypoactivation of the dorsolateral PFC and rostral anterior cingulate cortex was observed during defecting, all areas that have been associated with processing of reward and self-referential information during decision making (Lemogne et al., 2010; Nejad, Fossati, & Lemogne, 2013). These results may shed light on psychopathic individuals' egocentric inability to cooperate.

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<sup>1</sup> The Prisoners dilemma is a situation in game theory that provides players the opportunity to work together, or betray each other. Thus, trust is involved. Each course of action carries consequence for both players, though betrayers of one's trust may escape the dilemma without consequence and the other forced to assume the extra punishment.

Along with amygdala dysfunction, psychopathic individuals are also known to have cortical abnormalities in the prefrontal cortex (Umbach, Berryessa, & Raine, 2015). Research has consistently found abnormalities in the PFC in psychopathic individuals and other antisocial disordered people, particularly reduced grey matter in the antero-rostral PFC (BA 10; Gregory et al., 2012). Other studies have found nearly identical results in terms of grey matter reduction in the orbitofrontal cortex in psychopathy (De Oliveira-Souza, Moll, Ignácio, & Hare, 2008; Ermer, Cope, Nyalakanti, Calhoun, & Kiehl, 2012; see Umbach et al., 2015). The orbitofrontal cortex is associated with emotional, social, and behavioral regulation, and patients with lesions to these areas are irresponsible, socially inappropriate, and have flattened affect (Kringelbach & Rolls, 2004). Further, reductions in the bilateral temporal cortex and the entire right hemisphere (Dolan et al., 2002), dorsomedial prefrontal cortex, precuneus/posterior cingulate (Bertsch et al., 2013), and uncinate fasciculus (UF) connectivity, which links the PFC to the amygdala, have been documented in individuals with psychopathy (Craig et al., 2009; Wolf et al., 2015). While reductions in cortex may seem counterintuitive given the behavioral profile observed in successful psychopathy, it is possible that connectivity between important structures (via the UF) may be the most telling structural abnormality (to be discussed). In other words, PFC abnormalities may systematically vary with the relative success of the psychopath, while it is likely that dampened or abnormal emotional input to the PFC may be consistent throughout all types of psychopathy. The PFC's ability to inhibit altruistic behavior because of diminished emotional responses and calculate the potential outcome of selfish behavior may allow the individual to deceive and gain social credibility. Thus, understanding the abnormalities seen in the UF may be

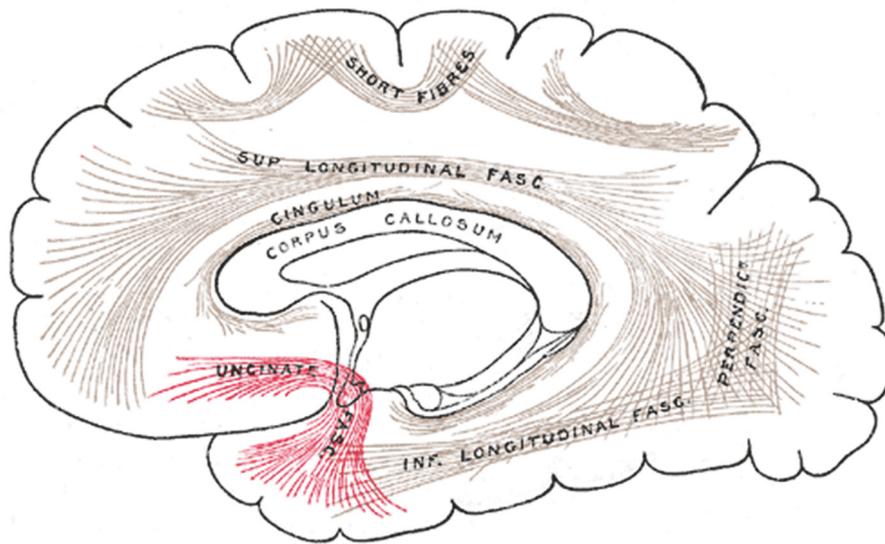
of great importance to our understanding of the structural communication between the PFC and amygdala.

The UF is a major white matter link between the ventral, frontal, and anterior temporal cortices (Wolf et al., 2015). The UF is pivotally involved with social-affective functioning as well as decision-making (Von Der Heide, Skipper, Klobusicky, & Olsen, 2013; Wolf et al., 2015). Craig et al. (2009) showed that when using diffusion tensor MRI to track the UF, a significant reduction in connective activity was observed in the right UF in psychopaths compared to IQ-matched controls. Similarly, UF functioning was negatively correlated with antisocial behaviors, indicating increased antisocial behavior was related to less functionality in the UF. Follow-up analyses showed that the connections were indeed specific to the amygdala:orbito-frontal cortex connection. Notably, the authors propose that UF abnormalities may underpin many antisocial disorders, and that observing this defect in psychopathy is not surprising.

Wolf et al. (2015) showed that right UF fractional anisotropy (FA; a measure of activity along white matter tracts) was negatively correlated with PCL-R scores and very specific to this white matter tract. Interestingly, Factor 1 traits of psychopathy, which include the interpersonal behavioral manifestations of psychopathy, were related to reduced right UF FA. The authors theorize that right UF abnormalities are related to the psychopathic-specific interpersonal behavior, and less so with the Factor 2 facets, which comprise the more generalized antisocial behaviors that are seen in other antisocial disorders as well.

Indeed, the right UF has gained attention in the recent years as its functional connectivity is implicated in the communication between the limbic system and the PFC.

This is logically consistent with certain successful psychopathic traits such as social and business success, as intact frontal lobe executive functioning is assumed to be necessary and critical for these achievements. Part of this success may be made possible by a dampened limbic input to intact PFC calculations, reducing the impact of fear and empathy on strategic calculations.



*Figure 1.* Uncinate Fasciculus. Fibers in red show the uncinate fasciculus. From "Gray751 - Uncinate fasciculus" by Gray. Licensed under Public Domain via Wikimedia Commons.

Abnormalities in the default mode network (DMN) have also been suggested as being present in psychopathic individuals. The DMN is a large network of neural regions that is active during untaxed, passive resting periods; it processes self-referential information. The DMN includes the precuneus/posterior cingulate, medial PFC, bilateral inferior parietal lobe, medial temporal lobe, and lateral temporal cortex (Fransson & Marrelec, 2008; Raichle et al., 2001; Freeman et al., 2015). During externally-oriented tasks (such as solving a problem), DMN activity is suspended in order to accomplish these tasks, and it returns to an active state once the task is complete (see Raichle &

Snyder, 2007). However, psychopaths' DMN remains relatively more active during these externally-oriented tasks, indicating the inactivation represents a failure to suspend self-referential neural activity (Pujol et al., 2011; Sheng, Gheyntanhi, & Aziz-Zadeh, 2010). This could possibly provide a reason for the egocentricism and narcissism seen in psychopathy in as far as the self is considered more prominently even when engaged in externally-motivated behaviors.

Freeman et al. (2015) compared DMN activation in high psychopathic trait prisoners (with the PCL-R) to incarcerated low psychopathic trait individuals. They used fMRI to assess the regional activation of the DMN during a go/no-go task<sup>2</sup>. Consistent with the previous literature, Freeman and colleagues found a failure to deactivate fully the DMN in high psychopathic trait individuals. The regions that failed to deactivate were in the posteromedial cortex of the DMN (located in the posterior temporal/inferior parietal region of the cortex). The authors note that this particular region may be a marker of failure to deactivate the DMN in high psychopathic trait individuals and thus, it may be heavily involved in the failure to reduce self-focus and demonstrate empathy. Moreover, the authors found that this deactivation failure was related to the Factor 1 domain of the PCL-R (also found in Wolf et al., 2015), which supports the relationship between the affective interpersonal aspect of psychopathic behavior and the DMN.

Lastly, one of the most iconic and long recognized aspects of psychopathic behavior is the inability to condition to punishment, with notable early findings showing failures to condition rapidly and generalize punishment stimuli properly (Lykken, 1955;

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<sup>2</sup> The go/no-go task is a task that involves pressing “go” for certain stimuli and withholding pressing “go” for other stimuli. Successful performance on the task necessitates a state of sustained attention.

Hare, 1965; Hare, 1968; Hare & Quinn, 1971). Not surprisingly, these findings have implications for the efficacy of criminal rehabilitation in these individuals. Raine et al. (2004) assessed the left and right hippocampal volumes in unsuccessful psychopaths. MRI results showed exaggerated asymmetric volumes with the right larger than the left; specifically, the right anterior region of the hippocampus was asymmetrical. These results are contrasted to healthy controls and successful psychopaths, which were defined as psychopaths that were “uncaught” or had no convictions. This work provides evidence of anatomical differences, discovered through structural imaging, that may underlie emotional dysregulation and fear conditioning abnormalities. These results, along with abnormalities in amygdalar functioning, illustrate a neuroanatomical profile that correlates with the emotional failures seen in the psychopathic profile.

### *Neurochemicals and Psychopathy*

Unfortunately, there does not appear to be a large body of neurochemical or pharmacological research with psychopaths. Even so, a review of the applicable neurochemical research may be helpful in understanding the behavioral manifestations of psychopathy. Indeed, there appear to be very peculiar neurotransmitter and neuroendocrine states associated with psychopathy and antisocial behavior. Van Honk and Schutter (2006) discuss the suppressive role of cortisol on the hypothalamic-pituitary-gonadal (HPG) axis, which can inhibit the production of testosterone as well as its efficacy on target tissue (Johnson, Kamilaris, Chrousos, & Gold, 1992). Testosterone has an inhibitory effect on the stress-induced activation of the hypothalamic-pituitary-adrenal (HPA) axis. Testosterone administration decreases sensitivity to punishment while also increasing aggression and social dominance (Ehrenkranz, Bliss, & Sheard,

1974; Boisseau & Bouissou, 1994). Further, testosterone has been shown to increase antisocial behavior, and decrease generosity in men (Zak et al., 2009). Also, a high testosterone:cortisol ratio might be predictive of both instrumental and impulsive aggression (Montoya, Terburg, Bos, & Van Honk, 2012; Terburg, Morgan, & Van Honk, 2009). In fact, a ratio with high levels of testosterone to cortisol may decrease the amount of communication involving emotional signals, between the amygdala and orbitofrontal cortex (Glenn, Raine, Shug, Gao, & Granger, 2011). Indeed, cortisol has been found to increase the communication between these regions and testosterone has been shown to reduce it (Schutter, Peper, & Van Honk, 2005; van Wingen, Mattern, Verkes, Buitelaar, & Fernandez, 2010).

These findings are consistent with the notion that psychopathy is heavily associated with a reduced sensitivity to anxiety producing stimuli as well as increased antisocial and impulsive behavior. The findings also shed light on psychopaths' impaired ability to condition fear to punishment. Stalenheim, Eriksson, von Knorring, and Wide (1998) found the antisocial and impulsive aspects of psychopathy to be positively correlated with testosterone, while the emotional aspects were not. Reduced cortisol levels have been found in young adult male psychopathic offenders with an established history of violence (Holi, Auvinen-Lintunen, Lindberg, Tani, & Virkkunen, 2006). Similarly, a study by Cima, Smeets, and Jelicic (2008) found lower average levels of daily cortisol in a group of psychopathic offenders. It is clear that a relationship exists, but testosterone alone does not seem to be the sole determinant.

