EXPLORING THE RELATIONSHIP BETWEEN PSYCHOPATHIC PERSONALITY TRAITS AND EXECUTIVE FUNCTION TASK ABILITY IN YOUNG ADULTS AND ADULTS GENETICALLY AT-RISK FOR FRONTOTEMPORAL LOBAR DEMENTIA

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ABSTRACT

The construct of impulsivity plays an important role in personality theory, and is related to cognitive processes subsumed under the heading of executive functions. Moreover, a relationship appears to exist such that individual differences in executive function coincide with variations in impulsive personality traits. The prefrontal cortex has been proposed to be the neuroanatomical site which orchestrates the relationship between both personality and higher-order cognition. Psychopathologies and neurological disorders which display high levels of impulsivity and prefrontal cortex dysfunction, such as psychopathy and Frontotemporal Lobar dementia (FTLD), provide support for this suggestion. This thesis reports two studies which further investigate this relationship.

In Study 1, undergraduate students completed the Psychopathic Personality Inventory-Revised (PPI-R) along with three tasks of executive function, the Stroop Task, Attention Networks Task (ANT) and the Iowa Gambling Task (IGT). Hierarchical regression analysis indicates that the PPI-R Factor Score, Self-Centered Impulsivity, significantly predicts inability to implement an advantageous decision making strategy on the IGT. Neither Self-Centered Impulsivity, nor the other PPI-R Factor Score, Fearless Dominance predicted performance on any of the other tasks of executive function.

In Study 2, individuals at familial risk for FTLD who were either symptomatic or asymptomatic for the disease completed the PPI-R, depression and anxiety questionnaires and a battery of tasks measuring attention and executive function. Results indicate that symptomatic individuals perform significantly worse on several measures of executive function than asymptomatic individuals but did not differ significantly with respect to mean levels of psychopathic personality traits. Partial correlational analysis demonstrated a significant negative relationship between Fearless Dominance and response latency on the Stroop task and ANT. Self-Centered

Impulsivity was significantly positively related to total rule violations and negatively related to response time on Trail Making Test B. Fearless Dominance was significantly related to depressive symptoms and trait anxiety.

Taken together, these results partially support the position that individuals with high levels of impulsive personality traits exhibit reduced executive function performance. It also contributes to the growing literature that suggests the factors comprising psychopathic personality relate differently to executive functions.

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DEDICATION

For my parents and teachers.

CO-AUTHORSHIP STATEMENT

For Study 1, Dr. Scott Carlson was involved in the identification and design of the research and suggested data analysis techniques. Data collection and analysis were performed by myself. For Study 2, Dr. Bradley Hallam, Dr. Ian Mackenzie and Dr. Howard Feldman were involved in the identification and design of the research. Dr. Scott Carlson suggested data analysis techniques. Data collection and analysis were performed by myself. The first draft of all chapters in this thesis were written by myself. However, Dr. Scott Carlson has provided considerable feedback throughout subsequent drafts of each chapter.

CHAPTER 1. INTRODUCTION

The construct of impulsivity or disinhibition is ubiquitous in our day-to-day lives. Each of us knows at least one person who repeatedly makes comments or acts without reference to the context or consequences. Furthermore, we have all personally experienced negative repercussions of behaving without regard for those around us or the future implications of our actions. Individual differences in impulsivity are a key component in theories of personality and higher-order cognitive processes involved in executive functions - influencing both who we are and how we control what we do. As our knowledge in neuroscience expands, we are also increasingly aware that the prefrontal cortex has a role in both personality and executive function. Given that impulsivity is a key part of what makes us human – from our biology to our "self", understanding the nature of these relationships is an important goal to pursue.

The purpose of the following review is threefold. The first is to outline the relationship between the personality trait of impulsivity and the cognitive domain of executive functions. The second is to discuss the role of the prefrontal cortex in maintaining control of behaviour and its relationship to impulsivity and executive function. The third is to examine these relationships in two etiologically disparate, yet phenotypically similar constructs, psychopathic personality and Frontotemporal Lobar Dementia.

Relationship Between Impulsive Personality Traits and Executive Function

Impulsivity

Regardless of how pragmatic we may consider ourselves to be, everyone, on at least one occasion, has behaved in an impulsive manner. Examples of such behaviors include having one drink more than one should, making a major purchase

before consulting one's finances or running a red light in one's car. However, some individuals behave impulsively a much greater proportion of the time than the rest of the population.

Research on impulsivity spans a number of disciplines such as behavioural neuroscience, psychology and economics and has been variously described in the literature as the preference for smaller immediate rewards over larger delayed rewards (Monterossa & Aimslie, 1999); acting on the spur of the moment, lack of planning ability and inability to focus on the task at hand (Patton, Stanford & Barrett, 1995); risk taking and sensation seeking (Zuckerman, Kuhlman, Joireman, Teta & Kraft, 1993) and disregard for future consequences (Moeller, Barratt, Dougherty, Schmitz & Swann, 2001). In an effort to sum up these descriptions into one coherent definition, Moeller and colleagues (2001, p. 1784) characterize impulsivity as "a [biological] predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individual or to others". Implicit in their definition is the idea that impulsivity is an enduring, stable, personality trait. As such, although all of us will likely commit an impulsive act from time to time, individuals who have high trait levels of impulsivity are more likely to behave impulsively more often, and in more varied contexts than individuals who have low levels of this trait.

There is much evidence to support the conceptualization of impulsivity as a personality trait. The construct of impulsivity (or lack of inhibition) figures prominently in all major trait-based taxonomic models of personality. For example, Eysenck's Three-Factor Model of Personality, posits that personality is composed of 3 higher-order factors: Extroversion, Neuroticism and Psychoticism. Factor analysis has found that those items related to behavioural disinhibition load primarily on the factor of Psychoticism, a disposition associated with thought disorder, aggression and antisociality (Eysenck & Eysenck, 1985). Tellegen (1982) also proposed a theory of

personality consisting of three higher order factors: Positive Emotionality, Negative Emotionality and Constraint. While the first two are directly related to mood, Constraint reflects caution, restraint, unwillingness to engage in risky behaviour, and conventionality. Individuals who are low on Constraint are likely to be described as impulsive. The Five-Factor Model of personality (Costa & Macrae, 1992) includes Extroversion and Neuroticism (similar to Eysenck's), Conscientiousness (a measure of constraint), Agreeableness, and Openness to Experience. Costa and Macrae (1992) specifically suggest that impulsiveness is related to the factors Neuroticism and Conscientiousness. Flory et al., (2006) confirm this relationship, demonstrating that impulsivity is strongly negatively related to Conscientiousness and positively related to Neuroticism. Furthermore, impulsivity is negatively related to Agreeableness (Flory et al., 2006).

With respect to psychobiological models of personality, impulsivity is one of the five main factors of Zuckerman's 5-factor Psychobiological model of personality, and is labeled Impulsive Un-socialized Sensation Seeking. This factor has been demonstrated to correlate positively with Eysenck's Psychoticism factor and negatively with the Five-Factor Model's Conscientiousness factor (Zuckerman et al., 1993). In contrast, Cloninger, Svrakic and Przybeck's (1993) Psychobiological theory of character and temperament consists of four personality dimensions which are present early in development and are proposed to be genetically independent and heritable – Novelty Seeking, Harm Avoidance, Reward Dependence and Persistence and three dimensions which mature in adulthood and relate to insight about self-concepts. While none of the four early dimensions correspond to impulsivity directly, characteristics associated with impulsivity are spread across each dimension.

Impulsivity is also one of the two main personality dimensions in Gray's (1987) Reinforcement Sensitivity Theory of personality. According to his theory, there are two basic brain/behavioural systems which respond to punishing and

reinforcing stimuli, the Behavioural Inhibition System (BIS) and the Behavioural Approach or Activational System (BAS). The BIS responds to signals of punishment, non-reward and novelty by inhibiting ongoing behaviour and increasing arousal and attention to the environment. The BAS responds to signals of reward and non-punishment of previously punished behaviour by initiating goal-directed activity and increasing arousal (Gray, 1987; Gray & McNaughton, 2000). Individual differences in the sensitivity of these two systems control the experience of emotion and give rise to the personality dimensions of trait anxiety (via BIS) and impulsivity (via BAS). In Gray's theory, impulsivity is assumed to be sensitive to signals of reward, rather than the tendency to engage in behaviour that occurs without forethought. While Gray's Sensitivity to Punishment (Trait Anxiety; BIS) has been shown to relate to other personality conceptualizations of anxiety such as Eysenck and Eysenck's (1985) and Costa and Macrae's (1992) Neuroticism, Reward Sensitivity (Impulsivity; BAS) does not appear to map on well to any one measure of impulsivity (Caseras, Àvila & Torrubia, 2003; Quilty & Oakman, 2004). As such, it has been suggested by Dawe, Gullo and Loxton (2004) that Gray's Reward Sensitivity is better conceptualized as two independent factors: Reward Sensitivity and Rash Impulsiveness. Reward sensitivity is most closely aligned with Gray's conceptualization of impulsiveness, while Rash Impulsiveness relates to behavioural disinhibition. This factor structure has since been confirmed by Franken and Muris (2005; 2006), indicating that impulsivity is made up of at least two separable dimensions.

The behavioural manifestations of impulsive personality traits are evident early in development. Rothbart and Ahadi (1994) highlight the importance of the development of effortful control with respect to individual regulation of impulsivity. This aspect of temperament is associated with attentional control, and begins to appear by one year of age. As effortful control develops, children are increasingly able to control the focus of their attention and therefore able to inhibit pre-potent

responses (volitional responses that are strongly pulled for or primed by an aspect of a stimulus) such as hitting or taking away a toy from another child. Longitudinal data demonstrate the reliable development of effortful control in children. Kochanska and colleagues (2000) have found that by two and a half years of age, children's performance on tasks of suppression of dominant responses in favour of subdominant responses shows remarkable consistency, which was reliable up to three and a half years of age. Better performance on reaction time tasks in toddlers has also been shown to be related to parent's perceptions of their child being skilled at attentional shifting and focusing, low on impulsivity and ability to tolerate frustration (Gerardi-Caulton, 2000). Effortful control has even been shown to map on to both the Big 3 and Big 5 adult conceptualizations of personality (Ahadi & Rothbart, 1994; Rothbart, Ahadi & Evans, 2000).

Finally, impulsivity figures in a number of conditions and psychopathologies such as: binge eating (bulimia), pathological gambling, suicide, substance abuse, conduct disorder (CD), oppositional defiant disorder (ODD), antisocial personality disorder (ASPD), borderline personality disorder, psychopathy, bipolar disorder and attention deficit hyperactivity disorder (ADHD). However, research indicates that levels of these traits lie on a continuum, ranging from normal to pathological. For example, self-reported impulsivity in normal individuals and individuals with psychopathology appear to differ in degree, rather than kind (Flory et al., 2006). Furthermore, disorders falling under the definition of "externalizing disorders" (Krueger & Tackett, 2003) such as substance use and antisocial behaviour disorders, all exhibit high levels of impulsivity and are regularly co-morbid with one another. Research investigating the heritability of the externalizing disorders demonstrates these disorders share a unitary genetic factor related to low behavioural constraint, which is strongly associated with impulsivity (Krueger et al., 2002; Young, Stallings, Corley, Krauter & Hewitt, 2000; Hicks Krueger, Iacono, McGue & Patrick, 2004).

Impulsivity figures prominently in the conceptualization of personality. Its regulation appears early in development and is related to greater attentional and emotional control. When its levels are too high, it can lead to non-adaptive disturbances in behaviour such as substance abuse and personality disorders, such as psychopathy.

Executive functions

Executive Functions have been defined as higher-order cognitive processes that allow an individual to plan, organize/categorize, problem solve, inhibit responses, hold information on-line, be mentally and behaviourally flexible and monitor one's emotions, thoughts and actions (Strauss, Sherman & Spreen, 2006). As such, they are often thought of as those processes that regulate the most fundamental aspects of being human. Disruptions to executive function may manifest in any number of problems in everyday life, including difficulties in making personally advantageous decisions, adapting to novel situations, resisting distraction, planning and working toward long-term goals and being socially appropriate.

Executive functions have been posited to mediate at least 10 domains of cognition (Spreen, Sherman & Spreen, 2006). These are: initiation, planning and organizing, inhibition, mental set shifting, working memory, mental flexibility, non-perseveration, ability to generate and implement strategies, ability to correct errors or utilize feedback, and attention to detail (Strauss, Sherman & Spreen, 2006). For executive functions to coordinate such diverse aspects of cognition and behaviour, they depend on information derived from numerous inputs. For example, appropriate executive function relies upon lower order cognitive processes such as visual perception, language and memory, immediate environmental information kept on-line in working memory, emotional reactions such as fear or anger, and visceral information such as autonomic nervous system activity or hunger.

While executive functions organize and integrate all of this information, ultimately controlling and regulating behavioural output, they may be conceptualized as more basic (e.g., inhibition and working memory) versus complex (e.g., decision making, utilizing feedback) processes. Three commonly investigated, core executive functions are response inhibition, working memory and mental set shifting (Miyake et al., 2000; Friedman et al., 2008). Response inhibition (resistance to interference/conflict resolution) may be defined as the ability to ignore irrelevant stimuli while inhibiting dominant, automatic, prepotent responses (Miyake et al., 2000; Friedman et al., 2008). An everyday example of response inhibition would be stopping oneself from blurting out an answer in class before the teacher has called on you. Working memory (monitoring/updating) is defined as the ability to hold information on-line in short term memory while monitoring incoming information for relevance to the task at hand and then appropriately updating by replacing old, no longer relevant information with newer, more relevant information (Miyake et al., 2000; Friedman et al., 2008). A real-life example of working memory would be going to the grocery store with a mental list of things to buy and then disregarding each item from memory once you have put it in your basket. Mental set shifting is the ability to flexibly switch back and forth between tasks or mental sets (Miyake et al., 2000; Friedman et al., 2008). Shifting attentional resources between trying to merge in traffic while simultaneously talking on a cell phone would be an everyday example of mental set shifting. Of note, while not considered an executive function per se, selective attentional processes are an important component of all executive functions. Selective attention is defined as the [limited] capacity to highlight the one or two important stimuli or ideas being dealt with, while disregarding competing distractions (Lezak, Howieson & Loring, 2004).