A recent study has found an association with urinary oxytocin levels and psychopathic traits in psychiatric patients (Mitchell et al., 2013). The PCL-R was given to

the participants and urinary oxytocin levels were assessed with results showing a significantly elevated level of oxytocin in offenders compared to controls. Also, the PCL-R Factor 2 scores were highly correlated with urinary oxytocin levels. Further analysis showed that early behavioral problems as well as juvenile delinquency (as assessed by the PCL-R facets) were significantly related to oxytocin. Unfortunately, the study included confounding variables including no diagnosed psychopaths, subjects with other mental disorders, and the majority of non-control subjects were taking psychiatric medication (including selective serotonin reuptake inhibitors). Intuitively, psychopathic traits would be associated with reduced oxytocin as this neuropeptide is heavily implicated in empathy and warmth (Hurlemann, et al., 2010; Holt-Lunstad, Birmingham, & Light, 2008). Thus, the interpretation of these results only evokes more questions. Despite the confounding variables, especially the serotonin-increasing antidepressants which may affect oxytocin production (Jørgensen, Kjær, Knigge, Møller, & Warberg, 2003) these results may indicate that the oxytocin system is involved in psychopathy. Any number of oxytocin system parameters could be the cause of this effect. Notably, conclusive data on psychopathy and the neuropeptide oxytocin does not exist, but its receptor has received recent attention.

Epigenetic changes to the oxytocin receptor (OXTR) gene have been suggested by recent evidence. Dadds and colleagues (2013) assessed the methylation of the OXTR in males aged 4 to 16 years old who met DSM-IV criteria for conduct disorder or oppositional-defiance disorder. In essence, gene methylation means that a CpG site (cytosine-phosphate-Guanine site) has a methyl group attached, thereby silencing the potential activity of the gene (Jones & Takai, 2001). As expected, variations in OXTR

gene methylation were found, with high callous-unemotional traits being associated with greater methylation of the gene as well as lower oxytocin levels in older males.

Importantly, higher oxytocin levels are associated with lower methylation of the gene, so with greater methylation comes lower oxytocin. The authors suggest that these results implicate an epigenetic role for oxytocin receptor variation that may account for the reduced empathy and interpersonal warmth that characterizes psychopathy.

These results have been supported by Hovey et al. (2015) who assessed the OXTR gene and antisocial traits in two twin study databases. Based on previous research, eight single-nucleotide polymorphisms (SNP) were assessed with the OXTR. Hovey and colleagues found that four SNPs were associated with self-reported delinquency as well as both overt and covert aggression scores. In terms of psychopathic aggression, which is often instrumental, the results associating SNP and covert aggression are of particular interest. Three SNPs were significantly associated with measures of covert aggression (e.g. Life History of Aggression scale), associating variations in the OXTR gene expression and antisocial disorders, especially covert aggression. Although these data were collected to assess antisocial behavioral SNP variations and not psychopathic behavior specifically, further investigation into the nuances of the genetic history, epigenetic factors, and life history could shed light on the relationship of psychopathy and epigenetics.

While 5-HT is most commonly related to depression, it has also been implicated in impulsivity (see Carver, Johnson, & Joorman, 2008 for a comprehensive review of serotonin function, depression, and impulsive aggression). Dolan, Anderson, and Deakin (2001) established a negative link between impulsivity and 5-HT during a fenfluramine

challenge. Similarly, Rogers et al. (2003) found that acute tryptophan depletion altered the ability of subjects to inhibit a response to previously rewarded cues, resulting in increased impulsive responses. Dolan and Anderson (2003) found that 5-HT receptor activation did not correlate with psychopathy as a unidimensional phenomenon, but rather was negatively related to impulsive-antisocial facets of psychopathy. It appears that low serotonin functioning is more related to issues of impulsivity, antisocial behavior, and overall poor behavioral control (Schweighofer et al., 2008; Berger, Gray, & Roth, 2009) but does not appear to be as directly related to the emotional component that is critical for a diagnosis of psychopathy. At the present time, no work points to a direct link between the serotonin system and psychopathy per se. These results may be most useful in understanding the impulsivity seen in antisocial disorders, though there is no clear connection between serotonin and psychopathy.

Although researchers have yet to define an exact hormonal and neurochemical profile related to psychopathic behavior, there seems to be some type of observable connection between particular neurochemicals and aspects of psychopathy. Further, it is clear that pharmacological treatment approaches are largely limited to related disorders that have overlapping features with psychopathy. At the present, the neurochemical research has been successful in finding some promising neurochemical relationships with behavioral components of antisocial disorders, while pharmacological research seeking definitive neurochemical predictors of the affective component of psychopathy has been less productive.

### *Clinical Findings*

Clinical studies of psychopathic individuals have yielded a behavioral profile that has at its focus a flattened affect and poor interpersonal connections. Psychopaths also demonstrate an overall small but definite decrease in the ability to recognize emotion in others (Wilson, Juodis, & Porter, 2011; Kosson, Suchy, Mayer, & Libby, 2002), which is also associated with decreased amygdalar function, particularly in response to fearful faces (Jones, Laurens, Herba, Barker, & Viding, 2009). Jones et al. (2009) studied seventeen male youngsters 10-12 years in age with elevated callous-unemotional traits and conduct problems. They captured an fMRI while a video of emotional faces were presented. The callous-unemotional subjects showed lower right amygdala activity compared to controls in the context of facial affect recognition. A recent, detailed meta-analysis found that psychopaths demonstrated a greater deficit in emotional processing especially when the task involved a verbal response (Wilson et al., 2011). Additionally, the decreased ability to recognize emotions in others was observed, with particular deficits seen in negative emotions (fear, sadness, and anger). Similarly, Kosson et al. (2002) showed a slight overall decreased ability to recognize emotion, but a large deficit in recognizing disgust in others when the task involved non-verbal responses. As mentioned, research indicates that psychopaths consistently fail to exhibit a conditioned response during aversive Pavlovian conditioning (Lykken, 1955; Hare & Quinn, 1971; Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002), which suggests deficiencies in limbic-subcortical and cortical structures (Ermer, Cope, Nyalakanti, Calhoun, & Kiehl, 2012). Thus, a reduction in empathy may in part stem from an unwitting inability to recognize emotions in others and not because of a volitional or conscious process.

There is an apparent relationship between trait psychopathy and degree of eye contact (Dadds, Jambrak, Pasalich, Hawes, & Brennan, 2011; Dadds et al., 2006). Dadds and colleagues (2008) tested whether psychopathic traits are associated with decreased attention to the eye region of other's faces. Although adolescent males who exhibit high psychopathic traits were significantly less proficient at fear recognition, they also had decreased eye fixations and gaze duration and frequency. These phenomena have been seen early in development, as Dadds et al. (2006) showed that psychopathic children had a deficit in recognizing fear in faces. This deficit was temporarily corrected when the children were instructed to focus on the eyes of other people. These findings may suggest a contextual component of this aspect of the interpersonal deficits seen in psychopathy. Additionally, Dadds et al. (2011) demonstrated that the fathers of children who scored high on callous-unemotional traits showed similar deficits, perhaps adding a genetic element. Genetic factors may play a major role in determining the presence of psychopathy and continue to influence psychopathic markers in children through adolescence (Forsman, Lichtenstein, Larsson & Andershed, 2008).

Lastly, a hallmark trait of psychopathy is a lack of empathy and callousness (Hare, 2003). Consistent with the findings of the eye gaze literature, Seara-Cardoso, Neumann, Roiser, McCrory, and Viding (2012) found that psychopaths show weaker empathic responses to fearful faces. Unlike healthy individuals, they were unable to infer the emotional characteristics of the face stimulus. Psychopathy is also inversely related to the ability to perceive emotion (in both male and females) and manage emotion (only in men; Lishner, Swim, Hong, Vitacco, 2011). Even less hopeful, research suggests that psychopaths may even feel positive emotions when looking at sad stimuli and experience

negative emotions from viewing neutral stimuli (Ali, Amorim, Chamorro-Premuzic, 2009).

Taken together, the empathic deficits and antisocial behavior demonstrated by psychopathic individuals in clinical studies drive a realm of research to understand and possibly develop a treatment paradigm for these individuals. Currently, no effective treatment is known, but a call to treat individual symptoms (e.g. impulsive aggression) has been suggested in lieu of direct or more global treatment (Felthous, 2015). In any case, behavioral science is left with unclear direction in how to address an increasing demographic class of disordered individuals in our society. Interestingly, vigilance states, where a person is required to give sustained attention while under cognitive load, results in a decreased ability to perceive emotion. However, no relationship between vigilance and psychopathy has been established to date.

### *Vigilance*

Sustained attention is necessary for several daily tasks in work, academics, and personal life. Vigilance is essentially sustained attention often operationalized to describe the form of attention necessary for high-demand, cognitive-loaded tasks (Sarter, Givens, & Bruno, 2001). It is considered a top-down process of the brain that encompasses the process of sustained attention to a task (Sarter et al., 2001). Notably, the specific construct of vigilance has not received a great deal of neuroanatomical study. This is because vigilance is conceptualized as a subcategory within the realm of attentional processing. Therefore, a discussion of vigilance is best understood as a discussion of task-focused, biased attention. Fortunately, the process of biased attentional resources

towards a particular target has been examined in functional imaging studies with a developing profile of neurofunctional loci.

### *Neuromodulation*

Sarter, Gehring, and Kozak (2006) reviewed the literature of the neurobiology of attentional effort, or cognitive incentive (definition based on Berridge & Robinson, 2003). This definition is important as incentive precedes the performance of sustained attention in that sufficient motivation is necessary to perform well. However, even if the incentive is desirable or critical, performance may decline. In this case, top-down processing may engage to counteract performance decline in a given task (Sarter et al., 2006). Top-down processing refers to the allocation of cognitive resources biased towards the detection and processing of relevant or target stimuli, including assessing and augmenting strategy, reassessment of available sensory stimuli, and motivation. Sarter et al. (2006) provides a synthesis of the literature regarding the functional neuroscience regarding top-down attention.

It appears that certain neurological processes are augmented when more resources are needed. Neuronal firing rate is modified during attentional states. Research in macaques has demonstrated that visual cortical firing is directly modulated by attention during a visual attention task (Treue & Maunsell, 1996). This experiment was intended to study which, if any, cortical structures activate during an increase in demand. Treue and Maunsell found that when there is a demand for increased resources to attend to visual stimuli, the medial superior temporal area becomes more active by increasing its firing rate. This appears to be one strategy the brain may use to increase attention when needed.