Traditionally, investigators have been concerned with examining the more discrete components of executive function such as response inhibition. However,

more recent research is beginning to examine complex aspects of real world behaviour management such as those concerned with self-advantageous decision making and responding to changing environmental demands. Importantly, these conceptualizations recognize the role emotion plays in cognitive processes. Bechara and colleagues (1994) have posited that self-advantageous decision making is the result of one's ability to use somatic and emotional input from reactions to pleasurable or aversive stimuli in our environment to guide future behaviour. When we are able to learn the probability of expected future rewards via the hedonic and emotional valence of a stimulus, we are able to anticipate the probability of future reward and make the most self-advantageous decisions. For example, obtaining a university degree, which is for the most part, monetarily disadvantageous in the short term, tends to be more advantageous financially in the long term than not attending post-secondary education. Reversal learning is a related construct, defined as the ability to learn that an external stimulus' reward value has changed, and now holds a different, or even opposite reward value than before. This learning mediates the programming and performance of new, self-advantageous behavioural outputs (Rolls, 2004). Ultimately, reversal learning allows an organism to adapt its behaviours advantageously to changing environmental circumstances. For example, it is advantageous to know (and use) the pop machine in the cafeteria because it is likely to both dispense a can of soda and accidentally return your money. However, when it begins to consistently take your money and <u>not</u> dispense your soda, then you should change your strategy and start buying pop from another machine in the building. Laboratory tasks which require decision making based on the learning of contingencies with respect to reward and punishment such as the Iowa Gambling Task or Reversal Learning tasks, have been variously labeled "affective" or "impulsive" decision making tasks (Bechara et al., 1994; Reynolds, Patak & Penfold, 2008). As this review is focused upon the relationship between impulsivity and

executive function, the term "impulsive decision making" will be used henceforth to refer to these types of tasks.

It is generally believed that, like personality traits, executive function abilities vary among individuals. It has been demonstrated that normal, college-age individuals vary in their ability to perform the executive functions: inhibition of pre-potent responses, shifting of mental sets, and monitoring and updating of working memory representations (Miyake et al., 2000). Furthermore, these three executive functions were found to be separable from one another, but also moderately correlated, suggesting both unity and diversity in the postulated executive functions (Miyake et al., 2000). Individual differences in executive functions have also been demonstrated in older, healthy adults (Ettenhofer, Hambrick & Abeles, 2006) and in impulsive decision making tasks such as the Iowa Gabling Task (Suzuki, Hirota, Takasawa & Shigemasu, 2003).

It also appears that executive function ability is highly heritable. A recent investigation by Friedman and colleagues (2008) examined the heritability of inhibition, working memory and mental set shifting (measured as latent variables) in 316 monozygotic and 266 dizygotic twin pairs. Results of this study indicate that these executive functions share a common latent factor which is approximately 99% heritable. Moreover, the diversity between the three components was due primarily to genetic (rather than environmental) influences unique to updating (working memory) and shifting of mental sets, while the variance in inhibiting was almost entirely related to the common executive function factor (Friedman et al., 2008). Coolidge and colleagues (2000) investigated the heritability of ADHD, CD, ODD and executive function deficits in 140 monozygotic and 84 dizygotic twin pairs. Heritability estimates were strong both within (ranging from 61-82%) and between the disorders (77%), suggesting a shared genetic variance in executive function ability across disorders (Coolidge, Thede & Young, 2000). Furthermore, a strong

heritable relationship has been demonstrated between many of the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (Text Revision) (DSM-IV-TR; 2000) Personality Disorders and executive dysfunction (Coolidge, Thede & Jang, 2004).

Executive dysfunction may lead to a number of real world difficulties such as inability to save for long-term investments, difficulty with time management in the workplace, and inability to attend to all factors while driving, resulting in accidents. Not surprisingly, executive dysfunction is a common correlate in both psychopathological and neurological disorders such as schizophrenia (Lewine, Thurston-Snoha & Ardery, 2006), bipolar disorder (Torrent et al., 2006), Huntington's disease (Peinemann et al., 2005) and Parkinson's disease (Muslimovic, Post, Speelman & Schmand, 2005).

The relationship between impulsivity and executive function

It has been posited that there are three overlapping, yet partially dissociable systems that are important to inhibition: attentional, motivational and executive inhibition (Nigg, 2000). Of those three, executive inhibition relates most consistently to the higher order cognitions outlined above as executive function, and to those behaviours that are disrupted by high levels of impulsive personality traits. Executive inhibitions are defined as processes for intentional control or suppression of response in the service of higher order or longer term goals (as opposed to immediate stimulus incentives) (Nigg, 2000). Specifically, executive inhibitions would include executive functions related to inhibition of pre-potent responses, learning to inhibit approach behaviours to immediate rewards in favour of long range rewards, and adapting to changing environmental contingencies.

As such, it appears there is an inverse relationship between impulsivity and executive functions – the latter generally being responsible for controlling the former.

Much research suggests that individuals in the normal population with high levels of impulsive personality traits also exhibit deficits in executive function (Pietrzak, Sprague & Snyder, 2008; Keilp, Sackeim & Mann, 2005; Reynolds, Ortengren, Richards & de Wit, 2006; Spinella, 2004). For example, Pietrzak and colleagues (2008) demonstrated that total scores on the Barratt Impulsiveness Scale (BIS-11) are moderately negatively correlated with performance on tests of planning and impulse control, and response organization (*r* ranged from 0.39-0.42). Consistent with their hypothesis, impulsivity was not associated with executive function tasks which measure problem solving and working memory. This latter finding however, is in contrast to other research demonstrating a positive relationship between deficits in working memory capacity and total BIS-11 scores (Whitney, Jameson & Hinson, 2004). It has also recently been shown that higher total scores on the BIS-11 are related to poorer learning on the Iowa Gambling Task (Davis, Patte, Tweed & Curtis, 2007). Moreover, specific facets of impulsivity appear to map on to specific executive function deficits. For example, Gorlyn and colleagues (2005) demonstrated that inability to inhibit pre-potent responses on a Stop-Signal task was positively related to the Motor Impulsiveness subscale on the BIS-11. Additionally, higher reaction time scores on a conflict resolution task were positively related to the Non-planning Impulsiveness scale of the BIS-11. The Non-planning Impulsiveness scale of the BIS-11 is also significantly negatively associated with total time on a Mazes test, indicating that individuals who score higher on this scale may have difficulties with planning than those with lower scores (Pietrzak, Sprague and Snyder, 2008). Finally, executive function is consistently found to be disrupted in those same psychiatric and neurological disorders which exhibit elevated levels of impulsive personality traits such as ADHD (Coolidge, Thede & Young, 2000), bipolar disorder (Kolur, Reddy, Kandavel & Jain, 2006), substance abuse (Deckel & Hasselbrock, 1996), and DSM-IV-TR Personality Disorders (Coolidge, Thede & Jang, 2004).

Imbalances in the relationship between impulsivity and executive function may lead to problems of regulation and conduct in everyday life, as evinced in a number of pathological neurological and psychological conditions. As such, it is not surprising that individual differences in executive function ability are related to variations in impulsive personality trait levels.

The Prefrontal Cortex and Its Role in Maintaining Control of Behaviour

The frontal lobes have long been considered the area of the human brain responsible for controlling behaviour. The dramatic behavioural and personality change seen in the case of Phineas Gage in 1848 is a well known demonstration. Gage, a well-liked, mild-mannered railroad foreman, exhibited profound changes in personality when an iron rod entered his eye socket and passed through the ventral surface of his frontal lobes. He became an impulsive, excessively gregarious and socially inappropriate individual with a complete inability to plan for the future (Damasio, 1994). Since that time, neurologists and psychologists have been interested in the ways in which the frontal lobes perform complex cognition and regulate behaviour. Numerous studies have investigated the psychological and behavioural changes incurred by individuals who have sustained brain injuries or lesions to the frontal lobes.

<u>What is controlled behaviour and what are the critical elements?</u>

In humans, examples of controlled behaviour include choosing to stay home and finish an assignment rather than going out with friends to a movie, not telling our obnoxious boss what we really think of them, and refraining from racing our car down the road at 130 miles per hour, even though it would be fun. It means that we make decisions to act in ways which will keep us safe and have advantageous long term consequences (not just momentary ones). Cognition, emotion, and self-

awareness are all necessary components in regards to controlling behaviour. Without emotions we would have no affective valence to guide decisions, without the ability to think we could not plan for the future and without awareness of the self as continuous in time – there would be no need to control our behaviour in accordance with long term benefits. This description of behavioural control parallels the role of executive functions described earlier and their inverse relationship with impulsivity.

How does the prefrontal cortex coordinate these elements to control behaviour?

While not nearly as well understood as other areas of the brain (e.g., Primary Visual Cortex), knowledge about how the prefrontal cortex is able to coordinate its efforts is developing at a phenomenal rate. Indeed, we are at a point where we are able to ascribe (for the most part) particular functions to architectonically (structurally similar) defined areas of the prefrontal cortex. One simple and commonly used distinction is between the dorsolateral prefrontal cortex (DLPFC) and the orbitomedial prefrontal cortex (OMPFC).

The DLPFC is located anterior to the premotor cortex and supplementary motor area, extending over the superior and middle frontal gyri of both hemispheres (Diamond, 2002). It is architechtonically related to the hippocampus, and is involved in spatial and conceptual reasoning processes (Mesulam, 2000). The DLPFC is involved in the control and direction of memory, and the monitoring and manipulation of information held on-line (operationalized as working memory). It also mediates attentional control in the top-down guidance and direction of other cognitive processes (Stuss & Levine, 2002). Because the DLPFC is engaged during more abstract, de-contextualized aspects of cognition, executive functions mediated by the DLPFC are sometimes referred to as "Cool" executive functions (Zelazo & Müller, 2002). Recent meta-analyses of neuroimaging studies investigating executive function confirm that the DLPFC is specifically involved in such processes

as working memory (Owen, McMillan, Laird & Bullmore, 2005; Wager & Smith, 2003), extra-dimensional shifting (ie., across perceptual dimensions, such as from shape to colour) (Buschbaum, Greer, Chang, & Berman, 2005) and the inhibition of a pre-potent response in favour of a secondary, less dominant one (e.g., Stroop task and Go/No Go task) (Derrfuss, Brass, Neumann, & von Cramon, 2005). Furthermore, functional neuroimaging studies demonstrate a negative relationship between trait measures of impulsivity, response inhibition performance and level of activation in the DLPFC (Horn, Dolan, Elliott, Deakin & Woodruff, 2003; Asahi, Okamoto, Okada, Yamawaki & Yokota, 2004). For example, Asahi and colleagues (2004) found that scores on the Motor-Impulsiveness scale on the BIS-11 were negatively related to right dorsolateral prefrontal cortex activation during response inhibition trials of a Go/No Go task.

The OMPFC is defined as the area of the cortex comprising the entire ventral surface and wall of the interior surface of each hemisphere of the frontal lobe up until its arbitrary boundary directed inferiorly from the central sulcus to the corpus callosum (Schmahmann & Pandya, 2006). It is comprised of the ventromedial prefrontal cortex and orbital prefrontal cortex (for the purposes of this review, referred together as the Orbitomedial Prefrontal Cortex; OMPFC). The OMPFC is architechtonically related to limbic brain areas such as the amygdala (Mesulam, 2000), and is involved in those functions that can be considered "superordinate" for their role in defining human individuality (Stuss & Levine, 2002). The ability to reflect on one's behaviours through self-evaluation, to make advantageous decisions about future behaviours via emotional input and to reverse previously learned reward and punishment contingencies ("Hot" executive functions; Zelazo & Müller, 2002) are all mediated by the OMPFC. As such, lesions in the OMPFC are consistently linked with inability to regulate social conduct (Beer, Heerey, Keltner, Scabini & Knight, 2003; Aron, Melinat, Aron, Vallone & Bator, 1997). Furthermore, these individuals

tend to make poor decisions in their approach to problem solving with respect to both real life (Heilman & Valenstein, 2003) and decision making laboratory tasks such as the Iowa Gambling Task (Bechara, 2004). Finally, evidence suggests that the OMPFC plays a major role in reversal learning (Clark, Cools & Robbins, 2004). This suggests that damage to the OMPFC would affect an individual's ability to evaluate and utilize information regarding changing environmental contingencies to help regulate their behaviour. Indeed, research suggests that individuals with lesions to the ventral prefrontal cortex not only perform poorly on experimental reversal learning tasks, but are also rated as displaying significant levels of inappropriate social behaviour by an informant (Rolls, Hornack, Wade & McGrath, 1994).

As outlined above, the DLPFC and OMPFC work together to coordinate the maintenance and control of cognition and behaviour. Damage to either or both of these areas can result in significant personality and behavioural disturbances, which can lead to profound individual and interpersonal consequences. For example, Berlin, Rolls and Kischka (2004) found that individuals with lesions of the OMPFC were significantly elevated on a self-report inventory of impulsivity (the BIS-11), demonstrated greater behavioural impulsivity and exhibited deficits in reversal learning tasks. Individuals with damage to the ventromedial prefrontal cortex also demonstrate less guilt and trustworthiness than both normal and brain damaged controls while playing a battery of simple economic games against (a believed) opponent (Krajbich, Adolphs, Tranel, Denburg & Camerer, 2009). Cato and colleagues (2004) have reported on a "modern day Phineas Gage". Prior to sustaining bilateral ventromedial prefrontal cortex damage, this individual held an exemplary academic and military record. Post-injury, his demeanor changed dramatically, both socially and occupationally. He was no longer able to hold a job for any sustained period of time, engaged in three unsuccessful marriages and became estranged from his children. Although he performed at normal levels on

formal tests of executive function (Delis-Kaplan Executive Function System), he committed many more errors than an age and education matched control sample. Early damage to the prefrontal cortex has also been shown to cause lifelong disturbances in personality and conduct. Anderson, Damasio, Tranel and Damasio (2000) discuss two case reports of children who sustained prefrontal cortex damage early in development (prior to 16 months of age). Both cases lead lives which were dominated by impaired decision-making, behavioural dyscontrol, social deficits and impaired executive function performance (Anderson, et al., 2000).

The prefrontal cortex is central to those qualities that make us human: our sense of self/personality and our ability to think about and control our behaviour in order to carry out future, goal-oriented activities. When damage occurs in these areas, it often results in problems related to impulsivity and executive functioning, which in turn lead to social and behavioural deficits.

Syndromes of Disinhibited Personality and Executive Function: The Examples of Psychopathy and Frontotemporal Lobar Dementia

The first two sections of this review aimed to demonstrate the relationship between impulsive personality traits and executive functions, and how the prefrontal cortex underlies their relationship. Furthermore, emphasis was given to the pathological outcomes that arise from dysregulation of this relationship or damage to their neuroanatomical substrate (i.e., psychopathology and neurological disease). While symptoms of these disorders may arise from diverse etiologies, they may also demonstrate a phenotypically similar profile. Exploring the similarities and differences between disorders that share these characteristics will help garner greater understanding of the relationship between levels of impulsivity, executive dysfunction and prefrontal cortex activity. Two conditions which can exhibit similar profiles in terms of impulsivity, executive dysfunction and neuroanatomical

abnormalities of the prefrontal cortex are the personality disorder, psychopathy and the neurodegenerative disorder, Frontotemporal Lobar Dementia (FTLD).

Psychopathic personality

Psychopathy is characterized by a specific constellation of interpersonal, affective and behavioural features which begin early in life and extend throughout adulthood. Interpersonally, psychopaths are described as arrogant, dominant and deceptive; while affectively, they appear glib, unempathic and without remorse. Their behaviour is marked by a lack of planning, impulsivity and often antisocial or criminal activities (Cooke, Michie & Hart, 2006). Interestingly, evidence is quickly accumulating to suggest that the features which underlie psychopathy are dimensional in nature, and that all individuals fall somewhere on the continuum of these traits (Lilienfeld & Andrews, 1996; Patrick, Edens, Poythress, Lilienfeld & Benning, 2006; Blonigen, Carlson, Krueger & Patrick, 2003; Maesschalck, Vertommen & Hooghe, 2002; Edens, Marcus, Lilienfeld & Poythress, 2006).

Research investigating the nature of these features indicates that they can be broken down into two factors[1] (Harpur, Hakstian, & Hare, 1988; Lilienfeld & Andrews, 1996; Benning, Patrick, Hicks, Blonigen & Krueger, 2003; Patrick et al., 2006). The first factor (Fearless Dominance) relates to the interpersonal and affective features described above, while the second factor (Self-centered Impulsivity) relates to the antisocial and impulsive behaviours which dominate psychopath's lives[2]. Importantly, this factor structure has been demonstrated in both incarcerated samples using the Psychopathy Checklist Revised (PCL-R; Hare 1991a) and in community samples using the Psychopathic Personality Inventory (PPI; Lilienfeld &

[1] Both 3 and 4 factor models of psychopathy have been proposed (Cooke, Michie & Hart, 2006; Hare & Neumann, 2006), however research on their validity is still in its infancy.

[2] For sake of consistency, psychopathy factors will be referred to by the names outlined in the PPI-R manual: Fearless Dominance and Self-Centered Impulsivity (Lilienfeld & Widows, 2005).

Andrews, 1996; Benning et al., 2003; Patrick, Edens, Poythress, Lilienfeld & Benning, 2006). However, it is unclear as to what extent the two factors are related to one another. For example, depending on whether these traits are assessed using an interviewer (PCL-R) versus self-report (PPI) assessment tool, the strength of the relationship between the two traits varies. Using the PCL-R, a moderate positive relationship exists; however, using the PPI, little to no relationship appears to exist (Hare, 1991; Benning et al., 2003).

As mentioned above, impulsivity is a hallmark of psychopathy, and figures prominently in numerous conceptualizations of the disorder (Hare & Neumann, 2006; Fowles & Dindo, 2006; Lilienfeld & Fowler, 2006; Patrick & Bernat, 2009). Research investigating the relationship between the construct of psychopathy and general theories of personality confirms impulsivity's role in psychopathy. For example, Benning et al.'s study (2003) found that Tellegen's higher-order factor of Constraint negatively predicted scores on the Self-Centered Impulsivity factor of the PPI. A more recent study investigating the psychopathic personality traits and their relationship to the Five-Factor Model of Personality demonstrated that Self-Centered Impulsivity was significantly positively associated with Neuroticism and significantly negatively associated with Conscientiousness and Agreeableness (Ross, Benning, Patrick, Thompson & Thurston, 2009). These results map on to Costa and Macrae's (1992) original theory regarding the Five-Factor Model and impulsivity (though Costa and Macrae did not predict the relationship with Agreeableness) and confirm the same relationships found by Flory and colleagues (2006) regarding impulsivity and the Five Factor Model. Researchers have also investigated the relationship between Self-Centered Impulsivity and Gray's Reinforcement Sensitivity Theory of personality. Results indicated that Self-Centered Impulsivity is positively associated with "Fun-Seeking" factor of the BAS-scale in Carver and White's (1994) BIS/BAS-Scales (Ross et al., 2009; Uzieblo, Verschuere & Crombez, 2007). Despite the existence of several

well-validated, specific measures of impulsivity such as the Barrett Impulsiveness Scale (BIS-11; Patton et al., 1995) or the I-7 Impulsiveness Questionnaire (Eysenck, Pearson, Easting & Allsop, 1985) only one study to date has investigated the relationship between Self-Centered Impulsivity and impulsivity more generally. In this study, Ray and colleagues (2009) investigated the relationship between factors on the UPPS impulsive behavior scale (Whiteside & Lynam, 2001) and the two PPI-R factors, Fearless Dominance and Self-Centered Impulsivity. The UPPS measures four different facets of impulsivity, Urgency, Premeditation (lack of), Perserverance (lack of) and Sensation Seeking. Correlational analysis revealed a significant positive relationship between Self-Centered Impulsivity and all four facets of the UPPS (r ranging from 0.44 - 0.7). Fearless Dominance, on the other hand, was only strongly related to one factor, Sensation Seeking (which measures aspects of fearlessness; $r = 0.68$), and weakly positively related to Premeditation (lack of) ($r = 0.23$). Fearless Dominance did not significantly relate to either Urgency or Perserverance (lack of). The results of this study provide strong confirmation for the proposed relationship between the psychopathic personality factor Self-Centered Impulsivity and various facets of the construct, impulsivity.

It has been posited that the impulsivity demonstrated by psychopaths is related to deficient executive function ability, which results in a lack of control over behavioural regulation (Patrick & Bernat, 2009; Sellbom & Verona, 2007; Sadeh & Verona, 2008; Miranda, MacKillop, Meyerson, Justus & Lovallo, 2009). While there is some evidence to support this assertion, research findings have been inconsistent. For example, Pham, Vanderstukken, Philippot and Vanderlinden (2003) found that incarcerated individuals diagnosed with psychopathy using the PCL-R exhibited significant executive function deficits such as increased qualitative errors on Porteus Mazes, increased errors on a cancellation task and increased planning errors on the Tower of London task, compared to inmates who did not meet criteria for

psychopathy. In addition, a recent study found that psychopaths performed significantly worse on a task of verbal ability when executive demands were high, but not low (Suchy & Kosson, 2006). A meta-analysis conducted by Morgan and Lilienfeld (2000), demonstrates that individuals with a history of antisocial behaviour show medium effect size deficits when compared on six reasonably well validated measures of executive function. However, other studies have not found a relationship between deficits on tasks of executive function and psychopathy (Hart, Forth & Hare, 1990; Hare, 1984). Research investigating the relationship between psychopathy and impulsive decision making using tasks such as the Iowa Gambling task suggests that individuals with psychopathy have deficits in their ability to learn which decks are monetarily advantageous and which ones are disadvantageous (Mitchell, Colledge, Leonard & Blair, 2002), though others have not found such deficits (Lösel & Schmucker, 2004). These individuals have also been found to perform significantly poorer than individuals without psychopathy on simple reward-based reversal learning paradigms (Mitchell et al., 2002; Blair et al., 2006).

Recent theories regarding the etiology of psychopathy (Fowles & Dindo, 2006; Patrick & Bernat, 2009) suggest that the two factors which underlie psychopathic traits are likely the result of impairment in two different neuroanatomical systems. Specifically, Patrick & Bernat (2009) have put forth the "Two Process Theory" which suggests that traits related to Fearless Dominance are the result of under-reactivity in the brain's core fear processing system (e.g., amygdala and associated structures of the limbic system); meanwhile, impairments in frontal-cortical circuits which mediate planning, inhibition and reward/punishment contingencies result in high levels of Self-Centered Impulsivity. Research investigating brain abnormalities in psychopaths has demonstrated support for abnormal neuroanatomical structure and/or function in those systems suggested by Patrick and Bernat (2009) (for a review, see Pridmore, Chambers & McArthur, 2006; Weber, Habel, Amunts &

Schneider, 2008 or Yang, Glenn & Raine, 2008). For example, Yang, Raine, Lencz, Bihrle, LaCasse and Colletti (2005) found reduced prefrontal cortex gray matter volume in community-dwelling individuals with psychopathy. A recent fMRI study examining classical fear conditioning in psychopaths and healthy control participants, demonstrated that individuals with psychopathy exhibited reduced activation in the amygdala and very little activation in the orbitalfrontal cortex compared to individuals in the control group (Birbaumer et al., 2005).

The "Two Process Theory" provides a compelling argument as to why a) there appears to be little relationship between the two factors of psychopathy and b) why equivocal findings occur when investigators research executive function ability in psychopaths. If impairment occurs in independent neuroanatomical system then this would explain why only a modest to negligible relationship exists between the two personality factors in psychopathy. Furthermore, this suggests that individuals may vary independently on levels of either trait. Only those who possess high levels of both traits (e.g., impairment in both systems) would be considered "psychopaths". Furthermore, the proposed independent neuroanatomical etiology of each factor predicts differential performance on tasks of executive function. For example, because dysfunction of frontal-cortical circuits is implicated in Self-Centered Impulsivity (and not Fearless Dominance), then only individuals with high levels of these traits would be predicted to perform poorly on these tasks (similar to the research outlined above in previous sections on impulsivity). Furthermore, it has been postulated that individuals who possess high trait levels of Fearless Dominance may even exhibit enhanced executive function abilities due to lower levels of anxiety (via deficiencies in their fear processing system) (Patrick & Bernat, 2009; Hiatt, Schmitt & Newman, 2004; Sadeh & Verona, 2008).

Most research investigating psychopathy and executive function ability has been conducted in incarcerated samples diagnosed as psychopaths using the PCL-R.

Because the PCL-R classifies psychopaths on the basis of cut off scores that do not differentiate between the two factors, someone diagnosed as a psychopath using the PCL-R could possess relatively unequal levels of either trait (e.g., high scores on factor 1 versus factor 2 and vice versa) and still meet criteria for psychopathy. As such, this may explain the equivocal research literature with respect to executive function deficits and psychopathy. Recent research investigating the relationship between each factor and executive function ability is beginning to confirm this hypothesis (Ross, Benning and Adams, 2007; Sadeh & Verona, 2008; Carlson, Thái & McLarnon, 2009; Miranda et al., 2009). For example, Sellbom and Verona (2007) have demonstrated an opposing relationship between Fearless Dominance and Self-Centered Impulsivity such that Fearless Dominance was positively associated with an Executive Function Composite Score while Self-Centered Impulsivity was, as one might predict, negatively associated with the Executive Function Composite Score.

Frontotemporal lobar dementia

Frontotemporal Lobar Dementia is a neurodegenerative disorder that has an insidious onset, and occurs earlier in life than other dementias. In general, the age of onset is between 45-75 years of age, with the mean age being in the 50s (Ratnavalli, Brayne, Dawson & Hodges, 2002). Diagnosis of FTLD is most often based on the Lund-Manchester clinical criteria (Neary et al., 1998) which was formulated by a consensus of specialists in the area of FTLD. In their criteria, they outline three variants of FTLD: frontal, temporal (semantic), and progressive non-fluent aphasia. Each variant has its own unique set of criteria consisting of both core and supportive diagnostic features which include behavioural and physical symptoms, neuropsychological test performance, and brain imaging findings (for a complete list of diagnostic features for each variant, please refer to Neary et al., 1998). In brief, the frontal variant is characterized by early impairment in regulation of personal conduct, early emotional blunting and early loss of insight. The temporal variant is

characterized by progressive, fluent, empty speech and loss of word meaning manifested by impaired naming and comprehension. The third variant, progressive non-fluent aphasia is characterized by non-fluent spontaneous speech related to disturbances in the production or comprehension of grammar and the phonemic structure of words. While the frontal variant is most associated with personality and behavioural changes typical of the disorder, the other two variants may also exhibit similar changes, though at different time points in the disease process (Neary et al., 1998). Approximately 70% of all cases of FTLD are phenotypically expressed as the frontal variant, 15% as the temporal variant and 10% as progressive non-fluent aphasia (Pickering-Brown, 2007).