As attentional effort increases, synchronized firing may serve as a functional means to support the effort. Synchronized firing has been observed in macaques that were required to attend to particular stimuli (and ignore distractors; Fries et al., 2001). These synchronizations were seen in the directly utilized visual cortex (V4). Similarly, human cortical attentional regions are conserved when processing novel distractor stimuli in that new cortical real estate is not recruited when more attention is needed (Weissman, Mangun, & Woldorff, 2002). That is, cortical regions work harder rather than utilizing more cortex to process novel stimuli. Conservation is seen when incongruent and congruent distractors were presented in an attentional task, and areas in the brain that were already part of the attention task increased in activity. This suggests that when allocating attentional resources towards stimuli, one potential strategy is to optimize firing and conserve cortex in order to process both the stimuli and evaluate the “distractors” or novel contextual stimuli. Enhanced processing would be accomplished by means of increased firing rate and synchrony. Not surprisingly then, in these circumstances cortical areas that process and represent non-relevant stimuli are down-regulated (O’Conner et al., 2002) and the brain becomes focused and vigilant to the task at hand.

### *Anatomy and Pharmacology*

Acetylcholine (ACh) is the primary neurotransmitter implicated in attentional tasks, with basal forebrain (BF) cholinergic nuclei projecting to all cortical areas (Sarter et al., 2006; Woolf, 1991; Everitt & Robbins, 1997). Indeed, cholinergic influence works to optimize cortical processing during attentional tasks (Sarter, Hasselmo, Bruno, & Givens, 2005). Arnold and colleagues (2002) showed that delivery of ACh via cannula to

the frontoparietal cortex of rodents increased performance over and above baseline levels in a sustained attention task as well as control tasks. Conversely, lesion studies to the BF are well established to be related to a decrease in vigilance (McGaughy, Kaiser, & Sarter, 1996), and loss of this ability is achieved by only lesioning the BF (McGaughy & Sarter, 1998).

Ptak (2012) reviewed the existing literature on the functional anatomy of attention. He produced a review of much of the existing imaging literature related to attentional effort and vigilance. In this review, he discussed the frontoparietal attentional network (FPAN), a specialized network within the frontal and parietal cortex that assesses, encodes, and prioritizes sensory inputs in a feature-, modality-, and response-independent way, removed from the environmental representation. The FPAN regions include the angular gyrus, supramarginal gyrus, dorsal premotor cortex, and superior parietal cortex (Figure 2). These regions communicate with the frontal lobe via the superior longitudinal fasciculus (see Figure 1). In this context, dorsolateral PFC maintains goals in working memory as well as preserves them as new sensory information is added. It is also responsible for refreshing goals as needed. Parietal regions ultimately maintain attentional bias and are responsible for initiating shifts in attention. Importantly, the FPAN integrates the bottom-up representations of perceived information with integrated sensory information in the premotor and dorsolateral PFC. Thus, this system is the established functional, anatomical neuro-network involved in the higher-order dance of attentional bias due to its consistent activation in attentional research. ACh inputs to the FPAN are assumedly responsible for their activation and sustained arousal in cognitively demanding situations.

Because pharmaceutical enhancers to attention are so frequently used, many pharmacological studies have been conducted to fully assess their cognitive-enhancing effects. Common drugs, such as nicotine and caffeine, can affect attention and effort. As a whole, much of the research regarding attention and vigilance has been done in the last three decades with the results virtually unanimously demonstrating that caffeine and nicotine reliably improve cognitive abilities (Newhouse, Potter, & Singh, 2004; Nehlig, 1999). Clearly, products containing nicotine and caffeine have oversaturated western markets, in part, for these reasons.

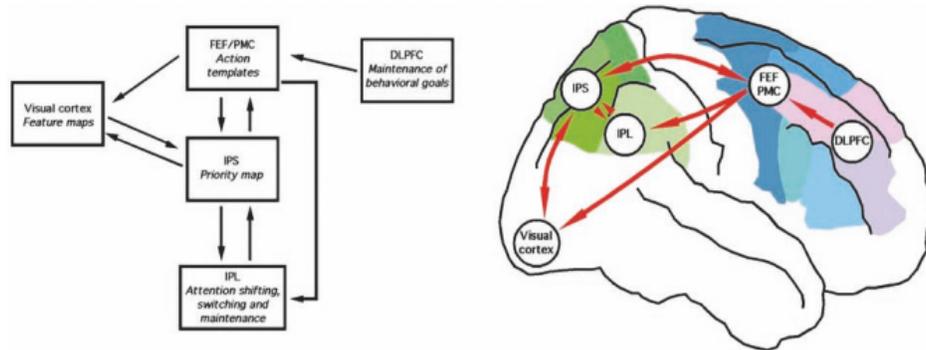


Figure 2. FPAN. Taken from Ptak, (2012). This figure shows the model of attentional selection. It illustrates the prioritization and function of attentional bias while also demonstrating the FPAN and superior longitudinal fasciculus. It also illustrates the much of the cortical effort involved in sustained attention.

Caffeine is a commonly available drug that acts as an antagonist on A1 and A2A Adenosine receptors (Wei, Li, & Chen, 2011). Adenosine receptors are found in several regions of the brain including the cortex, striatum, hippocampus, hypothalamus, spinal cord, and more. Examples of pharmacological studies involving vigilance, attention, and these drugs are voluminous; therefore a brief review of a few relevant studies will suffice here. Caffeine consumption, mood, reaction time, memory, and attention were assessed in participants receiving a 250mg dose over the course of four laboratory trials in two

conditions: a 30hr abstinent from caffeine compared to ad libitum caffeine consumption prior to testing (Addicott & Laurienti, 2009). Shortly before the testing period, participants were given either caffeine or placebo. Tolerance effects were observed in the active consumers; that is, the researchers observed a greater effect of caffeine in the 30hr abstinent group. They also saw notable improvements in performance on the selective attention task, where caffeine reduced reaction times to target stimuli. Further, caffeine decreased interference effects during these attentional tasks. In a similar study, oddball event related potentials (ERP<sup>3</sup>) were assessed in well-rested or fatigued participants administered 250mg caffeine/placebo prior to the task (Lorist, Snel, Kok, & Mulder, 1994). Overall, reaction times were improved in both groups of participants receiving the drug. Notably, P300<sup>4</sup> analysis showed that for fatigued subjects, the effect of caffeine on responding to target stimuli was greater. The N1 and N2b waveforms were also enhanced, suggesting that caffeine improved encoding and processing as well as aided the suppression of irrelevant information. The ERP data as a whole suggest that caffeine improved the processing, integration, and thus response time for target stimuli, particularly in fatigued subjects. Despite tolerance effects and route of administration, the effectiveness of caffeine has been established to enhance certain cognitive abilities.

Nicotine has been known for many decades to exert its CNS effects via nicotinic acetylcholine receptors. Nicotine increases attention and perception by its effect on ACh transmission in the brain (Sahakian, Jones, Levy, Gray, & Warbuton, 1989; Kumari et al.,

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<sup>3</sup> Event-Related Potentials generally are any characterized physiological event that occurs in response to a stimulus. In EEG studies, the stimulus may be a noise or image and the resulting characterized EEG wave that occurs as a result (within a given time frame) is said to be the ERP.

<sup>4</sup> The P300 is a peak waveform that occurs roughly at 300 milliseconds after a stimulus. It is at roughly this time that memory search processes occur. This characterized waveform is strongly believed to reflect stimulus integration, processing, and transmission (Lorist et al., 1994; Johnson, 1986)

2003). Like caffeine, there is ample evidence of its cognitive enhancement capabilities. However, unlike caffeine, nicotine agonizes the nicotinic ACh receptor, which is widely distributed throughout the CNS and PNS. Thus, its effect comes with more potential side effects, including addictive potential (Nestler, Hyman, & Malenka, 2009). An fMRI study assessed the networks involved after nicotine administration during a spatial and verbal working memory task (Kumari et al., 2003). Similar to studies with caffeine, participants experienced improved accuracy and a decrease in latency of response after nicotine administration. Nicotine produced increased activity in the anterior cingulate, superior frontal cortex, and superior parietal cortex during the working memory task. An increase in response in the tectum and the parahippocampal gyrus, cerebellum, and medial occipital lobe was also observed both during resting and task performance conditions. Lawrence, Rose, and Stein (2002) found similar network activation. In both smokers and non-smokers, the fronto-parietal-thalamic network was more active during a sustained attention task after nicotine administration. Further, nicotine increased the activation of the occipital cortex, presumably because of the visual component of the sustained attention task. Conversely, performance decreased when smokers were mildly abstinent from nicotine. Importantly, much of the literature concerning caffeine and nicotine shows that the cognitive improvements center on improving attention and, to a lesser degree, working memory. Thus, nicotine is considered to positively enhance attention.

### *Affect*

Most important in this discussion of attention is the interplay between emotional processing and cognitive load, where there is an inverse relationship between affective processing and vigilant states. Van Dillen, Heslenfeld, and Koole (2009) used fMRI to

assess this interplay. Participants viewed affective imagery from the International Affective Picture System<sup>5</sup> (IAPS) followed by performing arithmetic tasks of varying difficulty. Then the session concluded with the administration of a self-reported affective rating scale to assess current emotional state. As expected, an interaction between arithmetic task load and picture valence was found. Specifically, an effect was not found between task difficulty and neutral valence but only between task difficulty and negative valence. That is, participants reported less negative emotion when the IAPS picture was followed by a complex math problem compared to a simple problem indicating that as cognitive load increases, participants experienced less negative emotion. During negative emotional imagery, the bilateral amygdalae, right insula, right dorsolateral frontal cortex, left dorsal occipital cortex, and right superior parietal cortex were shown to be significantly active. However, when task load increased, an increase in activity in the aforementioned frontal, occipital, and parietal regions also occurred, while activity in emotional locations (amygdalae and insula) decreased with direct negative correlations between the limbic regions, dorsolateral frontal cortex and left dorsal occipital cortex. These results show that there is a reciprocal relationship between cognitive load and passive emotional perception.

In a similar study, Van Dillen and Koole (2007) found that participants felt less negative feelings towards negative imagery when they were instructed to solve math problems after viewing negative emotional imagery (similar to the methodology in Van Dillen et al., 2009). Similarly, aversive emotional states such as anxiety also decrease

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<sup>5</sup> IAPS is a database of affective images (or neutral) that are empirically established to evoke emotional responses with varying emotional weight (or valence). Valences could be neutral (such as a chair), high/low positive (nudity/sunrise), or high/low negative (mutilation/suspicious shadowy figure).

under high task load (Vytal, Cornwell, Arkin, & Grillon, 2012), suggesting that even with negative affect, task load may reduce the capacity for emotional processing. Other variables can reduce vigilance. Transcranial direct current stimulation (tDCS) to the dorsolateral PFC reduces vigilance to threat in healthy participants (Ironsides, O'Shea, Cowden, & Harmer, 2015). In this study, a state of vigilant attention to fearful faces was reduced by tDCS and this mimics effects seen with antidepressants (Murphy et al., 2009). These effects presumably occur due to a tDCS-mediated disruption or drug-induced sedation of neuronal networks involved in a state of vigilance, causing the person to fail to maintain vigilance.