The clinical syndromes of FTLD can each be associated with any of three major types of histopathology (Trojanowski & Dickson, 2001). FTLD-Tau (FTLD-T) is characterized by symptomatic accumulation of hyperphosphorylated tau protein in the cytoplasm of neurons and glial cells in the frontal and temporal lobes (Buee & Delacourte, 1999). FTLD with taupathies can include cases fulfilling pathological diagnostic criteria for Pick's disease, corticobasal degeneration and progressive supernuclear palsy (Buee & Delacourte, 1999) and are observed in approximately 25% of all cases (Pickering-Brown, 2007). FTLD with Ubiquitinated Inclusions (FTLD-U) is the most common pathology encountered in cases of FTLD, accounting for approximately 60% of all cases (Pickering-Brown, 2007). In the case of FTLD-U, the protein ubiquitin accumulates in spheroid-shaped neuronal inclusions in the superficial layers of the cortex (Zhou, et al., 1998). FTLD-U may present alone or in combination with motor neuron disease or amyotrophic lateral sclerosis (Mackenzie & Feldman, 2002; Hosler et al., 2000). FTLD-lacking distinctive histology is characterized by non-specific changes in neuronal loss, astrogliosis and superficial cortical spongiosis of the frontal and temporal lobes, with variable involvement of sub-cortical and limbic structures (Arnold, Han, Clark, Grossman, & Trojanowski,

2000). This histopathology was once thought to occur in about 15% of all cases. However, since the advent of increasingly precise ubiquitin histochemistry, many cases have been re-assigned as FTLD-U, making FTLD-lacking distinctive histology rarer than previously believed (Mackenzie et al., 2006).

While sporadic cases are common in FTLD, at least 30-40% of all cases appear to be genetic in nature (Sikkink, Rollinson & Pickering-Brown, 2007). Seven chromosomal loci on three different chromosomes have been linked to familial FTLD (Pickering-Brown, 2007). The first to be discovered results from mutations in the microtubule-associated protein (MAPT) gene which codes for tau on chromosome 17q21 (Hutton et al., 1998). This mutation is thought to account for 15-20% of all cases of familial FTLD (Pickering-Brown, 2007). More recently, linkage analysis in the same region on chromosome 17 has uncovered another familial form of FTLD resulting from ubiquitin pathology rather than tauopathy. Inheritance appears to follow an autosomal dominant pattern, though the exact penetrance has not been elucidated at this time (Baker, et al., 2006). FTLD-U has also been found to result from mutations found on chromosome 3 and chromosome 9 (Kumar-Singh & Van Broeckhoven, 2007; Pickering-Brown, 2007). Any of the three clinical phenotypes of FTLD can occur among any of the familial forms of FTLD, though some are more highly associated with one type of mutation versus another (Kumar-Singh & Van Broeckhoven, 2007; Pickering-Brown, 2007). For example, mutations of the PGRN gene produce the frontal variant and progressive non-fluent aphasia phenotypes. Interestingly, both phenotypes may occur within the same family (Snowden, et al., 2006).

First symptoms of the disease tend to reflect personality and behavioural symptoms. For example, individuals may become emotionally cold and self-centered. Their behaviour may also become increasingly disinhibited, and they may begin to make impulsive decisions or actions, including such behaviours as

shoplifting, driving recklessly or physically assaulting others (Passant, Elfgren, Englund & Gustafson, 2005; Boxer & Miller, 2005; Mendez & Cummings, 2003; Mendez, Chen, Shapira & Miller, 2005). They may also lose insight into their social conduct and behaviour, greatly under-evaluating their deficits in these areas (Eslinger et al., 2005). These changes have been referred to in the literature as "acquired sociopathy", being compared to the traits and behaviours expressed by those who possess psychopathic personality traits (Mendez, Chen, Shapira & Miller, 2005).

Cognitively, individuals have difficulties primarily in the area of executive function, with relative preservation of memory and visual spatial functioning (Kramer et al., 2003; Thompson, Stopford, Snowden & Neary, 2006). A recent study by Torralva et al., (2007) indicates that compared to education and age-matched control participants, individuals with early FTLD displayed significant deficits on tasks of attention such as Trails A and executive function such as Letter-Number Sequencing, and total number of categories completed on the Wisconsin Card Sorting task. In addition to these more traditional neuropsychological tasks, individuals with early FTLD also exhibit deficits associated with impulsive decision making on the Iowa Gambling task (Torralva et al., 2007) and reversal learning paradigms (Rahmann, Sahakian, Hodges, Rogers & Robbins, 1999).

As the name would suggest, Frontotemporal Lobar dementia is associated with neuroanatomical destruction of the Frontal and Temporal lobes of the brain. With respect to specific areas of degeneration, studies utilizing structural and functional neuroimaging consistently report degeneration of the ventromedial and posterior orbital frontal cortex, the dorsolateral frontal cortex, the anterior cingulate cortex and the anterior temporal lobes (Rosen, et al., 2002; Perry et al., 2006; Peters et al., 2006; Salmon et al., 2006, Boccardi, et al., 2005; Varrone et al., 2002). Investigation of the relationship between personality and behavioural

changes and neuroanatomy in FTLD is limited. However, research does suggest a positive relationship between orbital prefrontal cortex volume and Agreeableness (Rankin et al., 2004) and amount of blood flow to the orbital prefrontal cortex has been negatively correlated with antisocial behaviours such as stealing and physical assault (Nakano et al., 2006). Given the vast areas of prefrontal and temporal cortex destroyed by this disease, the link between neurodegeneration and cognitive and behavioural change is not surprising.

Tying it together

The similarities between psychopathy and FTLD are apparent. To begin, they share a number of personality characteristics that may be described as impulsive and socially disruptive. Individuals with psychopathy characteristically act on impulse and tend to engage in antisocial behaviours such as stealing, substance abuse and violence. They are also described as superficial, emotionally cold and manipulative. Furthermore, even though they may verbalize that they "know" their actions are morally wrong; they do not appear to have remorse for their actions (Hare & Neumann, 2006). Research also indicates that individuals who develop FTLD may also display traits and behaviours consistent with an "acquired sociopathy". These individuals may also display antisocial acts, poor decision making, lack of remorse and an emotionally cold personality style (Mendez et al., 2005).

Cognitively, individuals with psychopathy and FTLD both display deficits on executive function tasks such as response inhibition (LaPierre, Braun & Hodgins, 1995; Mendez et al., 2005) and error detection (Pham et al., 2003; Thompson et al., 2006). Furthermore, they also exhibit marked deficits in impulsive decision making and the ability to learn simple reward/punishment relationships (Mitchell et al., 2002; Torralva, et al., 2007; Rahmann et al., 1999).

Finally, neuroanatomical investigations in psychopathy and FTLD suggest that structural and functional abnormalities of the prefrontal cortex are present in both disorders (although more clearly pronounced in FTLD) (Raine, Lencz, Birhle, LaCasse & Colletti, 2000; Yang, et al., 2005; Birbaumer et al., 2005; Rosen et al., 2002; Salmon et al., 2006, Varrone et al., 2002; Boccardi, et al., 2005). Given the prefrontal cortex's role in personality and behavioural control, it may be posited that the similarities seen between psychopathy and FTLD are the result of a common dysregulation in the functional neuroanatomical systems which mediate social and behavioural control. Dysfunction in these systems then translates into real world problems of social conduct for these two disorders.

The relationship between psychopathy and Frontotemporal Lobar Dementia can be described in terms of equifinality, a concept borrowed from the developmental psychopathology tradition (Cicchetti & Rogosch, 1994). What is meant by equifinality is that although these two disorders clearly develop through different initial pathways, the end points for both disorders are phenotypically similar in terms of personality, cognition and possibly, the functional neuroanatomical systems that mediate the relationships between more distal etiological factors and their behavioural phenotypes.

Thesis Theme and Objectives/Hypotheses to be Tested

The overall theme of my dissertation is to explore how varying levels of impulsive personality traits relate to executive function ability in two etiologically distinct, but phenotypically similar disorders, psychopathy and FTLD. Currently, research investigating the relationship between impulsive personality traits and executive function ability in both psychopathy and FTLD is in its infancy. Research in the field of psychopathy is only now beginning to examine how the two factors which comprise psychopathy might account for the lack of consistent findings regarding

executive dysfunction in this population. What research that has been conducted appears promising, but more studies are needed to further refine our understanding of how different domains of executive function (e.g., response inhibition, working memory, reward/punishment contingency learning) influence psychopathic personality traits. With respect to FTLD, several studies have been conducted investigating general theories of personality, but none have looked at more specific traits such as impulsivity, or linked cognitive deficits to personality factors.

Given that research on psychopathic personality traits and executive function is in its initial stages, a major objective of my research is to expand our understanding of this topic from a general standpoint, by investigating this relationship in a non-clinical population of individuals without suspected neuroanatomical deficits. From there, I will extend this investigation to individuals who are "at-risk" for abnormalities in brain areas known to mediate executive functions, such as the prefrontal cortex. Specifically, I will first explore the relationship between the two major factors of psychopathy (Fearless Dominance and Self-Centered Impulsivity) and executive function ability in the university population. It is hypothesized that, similar to previous research, these traits will be normally distributed and unrelated to one another (Lilienfeld & Widows, 2005). Furthermore, individuals who possess high trait levels of Self-Centered Impulsivity are predicted to perform poorly on tasks of executive function compared to individuals who do not have high levels of this trait. Individuals with high levels of Fearless Dominance traits <u>may</u> demonstrate enhanced ability on these tasks. This prediction is based on the suggestion that these individuals naturally experience less anxiety and therefore less interference from potential negative affective states during task performance. However, at this time, there is very little empirical research utilizing non-clinical populations that demonstrate this hypothesis. As such, this prediction is much more tentative.

Investigating this phenomenon in a non-clinical population allows us to garner a greater understanding of the relationship between personality and executive function because we will be gathering data from individuals who vary more widely across the continuum of trait levels, compared to what would be seen in incarcerated samples. I will also investigate this same relationship in a population of people who are at-risk to develop FTLD due to a family history of the disease. Because some of these individuals will eventually experience degeneration of the prefrontal cortex, it may be the case that they already have traits or cognitive deficits suggestive of altered prefrontal cortex functioning.

If individuals in the normal population who have higher levels of impulsive personality traits perform poorly on tasks of executive function, and individuals who are genetically at-risk for FTLD perform similarly, it adds strength to the idea that impulsivity and executive function share a common functional neuroanatomical system. Furthermore, it suggests that this system can be dysfunctional because of both normal variations and genetic abnormalities.

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CHAPTER 2. STUDY 1: EXPLORING THE RELATIONSHIP BETWEEN PSYCHOPATHIC PERSONALITY TRAITS AND EXECUTIVE FUNCTION TASK ABILITY IN YOUNG ADULTS[3]

Because psychopaths' lives are characterized by impulsivity and poor decision making, many researchers have sought to understand whether individuals with psychopathy possess deficits in their executive function abilities. Despite keen interest by investigators in the field, it has remained an elusive subject due to the ubiquity of equivocal findings (Hiatt & Newman, 2006). For example, a meta-analysis by Morgan and Lilienfeld (2000) indicated that individuals with antisocial traits exhibit a moderate reduction in executive function abilities; however, many other researchers in the field have not found impairment in this area of cognition (Hart, Forth & Hare, 1990; Hare, 1984; Lösel & Schmucker, 2004; Hiatt, Schmitt & Newman, 2004). One potential reason for equivocal results is the fact that psychopathy itself is also a heterogeneous construct, comprised of two independent personality traits: Fearless Dominance (emotional and interpersonal deficits) and Self-Centered Impulsivity (rebellious and disinhibited behaviour) (Lilienfeld & Andrews, 1996; Benning, Patrick, Hicks, Blonigen & Krueger, 2003). Given that studies are beginning to demonstrate that the two traits differentially relate to a number of variables (Benning et al., 2003; Justus & Finn, 2007), it also suggests that these traits might also differentially relate to executive function ability, offering a possible resolution to previously ambiguous results. Indeed, recent evidence suggests that the two traits exhibit differential relationships with executive function task performance such that Self-Centered Impulsivity appears to predict poor executive function performance, whereas Fearless Dominance is either unrelated or

[3] A version of this chapter is currently being prepared for publication. LaMarre, A. K., & Carlson, S. R. (2009).

enhances performance (Sellbom & Verona, 2007; Sadeh & Verona, 2008; Carlson, Thái & McLarnon, 2009). Given the heterogeneity of processes subsumed under the heading of executive function (for a reference, see Strauss, Sherman & Spreen, 2006) research efforts should focus on clarifying which specific domains of executive function might be affected by psychopathic personality traits.

Psychopathy is often described as a combination of inferred personality traits and socially deviant behaviours which begin early in development and persist throughout the lifespan (Hare & Neumann, 2006). Psychopaths are characterized by a callous, unempathic and manipulative interpersonal-affective style, combined with antisocial and reckless behaviour which includes impulsiveness, a lack of behavioural control and often criminality (Mitchell, Colledge, Leonard & Blair, 2002). While most research on psychopathy has focused on investigating the phenomenon in forensic or clinical samples of individuals, others have argued that the personality traits underlying psychopathy vary in the normal population (Lilienfeld, 1994; Benning et al., 2003; Miller, Lynam, Widiger & Leukefeld, 2001). Empirical evidence appears to support this assertion; research consistently indicates that these traits follow a normal distribution and are dimensional, rather than categorical in nature (Lilienfeld & Andrews, 1996; Patrick, Edens, Poythress, Lilienfeld & Benning, 2006; Blonigen Carlson, Krueger & Patrick, 2003; Maesschalck, Vertommen & Hooghe, 2002; Edens, Marcus, Lilienfeld & Poythress, 2006). As such, increasing importance has been given to studying individual differences in these personality traits in college and community populations.