Taken together, vigilant states/sustained attentional effort appear to be inversely related to emotional perception. Evolutionarily analogous situations of vigilance such as predating or hunting naturally warrant a state where emotional activation may be detrimental to success. It is important to be able to ignore irrelevant information when focusing on understanding and predicting the future movement of prey, including affective input from conspecifics or the self. This phenomenon appears to be a rather well preserved trait amongst the evolutionary development of emotions.

### *Vigilance and Yawning*

Yawning, considered to be a phylogenically old reflex that is related to emotional perception (Guggisberg, Mathis, Schnider, & Hess, 2010), has rarely been considered in the context of vigilant states save for one study that showed this relationship (Guggisberg, Mathis, Herrmann, & Hess, 2007). Guggisberg and colleagues (2007) examined spontaneous yawning during a decreasing vigilant state and an increasing sleepiness state. The researchers assessed EEG and heart rate variability outputs

associated with yawning compared to voluntary movements while participants were instructed to stay awake in a quiet, dimly lit room. Participants were chosen based on complaints of sleepiness. The authors found that spontaneous yawning occurs as drowsiness increases, yet it does not physiologically arouse the individual nor reduce drowsiness. This was determined by examining delta wave activity, as delta waves increased before and after yawns but were reduced with voluntary movements. Only voluntary movements such as stretching or adjusting posture changed delta waves. Delta waves decrease during sleep and increase throughout wakefulness (Borbely et al., 1981), and thus are established indicators of a sleep-promoting process. A “delta state” is characterized by delta wave activity across the topographical map of the cortex. Delta activity increases in the anterior and central regions during the transition from wakefulness to sleep and concentrates in the frontal-central midline during drowsy states (De Gennaro, Ferrara, & Bertini, 2001; De Gennaro, Ferrara, Curcio, & Cristiani, 2001). These researchers found that during physical movement, delta waves indicated a reduction in sleep pressure. Further, no short-term cortical EEG activity change was observed in relation to yawning, which provides evidence against top-down, cortical initiation of yawning and supports the notion that yawning is an evolutionarily preserved reflex initiating in phylogenically older areas (i.e., brainstem). Further, autonomic responses did not appear to predict yawns. In fact, the best predictor of physiological arousal in this experiment was adjusting posture or stretching, reinforcing the observation that physical movement can decrease drowsiness.

Guggisberg et al. (2007) passively conceptualize vigilance in their study. Only when participants were rested and seated in the quiet dim room did they begin to calm

and “become sleepy.” In other words, the reduction of vigilance due to an increasing physiologically calm state produced the physiological requirement (drowsiness) for spontaneous yawning to occur. When it did, physiological evidence showed that yawns were neither arousing nor did they change a biomarker of drowsiness, Delta activity. The authors note that these results point towards a communicative theory of yawning, as competing theories generally point towards physiological arousal or stimulation of some kind (Guggisberg et al, 2010). Guggisberg’s research helps with understanding contagious yawning, which has been tied to empathic ability and may be related to vigilant states, though no more data have been collected.

### *Yawning*

Yawning is a stereotyped behavior that, in our evolutionary history, has deep roots as evidenced by its widespread occurrence in mammals as well as many other vertebrates (Argiolas & Melis, 1998; Lehmann, 1979). It is characterized by long inspiration followed by a shorter expiration (Argiolas & Melis, 1998). There is a considerable literature available concerning the pharmacology and functional anatomy of yawning (Nahab, Hattori, Saad, & Hallett, 2009; Argiolas & Melis, 1998; Guggisberg, Mathis, Schnider, & Hess, 2010). Yawning can be divided into two categories: spontaneous and contagious yawning (CY) types. Millen and Anderson (2011) demonstrated that neither infants nor toddlers catch yawns from their mothers yet still spontaneously yawn, suggesting that spontaneous and contagious yawning are two different phenomena. Developmentally, CY begins between 4-6 years of age in typically developing children (Anderson & Meno, 2003; Helt, Eigsti, Snyder, & Fein, 2010). The emergence of CY at this specific age is likely due to the development of other

neurocognitive based social behaviors and constructs such as Theory of Mind and empathic behavior (Brüne & Brüne-Cohrs, 2006). Both of these are constructs related to contagious yawning theory.

Contagious yawns, which are spurred by thinking, hearing, reading, or observing another conspecific (or other species) yawn, have been strongly linked to empathy (Platek, Mohamed, & Gallup, 2005; Platek, Critton, Myers, & Gallup, 2003; Lehnmann, 1979). They are even well documented in other higher primates such as chimpanzees (*Pan troglodytes*) and, there too, are linked to empathy (Campell & Waal, 2011).

Anthropological evidence from primates has shown that yawns are more often observed in males than females in primate social groups (Vick & Paukner, 2010). Further, rank of yawn initiator is important, as higher-ranking males are observed to yawn more frequently than subordinates (Adams & Schoel, 1982). Insofar as the yawn is a contagion, the dominant males are more likely to initiate yawns amongst the group. The assumption is that dominant males must spontaneously yawn in order for lower ranking individuals to respond with contagious yawns. Though no evidence currently exists for contagious yawning and social dynamics in humans, yawning may serve a role for social cohesion and communication amongst higher primates with elements of social status involved.

In addition to social structure, higher primates show a marked resemblance to humans in terms of CY. Researchers observed that CY frequency was increased between gelada baboons (*Theropithecus gelada*) that were socially close (Palagi, Leone, Mancini, & Ferrari, 2009). Interestingly, the type of yawn was mirrored in emotionally familiar females (such as covered teeth, uncovered teeth, or uncovered gums). Chimpanzees similarly respond with a yawn when shown videos of conspecifics performing a yawn

(Anderson, Myowa-Yamakoshi, & Mtsuzawa, 2004). This holds true even when chimpanzees are shown videos of digitally-created yawning chimpanzees (Cambell, Carter, Proctor, Eisenberg, & de Waal, 2009). This speaks to the potency of contagious yawning, even in other species.

### *Neuroanatomy*

A discussion of the neuroanatomy of contagious yawning requires a distinction between contagious and spontaneous yawning. In general, yawning as a reflex is so well preserved evolutionarily that it occurs in socially impaired individuals (Giganti and Esposito-Ziello, 2009; Senju et al., 2007) and anencephalic newborns (Price Heusner, 1949). Nonetheless, there is a notably different neuro-behavioral pathway underlying the two types, as their frequency of occurrence throughout the day varies slightly. There is an increase in both types in the morning and evening, a similar likelihood of occurrence throughout the day, and a clear increase in the occurrence of contagious yawns at 1900 hours (Giganti & Zilli, 2011), perhaps suggesting a temporal-hormonal relationship. Unfortunately, yawning neurobiology is not fully unraveled and there exists difficulty separating spontaneous from contagious yawning in research.

Given the social and seemingly reflective nature of contagious yawning, some have suggested a connection to the mirror neuron system (MNS); however, there is in fact very little evidence that the MNS is wholly involved (Platek et al., 2005). The MNS, a network of visuomotor neurons, activates when both observing an action and performing the action (Rizzolatti & Craighero, 2004; Rizzolatti et al., 1996), but is also implicated during higher-order operations such as cognitive empathy (Haker et al., 2010). Platek et al. (2005) argues that the MNS is not involved in CY due to insufficient

activation of the MNS in his study (Platek et al., 2005). However, some have shown otherwise. Haker and colleagues (2013) demonstrated activation of a subset of MNS loci in a contagious yawning paradigm when compared to neutral and scrambled faces. Though not a potent activator of the MNS (likely due to its reflexive nature), some subsections are activated enough to suggest some empathic and social processing is occurring. Haker et al. (2013) showed activation of Brodmann's area 9 and areas of the right inferior frontal gyrus, the area largely responsible for the motor aspect of the MNS. The author noted that this was only a subset of the traditionally understood MNS sites, and therefore Platek's conclusion may not be completely accurate. Haker and researchers explained their different conclusions regarding CY and the MNS as being the result of two different paradigms. Platek et al. (2005) imaged CY to a neutral condition of their paradigm with yawning and laughing stimuli. Haker and colleagues (2013) examined CY in the context of observing only yawning faces. Essentially, the addition of laughing faces stimuli may have obscured the detection of the minor role of the MNS in the yawning condition, as laughing presumably potently activates the MNS.

Nahab et al. (2009), using fMRI, documented that contagious yawning activates the ventromedial prefrontal cortex (vmPFC), suggesting that this result is evidence that contagious yawning utilizes areas known for empathic processing and theory of mind (Baron-Cohen et al., 1994; Calder et al., 2002). The fact that this area appears to be necessarily involved in the initiation of contagious yawning suggests that it may be part of a cortical system that initiates yawns in a social context. In other words, the vmPFC may be the social "gate" that allows a reflex to partially depend on social cues. It also illuminates why contagious yawning is found exclusively in higher primates such as

humans and great apes. These results are consistent with the discussion on the MNS (Haker et al., 2013) as well as Guggisberg et al. (2007), as little cortical processing may be necessary in order to produce the social contagion, but not necessarily spontaneous yawns.

Other brain areas are also involved in the phenomena of contagious yawning. For example, hearing yawns activates the right posterior inferior frontal gyrus (pIFG; Arnott, Singhal, & Goodale, 2009), an area shown to house mirror neurons (Rizzolatti & Craighero, 2004). Schürman and colleagues (2005) found activation of the medial visual cortex when viewing yawns along with the cuneus and superior temporal sulcus. Importantly, brain regions necessary for imitation are insufficiently activated during CY, strongly suggesting the behavior is not reflective. Amygdala activation was also negatively correlated with the level of perceived contagiousness of yawning stimuli (Schürman et al., 2005). The salience and strength of a yawn contagion for an individual is inversely related to the strength of amygdala activation. This suggests that high amygdala activation (and thus negative emotion) is not likely to allow the perception and thus manifestation of a yawn in response to a yawn stimulus. This calls to back to the discussion of vigilant states, where intense focus to aversive stimuli dampens emotional perception. It would follow that high vigilance states would result in low responses to contagious yawning. Platek and colleagues (2003) identified the precuneus and bilateral posterior cingulate as activated during a contagious yawn. Additionally, the bilateral thalamus and parahippocampal gyrus are activated. Self-processing is known to be related to the posterior cingulate and precuneus (Keenan, Wheeler, & Gallup, 2000; Kremen, Faraone, Toomey, Seidman, & Tsuang, 1998), while the thalamus and

parahippocampus are likely related to facial perception of the stimulus, the authors suggest. This may suggest that higher-order processing may be occurring when contagiously yawning, including processing the self when observing a CY.

The subject of CY is still under scientific evaluation for its social and reflexive qualities. In recent decades, the social aspect of CY has received considerable attention. Indeed, studies examining the relationship between CY and social familiarity, empathy, and other higher-order cognitive processes have been carried out with interesting findings.

### *Yawning and Empathy*

Numerous studies have indicated a positive relationship between measures of empathy and responsiveness to contagious yawning (see Guggisberg et al., 2010). Norscia and Palagi (2011) found that people show a large susceptibility to contagious yawns when elicited by a related individual in terms of occurrence and frequency of yawns. Strangers show a marked latency period of contagious yawns, strongly suggesting a component of familiarity involved with the contagion. Platek et al. (2003) conducted a series of experiments assessing the role of self-awareness and mental state awareness and CY, both constructs that are related to empathic behavior. For example, schizotypal personality disordered individuals, who have a deficit in processing information about the self (Platek & Gallup, 2002), are not susceptible to CY. Furthermore, performance on tests of Theory of Mind was found to be positively associated with participants who scored high on CY. Lastly, they found an association between self-facial recognition and CY. Schizotypal individuals who were faster to recognize their own faces also showed increased susceptibility to CY. The authors suggest that the results of these experiments

may place CY under the umbrella of “mental state attribution,” or the ability to model the mental states of others (Platek et al., 2003). The findings in their series of experiments place CY within the realm of empathetic cognitive proficiency.

As previously discussed, a subset of the MNS has been shown to be involved in CY as shown by Haker et al. (2013). However, given the seemingly recent evolutionarily retrofitted purpose of CY (for social synchrony/group cohesion), it is not surprising that some cortical areas (i.e., the right inferior frontal gyrus and ventromedial PFC) are involved with mirroring and empathy. As mentioned, this may also be a structural trigger which makes yawning of this kind social in nature for mature members of our species and other higher-primates.

Helt et al. (2010) showed that typically developing children begin empathic yawns at 4-6 years of age, while autism spectrum disorder (ASD) children do not demonstrate a susceptibility to CY. ASD and normal children were sat in a familiar room and told they were going to be read a story. The reader (familiar to the children) read a story to the children and yawned at selected intervals throughout the story. Aside from demonstrating the contrast of typical development compared to ASD children in this context, the paradigm maintains a greater degree of ecological validity than many other studies that used computer-based videos (Platek et al., 2005; Rundle, Vaughn, & Stanford, 2015), as the presence of a conspecific is likely a more potent stimulus than a computer screen with videos of strangers yawning. Interestingly, Senju et al. (2009) found that the contagion deficits seen in ASD children can be corrected by instructing the children to specifically focus on the eyes of a video stimulus. Usui et al. (2013) used eye tracking technology and a similar paradigm to Senju et al. (2009) with similar outcomes.

These results further suggest a cortically-mediated model of CY, where dampened social signals in socially impaired individuals become corrected with sufficient concentration and effort, like the corrected empathic deficits seen in psychopathy (Dadds et al., 2006). While social tuning may be automatic for some, other populations may require effortful initiation of social information gathering in order to achieve normal functioning. The connection between CY and empathy is becoming more and more apparent. As such, there is a growing amount of evidence linking the two, suggesting that this form of yawning is a specialized reflex that occurs when the capacity for empathy is present.

### *Psychopathy and Vigilance*

Perhaps underappreciated are some of the potentially useful aspects of psychopathic traits. For example, a diminished ability to condition to punishment could also produce qualities of resiliency and vigilance in particular situations. Violently defending territory or the modern equivalent, military operations, may necessitate some of these qualities (e.g., coldheartedness, fearless dominance, flattened affect, low fear). Indeed, psychopathic traits and heroic traits (defined as altruism with some degree of risk) are related (Smith, Lilienfeld, Coffey, & Dabbs, 2013), with subscales of the PPI-R such as Carefree Nonplanfulness, Coldheartedness, and Social Potency being positively correlated with self-reported altruism and heroic acts over a lifetime. While the egocentricism typified by psychopathic traits may explain away self-reported altruism, it may actually be the case that psychopathic traits carry certain social advantages not only to individual psychopaths but to the whole of society. Considering psychopathy as a spectrum casts a different light on the term “fearless leader.”

Sandvik et al. (2015) recently investigated the relationship between psychopathy, resiliency, and anxiety using statistical mediation modeling. They found that psychological hardiness mediated the effects of state anxiety on psychopathy. They reasoned that having traits such as commitment (general sense of engagement and purpose in life), control (a belief in personal control and influence over one's life experiences/events), and challenge (anticipation and ability to view change as positive and to have potential for growth and change) may actually be important qualities that reduce the experience of state anxiety. Sandvik and colleagues showed that the interpersonal Factor 1 traits positively correlated with commitment while antisocial Factor 2 traits showed a negative relationship. This suggests that emotional detachment or flattened affect as well as lower levels of commitment may predict lower anxiety. These results potentially indicate that psychopathic traits, especially the decreased effect of state anxiety, could be protective in some social situations (such as unrequited romantic interest or lost job opportunity) and detrimental in others (such as criminal rehabilitation).

Several questions arise as a result of this discussion, as some of these advantageous traits seem critical for developing into a healthy individual. Is it possible for healthy individuals to display traits such as the ones operationalized by Sandvik et al. (2015)? Conversely, are high psychopathic trait individuals able to suppress emotional deficits? More appropriately, are psychopathic traits related to vigilant states?

## *Synthesis*

### *Evolution and Dual-Source Model of Yawning*

A survey of the literature lends strong support for re-conceptualizing the nature of yawning. Attempts at deconstructing the phenomenon of yawning has largely resulted in describing physiological correlates (see Daquin, Micallef, & Blin, 2001). Alternatively, arguments for the evolutionary origins of yawning are often given without sufficiently considering the neuroimaging data or have been done with poor methodology (see Gallup & Gallup, 2007).

Guggisberg et al (2007) provides some of the best evidence for the evolutionary origin of yawning. Spontaneous yawning is most likely to occur during drowsy states (most often seen in the morning and evening; Giganti & Zilli, 2011). There is evidence that this is 1) not a top-down process, 2) not physiologically arousing, and 3) a reflexive, ballistic, stereotyped behavior. Further, Guggisberg et al. (2007) asserts that they found no evidence that spontaneous yawning serves an immediate physiological function, and that it is likely communicative in nature. This suggests that yawning occurs when an animal is drowsy and presumably less attentive to its environment and, thus, more vulnerable. The yawning reflex also tends to require baring a full set of teeth in the process. Consider that yawning is a passive self-defensive reflex for all those potentially observing, predated, or considering usurping territory. Dominant males may initiate contagious yawns amongst the group with a spontaneous yawn in order to preserve their dominant role (by baring teeth) while simultaneously synchronizing the group. Dominance, territorial behavior, and passive self-defense may be several evolutionary reasons spontaneous yawning exists.

Post hoc attempts at explaining the evolutionary origin of CY have been mostly convincing, with the most appealing arguments centering on yawning being a social synchronization tool. In essence, baboons that get tired together, sleep together, and unlike any would-be solitary night-owls, would not invite predators. Research and theoretical speculation continue as the specific details of the evolution of contagious yawning are currently being shaped by the results of several studies involving this phenomenon. Interestingly, much of the physiological data on yawning points towards a duality of initiation (Guggistberg et al., 2007; Haker et al., 2010). That is, spontaneous yawning requires no cortical input (Guggistberg et al., 2007) while contagious yawning appears to require minimal cortical activation (Haker et al., 2010). This follows because social behaviors for our species are generally assumed to involve cortical processing. Understanding yawning as having dual-initiation may aid researchers in organizing their experiments, particularly physiological or imaging ones, appropriately. Furthermore, there appears to be a required physiological state of decreased vigilance or an increase in drowsiness for CY to occur. For psychopaths, perhaps there is a relationship between vigilant brain states and yawning, in that the dearth of CY reactivity may be related to some neurofunctional inability to decrease vigilant states. If so, could there be a quality to psychopathy that diminishes the potency of a yawn and can it be manipulated or modulated?

### *Conclusion and Hypothesis*

Given the information previously discussed as well as the scarcity of scientific investigation relating yawning and mental health, I propose an extension of Rundle and colleagues (2015) which investigated the relationship between psychopathic traits and

susceptibility to contagious yawn. We showed that psychopathic traits (namely Coldheartedness) negatively predicted susceptibility to contagious yawning in a video paradigm. This was validated with an emotion-related startle paradigm, where electromyographic responses to a startle stimulus predicted frequency of yawning to yawning stimuli. Similar to other contagious yawning studies, this study lacked an ecologically valid aspect of contagious yawning. I was concerned that computer screens and videos may not capture the essence of the contagious yawn, especially the social essence. I wondered whether a physical presence may provide a more ecologically-valid stimulus. The current study exposed individuals that have been assessed by the PPI-R to the paradigm previously utilized, followed by a social-yawning paradigm (SY; similar to Helt et al., 2010) and a vigilance task (VT; novel paradigm). The SY task involved one-on-one interaction with the participant where a story was read. The participant was asked to relax and listen to the story, while the researcher yawns at set times throughout the story in hopes to evoke a yawn from the participant. The VT involved yawning in the context of having the participant perform a timed task with high-cognitive load, which necessitated a state of sustained focus and attention. I hypothesized that yawning initiated by the computer task (CT) would replicate Rundle et al. (2015); the vigilance condition would reduce the frequency of contagious yawning across all individuals; the in-person stimulus (SY) would be sufficient to evoke contagious yawning; and the SY condition would increase the frequency of contagious yawning compared to the CT stimulus (see statistical analyses).

The results of this experiment were expected to shed light on several facets of both empathy and psychopathy. First, replication of Rundle et al. (2015) is important to

more firmly establish the connection between contagious yawning and psychopathic traits, namely the Coldheartedness facet of psychopathy measured by the PPI-R. Second, due to the previously discussed emotional processing attenuation during sustained attentional efforts, no group was expected to yawn during the VT. Third, it was predicted that lower-trait individuals will demonstrate typical contagious yawning in response to the SY like the CT, with an increase in yawning frequency when an actual person is the stimulus. The expectation was that the yawning contagion will be potentiated by actual interpersonal interaction over and above the computer stimulus. Results of from this study may shed light on the potential conditional nature of contagious yawning in psychopathy and thus, the behavioral manifestation of these psychopathic traits in certain contexts. Results from this work may serve as catalyst for further study of the conditional states of certain psychopathic traits, as well as yawning during certain physiological states. It may also produce more questions concerning the relationship between vigilant states and psychopathic traits. In conclusion, social context may be critically important for psychopathic behavior, because while some contributing traits are relatively static and unchanging, other traits, such as the affective component, may be conditional. This may be critically important in understanding the nature of psychopathy.

## CHAPTER TWO

### Methods

#### *Participants*

The desired sample size for this experiment was  $n = 112$ , based on a power calculation from Rundle et al. (2015),  $d = 0.40$ . Participants were selected (via online screening) based on their scores on the Coldheartedness subscale of the PPI-R.

Participants were selected from a pool of respondents and were included if they had valid PPI-R scores; were between 18-45 years of age; and were otherwise healthy individuals. Exclusion criteria were having known medical, psychological, or neurological conditions. Screening included declaring and recording how many hours since the participant last consumed caffeine.