Theoretical and empirical evidence demonstrate that psychopathy is a multidimensional construct (Harpur, Hakstian, & Hare, 1988; Cooke & Michie, 2001; Hare & Neuman, 2006; Benning, et al., 2003). Factor analysis of the "gold-standard" instrument for the assessment of clinical psychopathy, the Psychopathy Checklist (PCL) and its revision (PCL-R; Hare 2003) and a self-report measure of psychopathy

intended for use in the general population, the Psychopathic Personality Inventory (PPI; Lilienfeld & Andrews, 1996) and its revision (PPI-R; Lilienfeld & Widows, 2005) consistently find that psychopathy is underpinned by two distinct factors (Harpur, Hakstian, & Hare, 1988; Lilienfeld & Andrews, 1996; Benning et al., 2003; Patrick, et al., 2006)[4]. The first factor (referred to as Fearless Dominance in the PPI-R) comprises those personality traits related to affective and interpersonal deficits, while the second factor (referred to as Self-Centered Impulsivity in the PPI-R)[5] encompasses the unstable, often socially deviant behaviours engaged in by psychopaths. While investigation of the relationship between the two factors using the PCL-R suggests that they are positively correlated ($r \approx 0.50$; Hare et al., 1990; Harpur, Hakstian & Hare, 1988), analysis of PPI factor structure in community dwelling individuals demonstrates small to negligible correlations between the two dimensions (Benning et al., 2003).

As mentioned above, the relationship between psychopathy and executive function ability has been an important area of research in this field (Hiatt & Newman, 2006). Broadly defined, executive functions are cognitive abilities mediated by the prefrontal cortex of the brain, that allow us to plan, organize, delay gratification and work toward future oriented goals (Lezak, Howieson & Loring, 2006). Unfortunately, inquiry into psychopath's ability on these tasks has produced inconsistent and puzzling results. For example, investigations into psychopaths' ability to focus attention and resist interference by conflicting stimuli suggest that they perform either similarly or better than control participants on such tasks (Hiatt, Schmitt & Newman, 2004; Newman, Schmitt & Voss, 1997). For example, psychopaths have

[4] Both 3 and 4 factor models of psychopathy have been proposed (Cooke, Michie & Hart, 2006; Hare & Neumann, 2006), however research on their validity is still in its infancy.

[5] For sake of consistency, psychopathy factors will be referred to by the names outlined in the PPI-R manual: Fearless Dominance & Self-Centered Impulsivity (Lilienfeld & Widows, 2005).

been shown to exhibit significantly better performance on a picture-word and box Stroop task compared to control participants (Hiatt, Schmitt & Newman, 2004). Similarly, Christianson and colleagues demonstrated that unlike control participants, psychopath's attention is not derailed from attending to the particular details of a slide (e.g., the colour of a woman's coat) when the slide also contains aversive emotional content (Christianson, Forth, Hare, Strachan, Lidberg & Thorell, 1996). Such findings have led to the suggestion that psychopaths have an ability to over-focus their attention on the primary task at hand (Forth & Hare, 1989), while ignoring secondary stimuli. As such, they may be better able to resist interference than non-psychopathic individuals. Similarly, others have not found that psychopaths perform significantly worse than control subjects on tasks of behavioural inhibition such as stop-signal tasks or go/go-no tasks (Arnett, Smith & Newman, 1997; Kiehl, Smith, Hare & Liddle, 2000). However, a recent study by Brazil et al., (2009) using a modified flanker task found that while psychopaths made similar numbers of errors as control subjects, they displayed significantly longer reaction times compared to those of controls which reflects challenged inhibitory control and therefore, a more impulsive response style[6]. In contrast, research indicates that psychopaths display deficits in decision making when they are presented with reward/punishment learning paradigms (Mitchell, et al., 2002; Budhani, Richell & Blair, 2006), though others have not found such deficits (Lösel & Schmucker, 2004). Despite the ubiquity of equivocal results in the research literature, a definitive answer for why these findings occur has yet to be revealed.

Much research on the etiology of psychopathy has largely focused on theorizing and testing the hypothesis that psychopathy is the result of a single,

[6] As impulsive individuals tend to experience greater interference from irrelevant stimuli and need greater cognitive resources to overcome their initial or pre-potent response, this translates into longer reaction times (or more errors if pre-potent responses are allowed to predominate).

underlying biological process such as a deficit in emotional or attentional processing (Lykken, 1957; Patrick, Bradley & Lang, 1993; Jutai & Hare, 1983; Newman & Kosson, 1986). Heterogeneity in findings has often been ascribed to etiologically distinct subtypes, with a primary (driven by long standing personality characteristics) and secondary (behaviorally similar, but etiologically distinct) form of psychopathy (Karpman 1941; 1948 - also see Poythress & Skeem, 2006 for a review). However, more recently, Fowles and Dindo (2006) have put forth the "Dual-Deficit" conceptualization of psychopathy, which suggests that psychopathy is the result of two unrelated factors coming together to produce negative emotional and behavioural outcomes. Their theory is based upon the research indicating that the two factors underlying psychopathy appear to exhibit independent (and often opposite) relationships with other variables (e.g., level of education, income, Verbal IQ, positive and negative emotionality, aggression, anxiety, depression; Benning et al., 2003; Lynam & Derefinko, 2006; Hicks, Markon, Patrick, Krueger & Newman, 2004; Hicks & Patrick, 2006; Falkenbach, et al., 2008).

Patrick and Bernat (2009) have extended Fowles and Dindo's theory to suggest an etiological basis for these discrepancies. The "Two-Process" Theory of Psychopathy (Patrick & Bernat, 2009) suggests that psychopathy is the result of deviations in two distinct neurobiological systems which occur simultaneously in an individual. The authors suggest that psychopaths' deficits in affective and interpersonal function (termed Trait Fearlessness; Patrick & Bernat, 2009) are the result of under-reactivity in the brain's core defensive (fear) system, while their disorganized, impulsive and often antisocial lifestyle (termed Externalizing Vulnerability; Patrick & Bernat, 2009) results from impairments in fronto-cortical systems that mediate anticipation, planfulness and affective/behavioural control. Based on this theory, individuals may possess irregularities in one system or the other and therefore, varying levels of the personality traits associated with each. In

order for psychopathy to occur, individuals would need to possess irregularities in both neurobiological systems.

The "Two-Process" Theory of psychopathy has strong explanatory power for why many studies investigating executive function ability in psychopathy have found equivocal results. If Trait Fearlessness is the result of a deviation in normal limbic system function while Externalizing Vulnerability is the result of frontal lobe deficits, this predicts that only individuals possessing high levels of Externalizing Vulnerability (with or without Trait Fearlessness) will exhibit relatively poorer performance on tasks of executive function than those who do not. For example, investigation of the personality trait impulsivity (one facet of Externalizing Vulnerability, Patrick & Bernat, 2009) indicates that individuals who have high levels of this trait tend to perform poorly on tasks related to behavioural inhibition and decision making in reward/punishment paradigms (Gorlyn, Keilp, Tryon & Mann, 2005; Davis, Patte, Tweed & Curtis, 2007). Furthermore, given that individuals possessing high levels of trait anxiety demonstrate poorer performance on tasks of complex cognition (anagram task) and decision making (Zarantonello, Slaymaker, Johnson & Petzel, 1984; Miu, Heilman & Houser, 2008), individuals who possess elevated levels of Trait Fearlessness may demonstrate enhanced ability to attend to information and resist conflict due to low levels of anxiety (Hicks & Patrick, 2006). As such, inconsistent findings may be the result of using measures which do not make psychometric distinctions between the two factors of psychopathy, thereby combining individuals who possess high levels of one factor or the other, but nevertheless pass the somewhat arbitrary cut-off score of "psychopath".

Given the evidence suggesting psychopathic personality traits vary in the normal population (Patrick & Bernat, 2009; Blonigen et al., 2003; Maesschalck, et al., 2002) and that the two factors are largely dissociable (Benning et al., 2003; Uzieblo, Verschuere, Crombez, 2007; Ross, et al., 2007), research efforts are now

beginning to focus on understanding how individual differences in these two traits relate to many of the research questions which have been previously addressed in clinical samples of individuals with psychopathy. For example, Sellbom and Verona (2007) investigated traditional executive function task performance in a group of college students. Results of the study revealed that higher levels of Fearless Dominance were positively associated with the Executive Function composite score, while Self Centered Impulsivity was negatively correlated with the Executive Function composite score (but only when Fearless Dominance was partialed out) and Flanker task Errors of Commission (Sellbom & Verona, 2007). Ross, Benning and Adams (2007) utilized a self-report measure of executive function (Frontal Systems & Behavior Scale, FrSBE; Grace & Malloy, 2001) to explore possible differential relationships between the PPI Factor Scores. Ross et al., (2007) found that higher scores on Fearless Dominance significantly predicted lower scores on the FrSBE Apathy scale and Executive Control scale, while Self-Centered Impulsivity significantly predicted higher scores on the FrSBE Apathy, Disinhibition and Executive Control scales and on the FrSBE Total Scale (where lower scores equal less dysfunction) (Ross, et al., 2007).

Others have focused on more specific aspects of executive function such as behavioural inhibition, attentional control and impulsive decision making[7]. For

[7] Of the many cognitive processes that fall under the heading of executive function, resistance to interfering stimuli, behavioural disinhibition and impulsive decision-making have been of particular interest to researchers in the field of psychopathy (Hiatt & Newman, 2006; Mitchell, et al. 2002; Arnett, Smith & Newman, 1997; LaPierre, Braun & Hodgins, 1995). Specifically, resistance to interfering stimuli requires an individual to ignore irrelevant distractors while completing a primary task (Hiatt & Newman, 2006). Behavioral disinhibition has been referred to as the ability to inhibit prepotent motor behaviours (Reynolds, Patak & Penfold, 2008) and impulsive decision-making requires an individual to learn to make advantageous decisions about delayed versus immediate or probabilistic versus certain outcomes (Reynolds, Patak & Penfold, 2008). Examples of relevant laboratory tasks would be the Stroop task (resistance to interfering stimuli), flanker task or go/no-go task (behavioural disinhibition) and gambling tasks or delayed discounting tasks (impulsive decision-making).

example, Carlson, Thái and McLarnon (2009) investigated an electrocortical measure, P300 amplitude, in relation to the Rotated Heads task (a complex task dependent on frontally mediated aspects of cognition such as working memory, executive attention allocation and inhibitory control; Begleiter & Porjesz, 1999; Polich, 2007) in a sample of undergraduate students. In line with the "Two Process" theory, they demonstrated an inverse relationship between levels of Self-Centered Impulsivity and P300 amplitude in all three frontal scalp sites examined. Furthermore, evidence of a significant positive relationship between Fearless Dominance and P300 amplitude was demonstrated when the content scales related to Self-centered Impulsivity were entered into the hierarchical regression equation. Sadeh and Verona (2008) explicitly examined the hypothesis that high trait levels of Fearless Dominance are associated with enhanced allocation of attention. Not only did they confirm that high levels of Fearless Dominance are associated with reduced processing of embedded distracter targets irrelevant to the completion of a perceptual load task, Self-Centered Impulsivity was again found to be significantly negatively related to measures of cognitive control.

Cleckley (1941; 1976) argued that poor judgment and failure to learn by experience are core traits exhibited by psychopaths. Reward/punishment based decision making tasks such as the IGT provide a novel way to measure this suggestion in a laboratory setting. For example, Miranda and colleagues (2009) recently investigated the relationship between Fearless Dominance, Self-Centered Impulsivity and Iowa Gambling Task (IGT) performance in individuals with and without a diagnosis of alcohol dependence and/or antisocial personality disorder. They found that Self-Centered Impulsivity mediated the relationship between poor performance on the IGT and alcohol dependence. Furthermore, Fearless Dominance was not related to either performance on the IGT or diagnostic status (Miranda, MacKillop, Meyerson, Justus & Lovallo, 2009). It can be argued that while Miranda

and colleagues examined judgment, by quantifying net advantageous versus disadvantageous deck choice on the IGT, they did not quantify ability to improve one's advantageous response strategy (or "ability to learn from experience"), thereby missing an important aspect of psychopathic personality. As such, this is an important aspect of IGT performance that remains to be addressed with respect to Self-Centered Impulsivity and Fearless Dominance.

Consistent with the "Two-Process" Theory (Patrick & Bernat, 2009), high levels of Fearless Dominance appear to be associated with enhanced attention and executive function, while Self-Centered Impulsivity is associated with reduced behavioural control. Based on this evidence, the following study seeks to address whether Self-Centered Impulsivity and Fearless Dominance (as measured by the Psychopathic Personality Inventory-Revised; Lilienfeld & Widows, 2005) will differentially predict performance on three separate tasks of executive function in a sample of undergraduate students (a population who are presumably in the low to moderate range of the construct). Specifically, we decided to target the executive function domains of inhibition and impulsive decision making due to a) the ubiquity of equivocal results when investigating these domains in psychopathic populations (Hiatt, et al., 2004; Brazil et al., 2009; Mitchell, et al., 2002; Lösel & Schmucker, 2004) and b) a distinction that is made in the literature between impulsive behaviour and impulsive decision making such that impulsive behaviour is thought to relate to the ability to inhibit pre-potent motor behaviours whereas impulsive decision making is related to the ability to make advantageous decisions about delayed versus immediate (or probabilistic versus certain) outcomes (Reynolds et al., 2008).