#### *Materials*

##### *Yawning Paradigms*

The following paradigms represent various stimulus situations intended to induce a yawn from the participant. Each method was given in a pseudo-randomized order for each subject so as to control for sequence effects. All tasks were video recorded in order to assess and score yawns after the fact.

##### *Computer Task – Video Stimulus Induced Yawning*

The computer task (CT) was a replication of Rundle et al., 2015. Videos of individual males and females unknown to any participants were selected to provide 7-10

second videos of a yawn, a laugh, or a neutral face. This paradigm followed the methods listed in Platek, Mohamed, Gallup (2005), a method shown to induce yawns. Participants viewed a series of video blocks consisting of three videos containing a random ordering of yawning, laughing, or neutral clips. To be clear, each video block did not contain the videos from only one individual, but rather a pseudo-random and exhaustive selection of yawns, laughs, or neutrals from the pool of videos recorded from the strangers. Each individual video was 7-10 seconds long and each block was 24-33 seconds long (with a one second interval between each video in the video block). Ten seconds of a blank black screen separates each block and participants viewed 20 blocks.

#### *Social-Yawning Task – In-person Yawning Stimulus*

The social yawning (SY) task was modeled after Helt et al. (2010), where children were read a story, and the teacher yawned intermittently throughout to elicit yawns. In our experiment, an innocuous and simple story was read to the participant; they were instructed to listen but nothing more. The researcher and participant faced each other and the participant began reading. The researcher yawned at five set times throughout the 7-10 minute story and yawn frequency was recorded.

#### *Vigilance Condition – In-Person Yawning Stimulus*

The vigilance condition was added as a control condition since vigilance tasks suppress emotional perception. The vigilance task (VT) was a novel task generated by our lab. The purpose was to cognitively load the participant. A rolodex of laminated cards containing Stroop words (a printed word naming one color printed in another color's ink), moderate-to-difficult arithmetic problems, and matrix of symbols with an oddball figure.

The participants were instructed to time themselves with an audible stopwatch (EAI<sup>®</sup> 822.0201 Mechanical Stopwatch, USA), then answer each card presented to them as fast as possible. The rolodex of problems was presented by the researcher and held at the height of the upper chest. This allowed a frontal (but necessarily peripheral) view of the researcher's face as the participant attended to the rolodex. The task lasted approximately 7-10 minutes. During this time, the researcher intermittently yawned (simulated if necessary) at five set times.

The goal was to have the researcher and the participant face each other during this task. The yawns by the researcher were just above the direct line of sight by the participant, which was directed at the rolodex located at chest height. This arrangement provided the most potent stimulus for CY available amidst a task that involves sustained attention.

#### *Self-Report Measures.*

##### *Psychopathic Personality Inventory – Revised (PPI-R)*

The PPI-R is a 154 item inventory that is the first line measure to assess psychopathy in non-incarcerated populations. The PPI-R assesses three different factors: Self-Centered Impulsivity (SCI), Fearless Dominance (FD), and Coldheartedness. Within SCI and FD, there are several scales that load on each factor (see Table 1). Of particular interest is the Coldheartedness scale, which measures levels of deep feelings of guilt, empathy, loyalty, and lack of enduring attachments to others (Lilienfeld & Widows, 2005).

### *Triarchic Psychopathy Measure (Tri-PM)*

The Tri-PM is a 58 item self-report measure that aims to measure psychopathy by its phenotypic elements (Patrick, Fowles, & Krueger, 2009; Patrick, 2010). Patrick and colleagues have identified three consistently phenotypic constructs that are consistent across demographics, Boldness, Disinhibition, and Meanness. The authors conceptualize psychopathy by its phenotypic elements based on historic psychological and neurological research. This conceptualization is intended to stand independent of age, demographic, or incarceration status.

Table 1

<i>PPI-R Factor Loadings</i>	
Factor	Scale
Self-Centered Impulsivity	Machiavellian Egocentricity Rebellious Nonconformity Blame Externalization Carefree Nonplanfulness
Fearless Dominance	Fearlessness Stress Immunity Social Influence
Coldheartedness*	n/a

\*Coldheartedness is a stand-alone factor and does not have any factor loadings.

### *Procedure*

The tasks were presented to the participants in a pseudo-randomized order. Between each task, there was a short resting period to restore a physiological baseline, as some tasks may induce too much drowsiness or physiological arousal.

### *Computer Task (CT)*

Participants were instructed to sit in a padded chair in a dimly lit testing room. Participants were sat in front of a computer monitor and were asked to relax for one minute's time before the procedure begins. They were told that they were watching a movie of different people's expressions, that they needed to remain comfortably seated, and to keep their attention on the screen. Further, if they felt the need to adjust themselves, laugh, cough, yawn, or blink, that they were allowed to do so as long as their attention remained on the screen and that they returned to a still, comfortable position.

### *Social-Yawning Task (SY)*

Participants sat in the same room as the other tasks. Participants faced the researcher and were told that they were to relax and listen to a story that would be read to them. They were told that they would not have to remember anything specific from the story and that this was simply a "relaxation" task. A story that lasted between 5-7 minutes was read and the researcher yawned at five determined intervals as the story progressed. The goal was to allow an uninhibited view of the researcher in a context where the participant could relax.

### *Vigilance Task (VT)*

Participants sat in the same room as the other tasks. To complete this procedure, the participant and researcher faced each other, and the participant held the stopwatch. The task began when the participant initiated the stopwatch. At that time, the rolodex was held up and the first problem presented. As each problem was solved, the next problem

was presented until the end of the rolodex. As mentioned, the researcher yawned five times at set intervals during the task. The task ran until the rolodex is finished.

### *Statistical Analyses*

First, for all conditions and sex, a 3 x 2 ANOVA was computed and in order to evaluate the effects of sex and contagious yawning (Massen and Gallup, 2016; Norscia, Demuru, and Palagi, 2016). Similarly, 3 x 2 ANOVAs for task by median and quartile splits were computed. Subsequently, a step-wise regression analysis was performed to assess the predictive value of the PPI-R Coldheartedness scale on contagious yawning during the three yawning tasks. A step-wise assessment of the relative contribution of hours since caffeine intake, sex, and their interactions was also included. The first block assessed the Coldheartedness scale on yawning frequency. The second block included hours since caffeine intake. The third included sex of the participant. The fourth and subsequent blocks included interactions (Table 6). Notably, sex effects are controlled for in the Coldheartedness score of the PPI-R. As such, we did not expect to find an effect of sex in our analysis.

Finally, we compared the relative predictive value of the regression coefficients of the Tri-PM and the PPI-R by comparing our regression coefficients, given by the equation:

$$z = \frac{\beta_1 + \beta_2}{\sqrt{(SE_{\beta 1})^2 + (SE_{\beta 2})^2}}$$

(Paternoster, Brame, Mazerolle, and Piquero, 1998). Beta coefficients for the Tri-PM were acquired using the same procedure as with the Coldheartedness scale. Assessing the ability for other psychopathic measures to predict contagious yawning strengthens the

relationship between contagious yawning and psychopathic traits. Further, the use of alternative assessment tools may provide a more accessible and manageable means of assessing psychopathy in a laboratory setting using a student sample.

## CHAPTER THREE

### Results

#### *Participants*

A total of 117 participants (35 males, 82 females) were used in this study. Three participants were removed from the data prior to analysis due to becoming ill during testing, refusal to participate beyond providing consent, and sustained inattention in all tasks. Participants were college students between 18 and 25 years of age. All yawns were assessed by the principal investigator and were evaluated using the same criteria as Rundle et al. (2015) excluding physiological validation. That is, yawns were only counted if the participant initiated the full cycle of reflexive inspiration followed by expiration of air.

#### *Sex Differences and Caffeine*

Table 2 shows all variable means and standard deviations across conditions, as recent discussions of sex differences and contagious yawning have received attention in the literature (Massen & Gallup, 2016; Norscia, Demuru, & Palagi, 2016). An ANOVA across conditions of sex (male = 34, female = 79) and yawning showed no significant effect of sex in any condition (Table 3). Notably, females consistently yawn at a higher frequency than males across all yawning conditions, but the difference was not statistically reliable in this study. Furthermore, no interaction between sex and yawning task-type was observed (Table 3). The ANOVA only showed significant differences between yawning task-type (to be discussed). In the full regression model, the main effect

of sex in SY, where the participant relaxed and listened to the experimenter read a relaxing story was not statistically significant,  $\beta = 0.429$ ,  $p = 0.065$ . The same result is seen in the SY task when contagious yawning was considered a binary outcome (yawn or fail to yawn),  $\beta = 2.527$ ,  $p = 0.082$ .

Table 2

*Means and Standard Deviations of Variables by Sex*

Source	Variable	Male	Female
PPI-R <sup>a</sup>			
	Total	41.09(31.93)	41.59(31.73)
	Coldheartedness	48.14(30.37)	43.55(32.18)
	Fearless Dominance	41.66(32.94)	42.22(31.81)
	Self-Centered Impulsivity	43.60(25.39)	47.16(28.565)
Tri-PM <sup>b</sup>			
	Total*	64.59(17.15)	53.27(14.14)
	Boldness	31.24(8.30)	29.96(8.58)
	Disinhibition*	17.68(6.56)	13.54(6.53)
	Meanness*	15.68(8.57)	9.76(6.85)
Task <sup>c</sup>			
	Computer Video	2.68(3.43)	3.96(4.32)
	Social Yawning	0.94(1.56)	1.41(2.03)
	Vigilance Task	0.03(0.17)	0.10(0.61)

*Note.* Format is Mean(SD); "a" PPI-R numbers are percentile values. "b" Tri-PM numbers are raw scores; "c" numbers are yawn frequencies; "\*" denotes a significant difference at the  $\alpha < 0.05$  when using a t-test.

Next, hours since caffeine intake was not significant in our full model of the CT,  $\beta = -0.665$ ,  $p = 0.078$ . In the SY and VT condition, the effect of caffeine represented no significant portion of the variance,  $\beta = 0.185$ ,  $p = 0.639$  and  $\beta = 0.059$ ,  $p = 0.884$  respectively. In fact, hours since caffeine intake did not correlate with any variable in our study.

Table 3

*Analysis of Variance Between Sex and Yawning Task*

Source	df	Mean Square	<i>F</i>	<i>p</i>
Sex	1	8.28	2.69	0.10
Task <sup>†</sup>	1.35	380.65	45.33	0.00
Sex * Task <sup>†</sup>	1.35	12.38	1.47	0.23
		Mean Difference	S.E.	<i>p</i>
Pairwise Comparisons*	CT - SY	2.12	0.38	0.00
	CT - VT	3.23	0.42	0.00
	SY - VT	1.11	0.20	0.00

<sup>†</sup> denotes Greenhouse-Geisser corrected values. \* pairwise comparisons are Least Significant Difference

*Coldheartedness*

An ANOVA computed using the upper ( $n = 27$ ) and lower ( $n = 36$ ) quartiles of Coldheartedness across conditions showed between-subjects significance (Table 4). A significant interaction between quartile and condition also showed statistical reliability. All pairwise comparisons between yawning task-type are given in Table 3.

Table 4

*ANOVA Between Upper and Lower Quartile Split (QS) and Yawning Task*

Source	df	Mean Square	<i>F</i>	<i>p</i>
QS	1	52.21	18.69	0.00
Task <sup>†</sup>	1.49	235.31	35.87	0.00
QS * Task <sup>†</sup>	1.49	87.57	13.35	0.00

<sup>†</sup> denotes Greenhouse-Geisser corrected values.

The same procedure was performed for the lower ( $n = 66$ ) and upper ( $n = 47$ ) halves of the participants by Coldheartedness score, which showed similar results for the between-subjects effects (Table 5). The interaction between median split and condition was also significant.

Table 5

*Analysis of Variance Between Median Split (MS) and Yawning Task*

Source	df	Mean Square	F	p
MS	1	15.75	5.62	0.02
Task <sup>†</sup>	1.35	463.23	56.45	0.00
MS * Task <sup>†</sup>	1.35	28.26	3.44	0.05

<sup>†</sup> denotes Greenhouse-Geisser corrected values.

A summary of the results of the median split between subjects as well as the within task-type is shown graphically in Figure 3. Within the CT task, there is a statistically significant between-subjects difference. In addition, yawning frequency in each task was significantly different from the other tasks (Table 3).

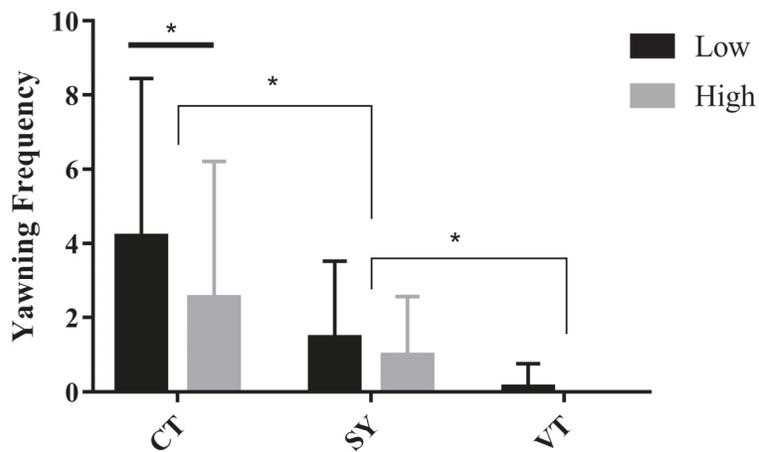


Figure 3. Median Split by Task. Graph shows high and low Coldheartedness traits by yawning task. “\*” denotes significance  $\alpha \leq 0.05$ . Mean yawns are statistically significant different between tasks. In the CT, there is a significant difference between high and low groups in frequency of yawning.

### *Yawning Tasks*

Mean yawning frequency was reliably different between tasks. All ANOVAs showed reliable within-subject task differences in yawning frequency (Figure 3). Follow-up comparisons showed that each mean yawn was reliably different from each of the

other mean yawns in the other tasks (Table 3). Means, standard deviations, and the results of the step-wise regression model are provided in the following sections.

### *Computer Task*

Table 6 shows the data for results of the model on all yawning tasks. For the Computer Task, on average participants yawned between three and four times,  $M = 3.55$  ( $SD = 4.10$ ). Frequencies in the CT task were regressed on the Coldheartedness scale and showed standardized  $\beta = -0.644$ ,  $p = 0.012$ . For the purposes of replication, CT yawns were logistically regressed (yawn or fail to yawn) on the Coldheartedness subscale of the PPI-R,  $\beta = -0.36$ ,  $p < 0.000$ . Frequency of yawning was inversely related to the Coldheartedness score.

Table 6

*Results of a Step-wise Regression Analysis on Yawn Frequency*

Predictors	Block	Computer Task		Social Yawning		Vigilance Task	
		$\beta$	$\Delta R^2$	$\beta$	$\Delta R^2$	$\beta$	$\Delta R^2$
CD	1	-0.644*	0.140	-0.143 <sup>†</sup>	0.042	-0.006	0.025
Caffeine	2	-0.665	0.002	-0.185	0.005	0.059	0.000
Sex	3	-0.132	0.018	0.429	0.013	0.210	0.003
CD * Caffeine	4	0.567	0.006	-0.391	0.001	-0.048	0.000
CD * Sex	5	0.309	0.003	-0.515	0.007	-0.224	0.007
Sex * Caffeine	6	0.604	0.006	-0.436	0.000	-0.078	0.000
CD * Sex * Caffeine	7	-0.448	0.009	0.558	0.015	-0.060	0.000
Total			0.185		0.083		0.036

*Note:* CD denotes the Coldheartedness subscale of the PPI-R; "Caffeine" variable denotes hours since last caffeine intake; "\*" denotes significance a  $p \leq 0.05$  in the full model; "†" denotes significance in block 1 and 2 before subsequent variables were added. All betas are standardized.

### *Vigilance Task*

During the Vigilance Task, participants yawned very infrequently,  $M = 0.08$  ( $SD = 0.518$ ). No significant relationship between yawning frequency in the VT and any measure was observed.

*Social-Yawning Task.*

On average, subjects yawned just over once during the Social Yawning task,  $M = 1.25$  ( $SD = 1.899$ ). Scores on the PPI-R subscale Coldheartedness did not predict yawning frequency in this task, standardized  $\beta = -0.143$ ,  $p = 0.592$ . Though the initial analysis with Coldheartedness as the sole predictor showed significance, it was not ultimately significant in the full model.

Lastly, the SY task did not appear to potentiate the yawning reflex over and above the Computer Task,  $M_{CT} = 3.55$  vs.  $M_{SY} = 1.25$ , thus not warranting statistical analysis.

*Tri-PM*

A preliminary correlational analysis did not show any relationship between Tri-PM subscales and outcome measures save for Meanness (Table 7).

Table 7

*Correlations between the Tri-PM and model variables*

Variable	Tri-PM Total	Meanness	Disinhibition	Boldness
Sex	-0.328**	-0.347**	-0.281*	-0.069
Caffeine	0.043	0.131	-0.130	0.063
CD	0.414**	0.644**	0.095	0.100
FD	0.621**	0.347**	0.088	0.775**
SCI	0.518**	0.442**	0.432**	0.219*
CT	-0.166	-0.296**	0.022	-0.053
SY	-0.262**	-0.293*	-0.115	-0.101
VT	-0.093	-0.087	0.012	-0.103

*Note: CD = Coldheartedness; FD = Fearless dominance; SCI = Self-centered Impulsivity; CT = Computer Task; SY = Social-Yawning Task; VT = Vigilance Task.*

\* $p < 0.05$ , \*\* $p < 0.001$

Meanness only correlated with yawning frequency in the Computer Task,  $r = -0.296$ ,  $p = 0.002$ , and Social-Yawning task,  $r = -0.293$ ,  $p = 0.002$ . In addition, Meanness correlated with all model variables except caffeine. This was not the case for Disinhibition and Boldness. Table 4 shows a summary of the correlations between the scales of the Tri-PM and model variables. Next, the same step-wise regression procedure was performed with the Meanness subscale in place of the Coldheartedness subscale. The full model did not show Meanness to predict yawning frequency in any yawning condition.

Finally, the results of a comparison of regression coefficients with measure type predicting frequency of yawning in the CT showed a significant difference when using the coefficients in the simplified model (i.e., with measure type as the sole predictor of yawning frequency),  $\beta_{CD} - \beta_{Mean} = -0.672$ ,  $SE_{\beta_{CD} - \beta_{Mean}} = 0.046$ ,  $z = -14.609$ ,  $p < 0.000$ . This suggests there was a reliable difference in the predictability of yawning frequency in the CT before removing the influence of other variables. The same result is seen when using the coefficients from the full model,  $\beta_{CD} - \beta_{Mean} = -1.101$ ,  $SE_{\beta_{CD} - \beta_{Mean}} = 0.152$ ,  $z = -7.24$ ,  $p < 0.000$ . These two measures, the Coldheartedness scale of the PPI-R and the Meanness scale of the Tri-PM, do not appear equally predictive of yawning in the context of our study.

## CHAPTER FOUR

### Discussion

We tested the hypotheses that scores on the PPI-R Coldheartedness scale would negatively predict yawning frequency using a computer stimulus; that Coldheartedness would predict yawning frequency with a human being as the stimulus (SY task); that a human stimulus would potentiate the yawning contagion over and above a computer stimulus; and that a vigilance state would eliminate the yawning response. In only two cases were our hypotheses confirmed. Coldheartedness predicted the frequency of yawning when accounting for sex and caffeine intake, and the vigilance task virtually extinguished yawning in all of our participants. Lastly, our exploratory analysis of the Meanness scale of the Tri-PM as a predictor of yawning frequency indicated that it was not as effective as the Coldheartedness scale at predicting contagious yawning.

#### *Sex Differences and Caffeine*

In line with Gallup and Massen's (2016) conclusion regarding sex differences in yawning, we found no statistically significant sex difference overall as well as at any level of yawning task in this study. Though females did yawn more often overall, this result was not statistically reliable compared to males (See Table 3). This result is consistent with our previous study, which also found females yawned more yet not statistically reliably so. This result, originally reported by Gallup and Massen (2016) appears to be reliable in our lab after two replications. Notably, sex trended towards significance in the SY task, which may suggest that females are more likely to yawn than

males when a human is the yawning stimulus. This trend was also seen when contagious yawning was a binary outcome (yawn or fail to yawn),  $\beta = 2.527$ ,  $p = 0.082$ . Potential interpretations are limited, and may include sample size as well as the sex of the researcher, who was male. This was not taken into consideration in this study. Massen and colleagues (2012) showed that groups of chimpanzees responded to yawning males more often than yawning females. Both males and females yawned more often, but males responded the most frequently in this study. In addition, our experimental paradigm was designed to habituate participants to the experimental setting in order to increase familiarity. It is possible that female participants were more perceptive or receptive to our attempts. One possible explanation for our results is that while the yawning response was suppressed in all participants because of an actual human stimulus in the experimental setting, the human presence affected females less as a result of greater habituation to the experimental setting as well as the fact that the human was a male.

The effects of caffeine did not appear to significantly affect the yawning response in our tasks, though the trend towards significance in the CT draws suspicion. A more in depth look at the relationship between caffeine and other popular xanthines and contagious yawning may help address whether contagious yawning supersedes the pharmacological sequelae of caffeine intake (e.g. elevated cortisol, ACh), which would theoretically suppress them. This is of importance in the CT specifically because of its tendency to elicit more variance in yawning frequency.