We selected commonly used and well-established tasks of executive inhibition related to impulsive behaviour (Stroop Task: Interference Trial; Attention Networks Task: Executive Attention Trial) and impulsive decision making (Iowa Gambling Task) to examine this phenomena. Moreover, each of these tasks has been shown to be

significantly related to psychopathic personality traits or to relevant phenotypes (e.g., antisocial traits) in previous studies (Morgan & Lilienfeld, 2000; Hiatt, et al., 2004; Newman et al., 1997; Sellbom & Verona, 2007; Miranda, et al., 2009). However, as these tasks are thought to be mediated by dorsolateral (Derrfuss, Brass, Neumann & von Cramon, 2005; Fan, McCandliss, Fossella, Flombaum & Posner 2005) and orbitomedial (Bechara et al., 1998) aspects of the prefrontal cortex, rather than subcortical limbic structures of the brain, based on the "Two-Process" theory (Patrick & Bernat, 2009), we would expect a differential relationship to exist between performance on these tasks and the two psychopathic personality traits, a finding which has not been demonstrated by specifically examining these tasks together.

As such, we hypothesized that higher levels of Self-Centered Impulsivity (impulsive/antisocial traits) will predict poorer performance on the above three tasks, while higher levels of Fearless Dominance (callous/unemotional traits) will either be unrelated to task performance or potentially facilitate performance on these tasks. If such relationships do exist in the manner hypothesized, this research will lend weight to both the "Two Process" theory of psychopathy proposed by Patrick and Bernat (2009) and to the suggestion that impulsive/antisocial personality traits and executive function are managed by a common neuroanatomical functional system.

Method

Participants

Participants were 134 (96 female) undergraduate students enrolled in Psychology courses at the University of British Columbia. They were recruited via the Department of Psychology's Human Subjects Pool and received two course credits for their participation. In order to be eligible to participate, individuals were at least 18 years of age, fluent in English and had normal vision (with correction). Participants were between 18 and 33 years old, with a mean age of 20.75 (*SD* = 2.96) years.

With respect to ethnicity, 39% of participants were of European descent, 37% were East Asian and 22% were of South Asian, African Canadian or Mixed descent. Eighty two percent were right handed and 53% were native English speakers. All participants provided written informed consent prior to participating. All procedures were approved by the relevant institutional behavioural research ethics board.

Measures

Personality measures. Participants completed the Psychopathic Personality Inventory–Revised (PPI-R), which is a 154 item self report measure of psychopathy (Lilienfeld & Widows, 2005). The PPI-R consists of eight content scales, 7 of which load on to two main orthogonal factors: Fearless Dominance and Self-Centered Impulsivity. A third factor, Coldheartedness is comprised of one content scale, which does not correlate with any of the other content scales. The PPI-R also includes three validity scales to detect positive impression management, malingering and careless or random responding. Individuals whose score was ≥ 45 on the Inconsistent Responding Scale of the PPI-R (indicating a potentially invalid profile) were removed during statistical analyses.

Lilienfeld and Widows (2005) report that the PPI-R has adequate internal consistency based on composite reliability scores ranging from .91 to .93 for the Total and Factors scores in a community/college sample. It also demonstrates good test-retest reliability on the Factor scores ranging from .82 to .95 over an average 20 day period. Construct validation of the PPI-R indicates moderate to high correlations on Content, Factor and Total scores of the PPI-R with other self-report measures of psychopathic personality traits, including Levenson's Self-Report Psychopathy Scale (Levenson, Kiehl & Fitzpatrick, 1995) and Hare's Self Report Psychopathy scale – II (SRP-II;1991). Finally, the two Factor scales of the original PPI display a clear

convergent/discriminant pattern with the two Factor scores of the PCL-R (Lilienfeld & Widows, 2005).

The PPI-R was chosen for use in this study for a number of reasons. To begin, self-report measures are economical both time-wise and financially. In addition, the item content of the PPI was chosen based on its exploratory approach which emphasized including a broad array of potential constructs related to psychopathy, thereby capturing aspects of the construct which may have been missed by measures which are based on specific theories of psychopathy such as the PCL (Lilienfeld & Andrews, 1996).

The PPI-R also avoids problems in the assessment of psychopathic personality traits that other self-report measures have not been able to. For example, some of the most widely used self-report measures used to assess psychopathy such as the Minnesota Multiphasic Personality Inventory- 2 Psychopathic Deviate scale and the California Psychological Inventory Socialization scale do not correlate with one another, suggesting that they do not measure the same construct. Furthermore, when compared to the PCL-R, these other measures do not appear to correlate with PCL-R Factor 1 (Callous/Unemotional traits). Rather, they correlate with Factor 2 (Impulsive Antisociality), suggesting that they are measuring non-specific behavioural deviance rather than psychopathy (Lilienfeld & Fowler, 2006). More recent self-report measures specific to psychopathy such as Hare's SRP-II (1991), and Levenson's Self-Report Psychopathy Scale (Levenson et al., 1995) have been developed for use in non-clinical samples; however, research on their reliability and validity has not been as extensive as that of the PPI. Furthermore, neither of these measures provide separate indexes of lower-order, specific traits of psychopathy such as lack of empathy or fearlessness (Lilienfeld & Fowler, 2006).

In our sample, two participants missed one item when completing the questionnaire. Their score for this item was pro-rated by taking their mean response

for the content scale the item belonged to as recommended by Lilienfeld and Widows (2005). Factor scores were calculated according to Benning et al., (2003) by computing *z*-scores for each of the content scales, summing across these scales to compute factor scores and then sex-correcting the scores. Sex-correction was performed by finding the mean and standard deviation of the factor scores for both males and females and then computing new *z*-scores for each individual's score (depending on their gender). This was done because males and females exhibit differential levels of these traits (Lilienfeld & Widows, 2005; Carlson, et al., 2009) and also because we did not have an even number of males and females in our sample. We chose to use Benning et al.'s (2003) approach to computing factor scores as most researchers who utilize the PPI use this approach (Benning et al., 2003; Selbom & Verona, 2007; Carlson, Thái and McLarnon, 2009). Furthermore, criterion and discriminant validity studies of the PPI also use Benning et al.'s (2003) approach (Falkenbach, Poythress, Falki & Manchak, 2006; Uzieblo, et al., 2007; Patrick et al., 2006).

Inconsistent with Lilienfeld and Widows (2005), the zero-order correlation between the two PPI-R Factor Scores, Self-Centered Impulsivity and Fearless Dominance was significant ($r = 0.18$, $p = 0.05$), suggesting a weak relationship between these constructs in our sample. Cronbach's (1951) alpha was computed in order to ascertain the reliability of the content scales of the PPI-R. Two participants were dropped from these analyses because their scales had been pro-rated due to a missing item. High levels of internal consistency were obtained for the PPI-R Content scales, ranging from $\alpha = 0.739$ (Coldheartedness) to $\alpha = 0.895$ (Social Influence). The internal consistency of the two Factor scores was unable to be computed due to the way in which the Factor Scores were calculated. See Table 2.1 for a complete listing of descriptive statistics and α for the PPI-R Content Scales.

As a way to assess the construct of impulsivity more specifically, participants were also administered the Barratt Impulsiveness Scale-11 (BIS-11; Patton, Stanford & Barratt, 1995), a 30-item self-report measure of impulsivity. Principle components analysis of the items on this measure indicates that impulsivity may be thought of as consisting of three higher-order dimensions: Attentional Impulsiveness (inability to maintain focus on a specific goal or object of interest), Motor Impulsiveness (rapid engagement in action without forethought) and Non-Planning Impulsiveness (lack of planning in the present and poor forethought for the consequences of one's actions) (Patton et al., 1995). Internal consistency of these dimensions is adequate, ranging from α = .59-.74 (Stanford et al., 2009).

Attention networks task. Participants completed the Attention Networks Task (ANT), which is a computerized reaction time task designed to measure three uncorrelated aspects of attention – alerting, orienting and executive control (Fan, McCandliss, Sommer, Raz & Posner, 2002). Alerting is defined as achieving and maintaining a state of high sensitivity to incoming stimuli, orienting is the selection of information from sensory input and executive attention involves the monitoring and resolving of conflict among thoughts, feelings and responses (Posner & Rothbart, 2007). Alerting, orienting and executive attention networks have been shown to be mediated by different neuroanatomical sites (Fan, et al., 2005).

The ANT has been shown to have good test-retest reliability for each aspect of attention, with executive attention having the highest (r = .77) and to show independence between the three aspects of attention (Fan et al., 2002). This was also true of our sample; no significant correlations between any of the three networks were demonstrated (all $p < 0.05$). Twin studies investigating the heritability of the three networks indicate strong heritability for the executive attention network, some for the orienting network and no apparent heritability of the alerting network (Fan, Fossella & Posner, 2001). The ANT was chosen for this study

because it allows for greater precision of measurement than more traditional non-computerized measures of attention and conflict resolution. Reaction time is measured in milliseconds (ms), and tallied by the computer which eliminates experimenter error. In addition, the ANT allows attention to be partialed out three ways, thereby allowing for the examination of executive control (behavioural inhibition), independent of any influence of alerting and orienting.

A session consisted of a 24 trial practice block with feedback given for each trial indicating whether the participant was correct or incorrect. The experimental block consisted of 64 trials with no feedback. The presentation of the trials was in random order. Participants were instructed to focus on a centrally located fixation cross throughout the task and to respond as quickly and accurately as possible. Stimuli were presented using the computer program E-prime V 1.0 on an 18 inch computer monitor. Participants viewed the screen from a distance of 56 cm and responses were collected via two input keys on a Psychology Software Tools, Inc. Deluxe Serial Response Box which sat on their lap. Stimuli consisted of a row of five visually presented arrows pointing either left or right against a white background. The target was the 3rd arrow in the center of the stimuli. This target was flanked on either side by two arrows which were either pointing in the same direction (congruent) or in the opposite direction (incongruent). The participant's task was to identify the direction of the centrally presented arrow by pressing the left-most button if the arrow head pointed left and the right-most button for the arrow head pointed right. A single arrow subtended 8º of visual arc and the contours of adjacent arrows were separated by 0.06º of visual arc. The stimuli (5 arrows) consisted of a total 8.17º of visual arc.

Each trial consisted of five events. First, there was a fixation period of random duration (400-1600 ms). A warning cue was then presented for 100 ms followed by a short (400 ms) fixation period. The target arrow and flanking arrows

were then presented simultaneously. These stimuli were presented until the participant responded (to a maximum of 1700 ms). After participants made their response, the stimuli disappeared immediately and there was a post-target fixation period for a variable duration which was based on the duration of the first fixation and reaction time. After this interval, the next trial began. Each trial lasted 4000 ms. The fixation cross appeared at the center of the screen during the whole trial.

To measure alerting and orienting, there were four warning conditions: no cue, center cue, double cue and spatial cue (16 trials each). For the no-cue trials, participants saw only a fixation cross for 100 ms which does not provide any alerting or orienting cues. For the center-cue trials, participants were shown an asterisk at the location of the fixation cross for 100 ms which alerted them to the upcoming presentation of the target stimuli. For the double-cue trials the time course was the same as for the center-cue trials except there were two warning cues corresponding to two possible target positions, either up or down. It was expected that alerting was involved but that the cue did not give any clues to the location of the target, therefore orienting could not be engaged. For the spatial cue trials, the cue was at the target position and the time course was the same as in the center-cue and double-cue trials. The spatial cues were always valid which means they were displayed at the same locations as the targets. It was expected that both alerting and orienting were involved under this condition. Alerting was calculated by subtracting the mean reaction time of the double cue condition from the mean reaction time of the no cue condition. Orienting was calculated by subtracting the mean reaction time of the center cue condition from the mean reaction time of the spatial cue condition. To measure executive attention, there were two equally probable, randomly sequenced across trials – either a congruent condition where all flanker arrows were the same as the target arrow or the incongruent condition where the flanker arrows pointed in the opposite direction of the target arrow (32 trials

each). Executive attention was calculated by subtracting the mean reaction time of the congruent trials from the mean reaction time of the incongruent trials. Individual cases whose error rate was > 20% on the ANT were removed from statistical analyses.

Colour-word stroop task. Participants were also administered the Colour-Word Stroop task, which is a measure of concentration and resistance to interference (Golden, 1978; Graf, Uttl & Tuokko, 1995). Good performance requires the selective processing of only one visual feature while continuously blocking out the processing of another (Lezak, et al., 2006). In this task, participants are presented with 3 stimulus forms. On the first form, participants are asked to read 80 colour words aloud that are written in black ink, as quickly as they can. The second form requires the participant to name the ink colour of 80 "X"s aloud as quickly as they can. The third trial, also called the interference trial, requires the individual to name the ink colour of 80 colour words, where the ink colour is incongruent to the actual colour word (Lezak, et al., 2006). Difference in time between naming XXX's aloud vs. colour words aloud, written in incongruent ink is used as a measure of resistance to interference. A stopwatch was used to time subjects for each trial.

The Colour-Word Stroop task was chosen for use in this study as it is one of the oldest and most widely used techniques to examine attention and resistance to interference (Strauss, et al., 2006). In addition, it has adequate test-retest reliability (Strauss, et al., 2006) and good construct validity with similar tasks such as the stop-signal task (Miyake et al., 2000) and omission errors on continuous performance tasks (Strauss, et al., 2006). Variations of the Stroop task have been utilized regularly in explorations of cognitive function and psychopathy (Hiatt & Newman, 2006).

Iowa gambling task. Participants completed The Iowa Gambling Task (IGT; Bechara, Damasio, Damasio & Anderson, 1994), which is a measure of impulsive

decision-making (Reynolds, Patak & Penfold, 2008). Participants were presented with four decks of cards (A, B, C, D) on the same computer monitor used during the ANT. From these four decks, they were instructed to pick one card at a time using the computer mouse, and that they may switch from one deck to another, as often as they wish. They were informed that the objective of the game is to win as much money as possible and to avoid losing as much money as possible. They were also informed that some decks of cards are worse than others, and to be able to win the game, they must avoid choosing cards from the "bad" decks. The "bad" decks (A and B) are financially disadvantageous as they give larger payouts, but higher losses, eventually resulting in a net loss of money. The "good" decks (C and D) are financially advantageous because although they give smaller rewards, they also give smaller losses, resulting in a net gain of money. For example, in 10 straight trials, if decks A and B are chosen consistently, participants will lose $250; if decks C and D are consistently chosen, they win $250. Participants completed 100 trials (or 5 "blocks" of 20 trials). They were not told which decks were "good" or "bad".

It has been suggested that externalizing psychopathology is characterized by an apparent failure to learn from experience (i.e., repeated engagement in dangerous behaviours despite awareness of harmful or negative consequences), indicating a possible neuropsychological deficit in action monitoring capacity (Patrick & Bernat, 2009). As such, participant's ability to adopt an advantageous decision making strategy on the IGT was of most interest. In this study, "ability to improve response strategy" (Δ (Good - Bad)) was defined as the difference between the number of "good" decks vs. "bad" decks selected in the final block (Block 5) of trials minus the difference between the number of "good" decks vs. "bad" decks selected in the first block of trials (Block 1). Operationally speaking:

Δ (Good - Bad) = [Block 5 (C + D) – (A + B)] – [Block 1 (C + D) – (A + B)]. The difference score between Block 5 and Block 1 was chosen as several other studies

investigating impulsive personality traits have found that the biggest differences in response choice appear to occur in the final block of the task (Miranda et al., 2009; Sweitzer, Allen & Kaut, 2008; Franken, van Strien, Nijs & Muris, 2008).

The IGT was chosen for use in this study as it has been validated in numerous populations, ranging from healthy adults to individuals with various psychopathologies such as schizophrenia and substance abuse (Suzuki, Hirota, Takasawa & Shigemasu, 2002; Davis et al., 2007; Sevy et al., 2007; Bechara, Dolan & Hindes, 2002). However, most of its validation has been with individuals who suffer from neurological problems such as lesions to the ventromedial prefrontal cortex or FTLD (Bechara et al., 1998; Tranel, Bechara & Denburg, 2002; Torralva et al., 2007).

Control measures.

In order to control for confounds that may potentially influence the relationship between psychopathic personality traits and executive function ability several other measures were administered to participants.

General intelligence. As there is evidence to suggest that intelligence and executive function are correlated with one another (Strauss, et al., 2006) participants were administered the Vocabulary and Block Design subtests of the Weschler Abbreviated Scale of Intelligence (WASI: Psychological Corporation, 1999) in order to control for verbal and perceptual-spatial intellectual ability. Research indicates that the WASI has good internal consistency, test-retest reliability and construct validity (Strauss, et al., 2006). By including these subtests we may be sure that any relationships that exist between psychopathic personality traits and executive function tasks are not merely due to general intelligence.

Because the Vocabulary subtest of the WASI is subject to greater levels of subjective measurement than the Block Design subtest, inter-rater reliability between the four experimenters was calculated in order to discern how reliably the test was scored. In order to calculate this, each experimenter was asked to score the responses on the Vocabulary subtest for ten randomly selected participants. An intra-class correlation indexing the inter-rater reliability between experimenters was $r = 0.94$.

Handedness. Individual differences in brain lateralization may contribute to cognitive task ability (Lezak, Howieson & Loring, 2006). As such, handedness was assessed in participants by having them complete The Edinburgh Inventory (Oldfield, 1970).

Substance use and neurological insult. Past or present substance abuse or previous neurological insult may cause damage to the prefrontal cortex, in turn causing deficits on tasks of executive function. While this relationship is unlikely given that personality traits such as impulsivity usually precede future substance abuse (Slutske et. al., 2002; Tartar et al., 2003) it is important to control for such variables. As such, participants were asked interview questions regarding current and past substance use such as number of years drinking, maximum quantity of alcohol consumed in one sitting and total past year alcohol consumption (frequency x quantity)[8]. Questions regarding alcohol use were taken from the Substance Use Module of the Composite International Diagnostic Interview (Robins, Baber & Cottler, 1987). Previous neurological insult such as concussion, loss of consciousness and seizure was also included in the interview. Because there were no cases with a history of previous neurological insult gauged significant enough to warrant

[8] Participants were also asked to provide information about total past year substance use (frequency x quantity) of other illicit substances such as marijuana, cocaine, amphetamines, heroin, etc. Examination of the correlation between this measure and the executive function tasks did not reveal any significant correlations. As such, it was not included in subsequent analyses.

investigation, this variable was not considered further in any analyses. The substance use questions were all significantly positively correlated with one another (r = 0.458-0.910, $p < 0.01$). As such, in order to simplify analyses and reduce multi-colinearity among these potential control variables, a principal components analysis (PCA) was conducted. A one component solution was found, with an eigenvalue of 5.44, which accounted for 90.23% of the variance. This component correlated 0.996 with total past year consumption (frequency X quantity), 0.936 with maximum alcohol consumption in one sitting and 0.520 with number of years drinking. As such, the scores resulting from this solution were saved and used in subsequent analyses, simply referred to as alcohol use.

Other. In addition, factors such as age, sex and English as a second language (ESL) status were assessed by asking participants to fill out a basic demographic questionnaire.

Procedure.

Participants were tested individually by one of four experimenters who had received extensive training in the administration of the neuropsychological tests, questionnaires and interview methods. Participants were first welcomed to the laboratory, given a short introduction to the study, and then asked to give informed, written consent. The study then proceeded in two stages, and took approximately two hours to complete.

In the first stage, participants completed the tasks of cognitive function: Iowa Gambling task, Attention Network task, Stroop task and the Block Design and Vocabulary subtests of the WASI. The order of these five tasks was counterbalanced across all participants in order to control for order effects.

In the second stage, participants were asked to complete the questionnaires: PPI-R, BIS-11, Edinburgh Handedness Inventory, and a brief demographics

questionnaire. Once again, the order in which the questionnaires were completed was counterbalanced across all subjects. Individuals were then asked short interview questions related to confounding factors. Following this, participants were debriefed regarding the background and hypotheses of the study, and given a written form outlining such details.

Statistical analyses.

Prior to analysis, all data were double entered and verified. Histograms for each variable were visually inspected for departures from non-normality. While several variables' distributions appeared slightly skewed, given that hierarchical regression is fairly robust to departures in normality, it was judged that the degree of skewness was minor and did not warrant transformation. In order to decide which control variables should be included in subsequent hierarchical regression analyses, their relationship with each of the executive function tasks was ascertained. Pearson-product moment bivariate correlations were computed between each of the executive function tasks and Age, Alcohol Use, Post-Cognitive Task Fatigue, Vocabulary and Block Design. Both Age and Block Design were significantly correlated with several of the dependent variables (see Appendix A.1 for these results). In order to ascertain whether Sex or English as a Second Language (ESL) were associated with each of the dependent variables, *t*-tests were computed. Associations between the dependent variables and Handedness and Ethnicity were evaluated using Analysis of Variance (ANOVA) as both of these variables were comprised of three categories (Ethnicity: European, East Asian, Other; Handedness: Right, Left, Non-Lateralized). None of these analyses were significant (all $p > 0.05$; lowest p value = 0.07) (see Appendix A.2, A.3, A.4 and A.5 for these results). As Age and Block Design were the only variables significantly related to the executive function tasks, they were utilized as control variables in subsequent hierarchical regression analyses.

Hierarchical Regressions were used to predict executive function ability from psychopathic personality traits. For each executive function task (IGT, ANT, Stroop), the first block of the regression analyses included the variables Age and Block Design as they were found in previous analyses to be related to performance on several of these tasks. In the second block, the PPI-R Factor Score for Fearless Dominance was entered, and in the third block, the PPI-R Factor Score for Self-Centered Impulsivity was entered as the final predictor in the equation. Hierarchical Regression analyses were also computed to predict executive function task ability from the three factors of the BIS-11[9]. All statistical analyses were conducted using SPSS Version 16.0[10]. Please see Appendix A.6 for additional information regarding tests for violation of regression assumptions and outlier analysis.

Results

Table 2.2 lists the means and standard deviations for demographic variables, PPI-R Factor z-scores, WASI Vocabulary and Block Design and the Executive Function Tasks.

We wanted to examine whether the PPI-R Factor Scores were able to predict executive function task performance. Therefore, a three-step hierarchical regression was conducted for each executive function task[11]. The change in executive function

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[9] No significant regressions were found between the three BIS-11 scales and the laboratory tasks of executive function. Therefore these relationships were not explored further and do not appear in the results or discussion.

[10] Please note *n*'s are not equal to overall group n for a number of analyses. This is due to removal of two outliers (please see Appendix A.6 for information related to outlier analysis) and to the removal of cases whose profile was potentially invalid on the PPI-R or whose error rate was >20% on the ANT.

[11] Given the substantial heteroscedasticity and deviation from normality presented by the residuals which may significantly bias standard errors, all *p*-values and inferences for the regression analyses for Stroop Conflict, ANT Orienting and ANT Executive were determined by re-sampling methods using 2999 re-samples (Andrews & Buchinsky, 2000; Efron & Tibshirani, 1993).

task performance variance accounted for at each step (R^2_{change}), the *F*-ratio for the test of significance for change in variance and the standardized partial regression coefficients (β) from the final model at block three are presented in Table 2.3 for each analysis[12].

With respect to the "ability to improve response strategy" (Δ (Good - Bad)) on the IGT, Age, Block Design and Fearless Dominance were not significant predictors. However, 4.4 % of the variance in Δ (Good - Bad) was explained by Self-Centered Impulsivity ($p = 0.017$) above and beyond the other predictors. Δ (Good - Bad) decreased by 21.6% of a standard deviation for every standard deviation increase in Self-Centered Impulsivity (all other predictors held constant)[13].

Neither Fearless Dominance nor Self-Centered Impulsivity was significantly associated with either of the other executive function tasks. With respect to Stroop Conflict, only Block Design was significantly associated ($p = 0.012$). Stroop Conflict decreased by 22.6% for every standard deviation increase in Block Design score (all other predictors held constant).

Finally, both Age and Block Design were significantly associated with ANT Executive Attention ($p < 0.001$). Thirteen point nine percent of the variance in ANT Executive was explained by Age and Block Design above and beyond the PPI-R Factor Scores. Furthermore, for every standard deviation increase in Age, ANT Executive (ms) increased 16.9% while ANT Executive (ms) decreased by 27.7% for every standard deviation increase in Block Design score ($p = 0.05$ and 0.001, respectively).

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[12] Because this study was focused on investigating the relationship between three specific aspects of executive function, rather than more basic aspects of cognition such as basic visual attention and object perception, specific predictions about ANT Alerting and Orienting were not made. Nevertheless regression analyses were performed on these tasks and are presented in Appendix A.7. None of the predictors were significantly associated with ANT Alerting or ANT Orienting (all $p > 0.05$).

[13] Please see Appendix A.8 and A.9 for descriptive statistics and correlations regarding IGT deck choice and PPI-EF Factor Score.

Discussion

The purpose of this study was to investigate whether psychopathic personality traits predict executive function ability in the domains of resistance to interference, behavioural inhibition and impulsive decision making in a sample of undergraduate students. The results of the study demonstrate that individuals with high levels of the trait Self-Centered Impulsivity perform more poorly on a measure of impulsive decision making, compared to individuals who do not. However, contrary to our hypothesis, there was no evidence that high levels of this trait predicted poorer performance on tasks of resistance to interference and behavioural inhibition. Fearless Dominance did not predict performance on any of the executive function measures.

Psychopathic personality traits and IGT performance

It appears that individuals who possess high levels of Self-Centered Impulsivity demonstrated a reduced ability to improve their response strategy to consistently choose the decks associated with advantageous decision making (i.e., resulted in a net gain of money) versus the decks that were least advantageous. As a result, these individuals were still picking disproportionately from the "bad" decks in the last block of the task, versus individuals lower on this trait. In contrast, Fearless Dominance did not predict performance on the IGT. Though the magnitude of the variance accounted for was modest, this finding is consistent with Miranda and colleagues (2009), who found that high trait levels of Self-Centered Impulsivity in a sample of individuals with alcohol dependence and antisocial personality disorder predicted poor performance on the IGT as measured by the total number of "good" decks vs. "bad" decks chosen over the last three blocks of the task. In their sample, IGT performance declined by 26% for every one standard deviation increase in Self-

Centered Impulsivity. Similar to our study, they found no relationship between Fearless Dominance and IGT performance.

Our findings extend Miranda et al.'s (2009) research in several important ways. To begin, we utilized a non-clinical sample of individuals, rather than a mixed sample of control participants, individuals with alcohol dependence and/or those with alcohol dependence and antisocial personality disorder (ASPD). Because chronic alcohol use is known to damage many areas of the brain, including those important to higher level cognition and adaptive decision making (Matsumoto, 2009; for a review, please see Crews & Boettigger, 2009; Fadda & Rossetti, 1998) and that alcoholism associated with ASPD tends to be more severe and has an earlier onset than alcohol dependence without ASPD (Westermeyer & Thuras, 2005), the results of Miranda et al.'s (2009) study may be confounded by the possible cumulative effects of years of substance abuse. Importantly, our sample was both non-clinical and screened for drug and alcohol abuse. Moreover, we investigated whether substance use was a potential covariate to be included in our analysis (and found that it was not). As such, it is unlikely that the relationship demonstrated between Self-Centered Impulsivity and "ability to improve response strategy" on the IGT was due to the effects of alcohol use on prefrontal brain function.

Another important difference between our study and Miranda et al.'s (2009) is their use of an all male sample, while ours was mostly female. To the best of our knowledge, this is the first study to examine the relationship between psychopathic personality traits and IGT performance in a sample of female participants. This is important as few studies have investigated laboratory measures of executive function and psychopathic personality traits in females (Sellbom & Verona, 2007; Sadeh & Verona, 2008; Carlson, Thái & McLarnon, 2009). Furthermore, it corroborates previous findings that correlates of psychopathic traits are the same for both men and women and is also consistent with the suggestion that psychopathic

personality traits are comparable across the sexes (Cale & Lilienfeld, 2002; Verona & Vitale, 2006).