### *Coldheartedness and Yawning Tasks*

The results of two ANOVAs help characterize the distribution of our Coldheartedness scores, which, theoretically, is a normally distributed trait (Lilienfeld

and Widows, 2005). When we compared the extreme scores (quartiles), the differences were significant (Table 4). The same result was seen when using a median split (Table 5). These results provide evidence that our sampling of a normally distributed trait met theoretical expectation. That is, reliable differences between upper and lower groups demonstrates sufficient variation in Coldheartedness scores.

Reliable within-subject differences in task type were also observed in our analysis. Pairwise comparisons between yawning frequency and task-type showed significant differences between the mean yawns for each task (Table 3). The mean yawns elicited by the CT were reliably greater than the mean yawns of the SY task. The mean yawns of the SY task were reliably greater than the mean yawns of the VT. Notably, the interaction between the between-subject split and task-type was significant for both Coldheartedness ANOVAs. Interpretations of the interactions seen in the ANOVAs are limited by the lack of yawning variance in some tasks. The data do show, however, that our computer stimulus reliably elicits a yawning response greater than any other task used in this study. Furthermore, our novel VT met the expectation that it would extinguish yawning next to any other condition.

### *Computer Task*

These current results provided a successful replication of Rundle et al. (2015), where scores on the PPI-R Coldheartedness scale negatively predicted frequency of yawning with a video stimulus of people yawning, smiling, and appearing neutral. Overall, participants in this study yawned more often ( $M = 3.55$ ) regardless of score on the PPI-R compared to our last study ( $M = 2.74$ ; unpublished data from Rundle et al., 2015). This iteration of the study did not include electrophysiological validation of

yawning, but rather video recordings of testing sessions that were scored at a later time. This is the likely contributor to the overall increase in yawning frequency, as the environmental tone of the testing session was altered by eliminating the presence of wires, gel, and preparation time for the participant. Nonetheless, the model still held whether predicting yawning as a binary outcome (yawn vs. fail to yawn) or as a frequency outcome. With the exception of the physiological recording, all environmental conditions were the same as in Rundle et al. (2015) for this study including the video stimulus. Overall, scores on the PPI-R negatively predict frequency of contagiously yawn as well as susceptibility to contagiously yawn in a college sample.

The relatively simple construction of a yawning video stimulus as described by Platek et al. (2005) has proved in our lab to reliably elicit yawning responses. When shown the video stimulus participants were not aware they were being recorded and no other person was in the testing room during this time. In line with Gallup et al., (2016), who showed that actual and implied social presence diminishes the expression of contagious yawning in a lab setting, a higher rate of yawning would be expected in the CT by virtue of the participant watching the video alone. The Social-Yawning condition and the Vigilance Task both involved the presence of the researcher and, thus, would diminish the yawning response. Notably, our prediction was that our Social-Yawning stimulus would elicit more yawns than our Computer Task; however, this prediction was made before the publication of Gallup et al. (2016). Our findings confirm Gallup et al. (2016) as the failure to observe the implied social presence (the camera) during the Computer Task resulted in more yawns than our previous study. As well, the researcher's presence during the SY task resulted in less yawns than hypothesized. In conclusion, if a

social presence is not detected and a video stimulus described by Platek et al. (2005) is used, it appears that contagious yawning can be reliably elicited.

### *Social-Yawning Task*

We hypothesized that the presence of a yawning conspecific would elicit more frequent contagious yawning, as it is a more ecologically valid stimulus. While the SY frequency was elevated above the VT as predicted, it was not comparable to the level occurring in response to the video stimulus. The Coldheartedness subscale did not predict SY induced yawning frequency in our full model, and the SY task was not able to evoke a higher rate of yawning amongst participants compared to the CT task.

One reason that the social stimulus failed to evoke more yawns may be that while familiar humans may indeed elicit more yawns than a video stimulus, participants in a research setting are not likely given enough time to feel a sufficient degree of familiarity with a strange person thus allowing for contagious yawning (Platek et al., 2005). We certainly found this to be true in our study even with effortful attempts to provide a comfortable, relaxed, and familiar environment for the participants. We predict that creating an ecologically valid environment for this condition may similarly prove difficult in future studies.

Gallup et al. (2016) discuss reasons why a social presence may not be as potent a stimulus as initially hypothesized. One possible reason why the Social-Yawning task was not a more potent stimulus than the CT could be due to evidence highlighting the nuances of social interaction. The audience effect in which behaviors are modulated as a result of mere social presence (Zuberbühler, 2008), may likely be extended to dampening the yawning response. Similarly, it has been shown that yawning frequency occurs less in

laboratory settings overall (Baenninger and Greco, 1991). Laboratory effects on yawning had not been formally examined until recently when Gallup et al., (2016) showed that a social presence in the laboratory, implied and actual, significantly dampened the potency of contagious yawning. In Gallup's study, yawns were self-reported less frequently when a researcher was present in the research space compared to being alone in a room, alone with a picture of a person's eyes above the stimulus screen, and with an inactive webcam. Self-reported yawns were only lower than the actual-presence group when an active webcam was presented as the independent variable. Interestingly, Gallup reported the urge (and consequently suppression) to yawn was the highest in the active webcam condition. Thus, participants modified their expressed behavior in the presence of a relatively unfamiliar researcher, despite the urge to yawn.

Our study varies from Gallup et al. (2016) in that all participants were ignorant of the fact that the researcher was recording them at the time of the computer stimulus presentation, as the camera was "hidden" outside of the participants' field of vision. Further, we measured actual yawning responses and not self-reported urges to yawn. In conclusion, the human stimulus was not as potent as the computer video stimulus, and sex of the participant may play a role in determining if they will yawn in an unfamiliar setting or not.

### *Vigilance Task*

Our results showed an average of 0.08 yawns in this condition. Essentially, less than ten of the 117 subjects yawned once. Our results were in line with our hypothesis that inducing a vigilant state would extinguish the yawning contagion in participants regardless of their score on the PPI-R Coldheartedness scale. Standing alone, this

experimental condition may provide a negative control condition during contagious yawning research, as it reliably prevented yawning from occurring in participants regardless of PPI-R score.

Participants were in an active state of vigilance during this condition while the researcher expressed a yawn well within their field of vision. This was accentuated by the audible component of yawning. Still, only a small handful of the participants responded to the yawning stimulus during this attentive state. These results alone support the body of literature that suggests that the perception of emotional stimuli are diminished during an attentive, vigilant state. This appears to be independent of emotional capacity in that our most frequent yawners were unresponsive to the stimuli. It is important to note that our results do not clearly differentiate whether participants were perceptive but not responsive or whether they failed to perceive yawning actions by the researcher at all.

#### *PPI-R vs. TriPM*

The Tri-PM contains three subscales that have been shown to capture the breadth of psychopathy: Meanness, Disinhibition, and Boldness (Patrick et al., 2009; Patrick, 2010). Meanness, which broadly compasses the emotional-behavioral aspects of psychopathy, only correlated with yawning frequency in the CT and SY tasks. This subscale is defined by Patrick et al. (2009) as a constellation of empathic deficits, disdain for and lack of close attachments, rebellious behavior, sensation seeking, empowerment through cruelty, and exploitation of others. The coefficient comparison showed that Coldheartedness from the PPI-R was superior to the Meanness subscale from the Tri-PM in predicting contagious yawning using a computer stimulus.

It is true that Meanness seems to encompass the social-emotional aspect of psychopathy. However, Meanness as a construct also contains elements of dominance and aggression, which have been accounted for by separate constructs in the PPI-R (e.g. Fearless Dominance and Self-Centered Impulsivity). Meanness was highly correlated with Coldheartedness, FD, and SCI, while Disinhibition correlated with SCI, and Boldness correlated with FD and SCI (Table 7). Its broadness, and therefore lack of specificity, as a construct may have alone prevented Meanness from being an appropriate predictor equal to Coldheartedness, which more precisely and narrowly assesses the extraordinarily important affective component of psychopathy. Further, means and standard deviations on the Tri-PM have not been normalized based on age group and sex in a nation-wide sample as they are for the PPI-R. This normalization is helpful as sex groups and age groups have different mean scores (Cale & Lilienfeld, 2002; Lilienfeld & Widows, 2005). Utilizing the Tri-PM requires correcting for sex differences, where the PPI-R provides separate norms for males and females.

For the purposes of predicting contagious yawning, the Tri-PM contains constructs that conceptualize psychopathy too broadly. It is possible that in some instances, the Tri-PM would have specific advantages over the PPI-R. First, it is both shorter and easier to administer to student populations. It requires less time to complete and is less likely to fatigue participants having only 58 total items compared to 154 for the PPI-R. Second, the Tri-PM maintains a phenotypic conceptualization of psychopathy. That is, its three core constructs were derived from simplifying the commonalities between historic behavioral and clinical assessment research (Patrick et al., 2009). Such a conceptualization stands independent of demographic factors and looks towards

dispositional traits found across all psychopathic populations. This is particularly important for psychopathy, as its etiology and expression varies widely by person (Felthous, 2015). Importantly, the Tri-PM is well documented to correlate with other well-established measures of psychopathy including the PPI-R,  $R = .79$  (Patrick, 2010; Blagov, Patrick, Oost, Goodman, & Pugh, 2015). In the end, however, the Meanness subscale of the Tri-PM was insufficiently precise to predict contagious yawning in any present task. This is likely because the trait Coldheartedness, alone, is most closely related to yawning because they are both indices of empathy. Clearly, while it may have usefulness in clinical setting for identifying psychopathic traits, the Tri-PM is not useful in yawning research.

### *Conclusion*

The aim of our study was to revisit the relationship between contagious yawning and psychopathy. In this study, we added two new conditions intended to evoke yawning: a social-yawning condition and a vigilance condition used as a negative control. We found that yawning in response to a yawning video is inversely related to a score on the Coldheartedness subscale of the PPI-R, and, contrary to our prediction, this stimulus is more potent than a human yawning stimulus (Social-Yawning task). The Vigilance Task was so efficacious that it completely inhibited the yawning response in about 97% of participants.

We also assessed the relationship of the subscales of the Tri-PM with contagious yawning and found that the Meanness subscale of the Tri-PM was not comparable to the Coldheartedness subscale of the PPI-R in terms of its ability to predict yawning

frequency. These results contribute to a clearer view to the methodology of contagious yawning and psychopathy research.

One of our limitations was the inability to create an ecologically valid social-yawning stimulus. Perhaps manipulating the nuances of familiarity and contagious yawning may be out of reach for a laboratory setting. In addition, it is not clear whether participants ignored yawns in the VT or if they did not perceive them all together. The sex of the researcher as a yawning stimulus and the potential sex differences in yawning in response to a human stimulus should be considered important variables in future work. Lastly, researchers should not dismiss the utility of the Tri-PM, especially in clinical settings, but merely take away from these results that its constructs are probably too broad for it to be predictive in this research domain.

In summary, these results further establish the relationship between contagious yawning and psychopathic traits. Further research should focus on more complex questions regarding the relationship between interpersonal behavior and contagious yawning. Further, the effects of caffeine on contagious yawning are unclear and warrant investigation. Importantly, these results further support the position that contagious yawning relates to emotional communication and the creation of social bonds in our species.

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