Finally, compared to Miranda et al. (2009), we tried to characterize the ability to improve one's response strategy, by creating a change score between number of advantageous cards chosen in the last block versus the first block rather than simply quantifying total number of "good" cards vs. "bad" cards chosen. This former approach does not allow one to identify where in the task the individual chose the proportion of their good cards. As failure to learn from experience is one of the sixteen core traits specified by Cleckley (1941; 1976) which characterize those with psychopathy, quantifying "ability to improve response strategy" is important to address with respect to furthering our understanding of psychopathic personality. Based on the results of this study, it appears that a limitation in the ability to adjust behaviour based on experience is exclusively related to the trait Self-Centered Impulsivity, helping to explain mixed findings in previous research investigating psychopathy and impulsive decision making (Lösel & Schmucker, 2004).

Self-Centered Impulsivity has been demonstrated to relate to the broader construct of general impulsivity (Benning et al., 2003; Ross, Benning, Patrick, Thompson & Thurston, 2009; Uzieblo et al., 2007), which is a key aspect of Externalizing Vulnerability (Patrick & Bernat, in press). Poor performance on the IGT has also been shown to be related to elevated levels of impulsive personality traits using several different self-report measures of impulsivity (Davis, Patte, Tweed & Curtis, 2007; Sweitzer, et al., 2008; Franken et al., 2008). For example, Sweitzer and colleagues (2008) demonstrated that individuals with high levels of trait impulsivity perform more poorly on the IGT than individuals with medium and low levels of impulsivity, but only in the final block of the task, where there was a sharp decline by the high impulsive group in number of "good" decks chosen, compared to the medium and low impulsive group. The authors suggested this decline may be

the related to difficulty in sustaining optimal decision making over time (Sweitzer, et al., 2008). Interestingly, the relationship between Self-Centered Impulsivity and "ability to improve response strategy" on the IGT also appears to be driven in the final block of the task in this study, as Self-Centered Impulsivity is significantly correlated with the "good" vs. "bad" deck score only on Block 5 of the task.

One question that is important to ask with respect to these results is whether poor performance by individuals with high levels of Self-Centered Impulsivity relates to a deficiency in modulating behaviour based on experience , or whether they simply exhibit difficulties with reward/punishment decision making in general. This interpretation seems less likely as if this were the case, there would have been a negative correlation between Self-Centered Impulsivity and number of good decks chosen for each block of the task, not just the final block. Finally, while they did not investigate psychopathic personality traits, Franken, van Strien, Nijs and Muris (2008) found that high impulsives perform the same as low impulsives on a basic task of reward/punishment decision making when there is no probabilistic learning component (Rogers Decision Making Task). However, on tasks in which a learning component is incorporated, such as the IGT and a reversal learning task, high impulsives demonstrate performance deficits compared to low impulsives (Franken et al, 2008).

Overall, this finding provides experimental evidence for the real-world decision-making deficits we know are associated with Self-Centered Impulsivity. Previous research indicates that this trait is positively associated with self-reported aggressive traits (Falkenbach et al., 2006), substance abuse, low behavioural constraint (Benning et al., 2003) and socially deviant or criminal behaviour (Benning et al., 2003; Justus & Finn, 2007).

Psychopathic personality traits and stroop task and ANT executive performance

Unfortunately, the predicted negative relationship between Self-Centered Impulsivity and the two other executive function tasks, Stroop Task and ANT Executive did not hold true. Further, Fearless Dominance did not predict performance on any of the tasks. One reason for these results may be due to the fact that Age and total score on Block Design were both significant predictors of performance on ANT Executive. It is important to note that both Age and Block Design have been shown to share common variance with measures of executive functions, and that all three share variance with fluid intelligence more generally (Salthouse, 2009; Salthouse, Atkinson & Berish, 2003; Friedman et al., 2006). In this study, when age is combined with Block Design, together they account for 13.9% of the variance associated with reaction time score on ANT Executive. While regression analysis without inclusion of these factors still does not find Self-Centered Impulsivity to be a significant predictor of performance for either of these tasks, Fearless Dominance does predict ANT Executive performance. When the variance associated with age and Block Design score is removed, it appears that for every one standard deviation increase in Fearless Dominance, reaction time on ANT Executive decreases by 18%. This suggests that by removing the shared variance of Age and Block Design, increasing levels of Fearless Dominance are associated with greater ability to inhibit prepotent motor behaviours.

Another possible reason why the predicted relationships between psychopathic personality traits and task performance were not demonstrated on either the Stroop Task or ANT Executive may have been due to examining each task separately. For example, Sellbom and Verona (2007) investigated the relationship between psychopathic personality traits and several well known tasks of executive function, including the Flanker Task (of which, the ANT is modified version of) and did not find any significant relationships between either Self-Centered Impulsivity or

Fearless Dominance and individual task performance. Rather, significant relationships were only seen once executive function composite scores were created by calculating z scores for each task and then taking the average of these scores. An additional comment with respect to Sellbom and Verona's findings relates to their use of a verbal measure to approximate intelligence in their study design. In our study, Vocabulary scores were not related to any of our dependent measures, while Block Design was significantly predictive of task performance on two out of three tasks. It is possible that had Sellbom and Verona controlled for perceptual-spatial aspects of intelligence, they may not have reached the same conclusions.

Relationship to the "two-process" theory of psychopathy

Our results relating to IGT task performance support the "Two-Process" Theory of psychopathy (Patrick & Bernat, 2009) which suggests that Self-Centered Impulsivity and Fearless Dominance are dissociable traits which have differential and sometimes opposing relationships with other variables, including executive functioning. Indeed, it appears that while Self-Centered Impulsivity is predictive of poor decision making in a reward/punishment experimental paradigm, Fearless Dominance is not. These results also speak to the "Two-Process" Theory's proposed neurobiological bases of each of these traits, which suggest that Self-Centered Impulsivity is the result of impairments in frontal-subcortical circuits while Fearless Dominance results from under-reactivity of the brain's core fear processing system. Through studies of individuals with discrete lesions (Bechara, 2004; Bechara, et al., 1998) and functional imaging studies in healthy control subjects (Northoff et al., 2006) it has been found that performance on the IGT is specifically related to ventromedial prefrontal cortex function (VMPFC). The VMPFC has long been thought to be the brain area of primary importance to behavioural self-regulation and higher-level decision making (Stuss, 2007). Given that those with high levels of Self-

Centered Impulsivity, but not Fearless Dominance performed more poorly on the IGT lends support to the idea that Self-Centered Impulsivity results from deficits in prefrontal cortex function, perhaps specific to the ventromedial aspect of the brain.

Surprisingly, Self-Centered Impulsivity was not related to the tasks which are thought to be mediated by more dorsal aspects of the prefrontal cortex. For example, the interference trial of the Stroop task activates areas of the mid-dorsolateral prefrontal cortex (DLPFC) and the inferior frontal junction (Derrfuss et al., 2005) making it a relatively sensitive task to DLPFC function. In addition, Fan and colleagues (2005) demonstrated that ANT Executive Control was related to activation of the anterior cingulate cortex and the DLPFC. However, our results are consistent with Blair and colleagues (2006), who found that psychopathy was associated with poorer performance on tasks of orbitofrontal cortex function, but was not associated with performance on tasks sensitive to dorsolateral or anterior cingulate cortex activity (Blair et al., 2006). Moreover, while some studies do document deficits in tasks of behavioural inhibition in psychopaths (Brazil et al., 2009; LaPierre, et al., 1995), this appears to be task dependent. Based on a review of the literature on psychopathy and behavioural inhibition, Hiatt and Newman (2006) propose that psychopath's ability to inhibit responses is either the same as, or enhanced, compared to that of controls, except in the context of tasks that have an explicit reward component. This suggests that on more abstract tasks of inhibition that do not elicit any kind of affective or reward seeking element, individuals with psychopathy do not experience cognitive deficits.

Patrick and Bernat (2009) suggest that deviations in frontal-subcortical circuits may be the etiology of the trait Self-Centered Impulsivity, but they do not address which specific circuits might be most likely to be affected. Bonelli and Cummings (2007) outline three behaviourally relevant frontal-subcortical circuits which originate in the prefrontal cortex: the dorsolateral circuit, which mediates

executive functions, the anterior cingulate circuit which is involved in motivation and the orbitofrontal circuit, involved in the integration of limbic and emotional information into appropriate behavioural responses. While purely speculative, it may be that Self-Centered Impulsivity is associated with impairments to the orbitofrontal circuit, rather than the anterior cingulate or dorsolateral circuit. This suggestion fits with the findings of Blair et al. (2006) and with our results which find Self-Centered Impulsivity predicts poor performance on the IGT, but does not predict performance on the two dorsally mediated tasks, Stroop and ANT Executive.

The fact that Fearless Dominance was unrelated to executive function task performance is not surprising when we consider the hypothesized neuroanatomical seat of Fearless Dominance in the "Two-Process" theory of psychopathy. However, a tentative suggestion was made that high trait levels of Fearless Dominance might enhance performance on these tasks, based on the theory that due to low levels of trait anxiety, they are less distracted by negative affect when performing cognitive tasks (Hicks & Patrick, 2006). In line with this suggestion, when we removed Age and Block Design from the regression analysis, we found that Fearless Dominance predicted faster reaction times on ANT Executive. Moreover, other studies have found that Fearless Dominance is positively related to executive function task performance (Sellbom & Verona, 2007; Sadeh & Verona, 2008). Given the overall paucity of research examining the possible differential relationship between psychopathic personality traits and executive function task performance; it will be interesting to see the evolution of our understanding of this aspect of psychopathy as our knowledge grows.

Limitations, implications & future directions

There are several potential limitations to this study. To begin, the majority of our sample was female. As men tend to have higher mean levels of psychopathic

personality traits and externalizing disorders than women (for reviews, see Cale & Lilienfeld, 2002; Verona & Vitale, 2006), it may be that our hypotheses were not confirmed simply due to the fact that psychopathic personality trait levels in our sample were too low based on sex composition of our sample. However, given that the correlates of psychopathic personality traits are largely the same across both sexes (Cale & Lilienfeld, 2002; Verona & Vitale, 2006) and that we sex-corrected the PPI-R factor scores in order to statistically account for mean differences in trait levels this seems unlikely to be the case. Another possible limitation may relate to the use of an undergraduate sample which likely restricted the range of variability in our sample. For example, by using a community sample of individuals, we would have been more likely to have had a more diverse sample with respect to age and general intelligence, factors known to share variance with executive function ability (Salthouse et al., 2003). Despite these limitations an important finding emerges from this study. Individuals with high levels of the personality trait Self-Centered Impulsivity have difficulties with advantageous decision making in a well-validated laboratory task, the IGT. These deficits might be the result of neuroanatomical abnormalities in brain areas, such as the VMPFC which mediate aspects of human behaviour such as self-reflection, decision making and advantageous behavioural strategies (Stuss & Levine, 2002). It will be important to determine whether performance on neuropsychological tasks such as the IGT, translate to real-world problems by examining the relationship between laboratory task performance and risk-taking or antisocial behaviours in individuals who possess high levels of these traits. In addition, this avenue of research should extend to include more heterogeneous samples, including greater numbers of male participants, greater age ranges and individuals from both community, and high risk samples.

Conclusion

The purpose of this study was to investigate the relationship between psychopathic personality traits and three domains of executive function: resistance to interference, behavioural inhibition and impulsive decision making. The results of this study extend previous research (Miranda et al., 2009) by demonstrating that individuals with high levels of the psychopathic personality trait, Self-Centered Impulsivity, demonstrate poor ability to adopt an advantageous decision making strategy. This is the first study to investigate this relationship in an undergraduate sample, mostly comprised of females, broadening the scope of knowledge to a non-clinical sample of individuals. In addition, this finding is consistent with the "Two-Process" theory of psychopathic personality (Patrick & Bernat, 2009) which suggests that Self-Centered Impulsivity will be associated with deficits on impulsive decision-making tasks, while Fearless Dominance will not. In addition, Fearless Dominance was not associated with task performance either. Future investigations should continue to explore the relationship between psychopathic personality traits and various domains of executive function given that equivocal findings from past research may have been due to lack of independent examination of the traits.

Table 2.1

Descriptive Statistics and Cronbach's Alpha For PPI-R Content Scales

PPI-R Content Scale	Mean	Standard Deviation	Number of Items	Cronbach's Alpha (α)
Machiavellian Egocentricity	44.53	8.98	20	0.833
Rebellious Nonconformity	33.82	8.59	16	0.874
Blame Externalization	27.13	7.01	15	0.852
Carefree Nonplanfulness	34.12	7.38	19	0.841
Social Influence	49.86	9.36	18	0.895
Fearlessness	34.04	9.51	14	0.889
Stress Immunity	32.37	7.10	13	0.854
Coldheartedness	30.65	5.73	16	0.739

Note. Fearless Dominance and Self-Centered Impulsivity were calculated by averaging the *z*-scores of the relevant scales and then sex-correcting each score. As such, internal consistency measures are not provided for the Factor scores. Internal consistency was evaluated on the 129 subjects included in the study with valid PPI-R protocols. PPI-R: Psychopathic Personality Inventory-Revised.

Table 2.2

Descriptive Statistics for Demographic Variables, PPI-R Factor Scores and Neuropsychological Tasks

Variable	n	Mean (Standard Deviation)
Age	134	20.75 (2.96)
Year in University	134	2.39 (1.26)
Number of years drinking	132	4.65 (3.72)
Post Cognitive Task Fatigue	134	4.96 (1.95)
Maximum alcohol consumed in one sitting	132	7.24 (7.39)
Total past year alcohol consumption	132	150.80 (220.00)
PPI-R Self-Centered Impulsivity (z score)	129	-0.003 (1.00)
PPI-R Fearless Dominance (z score)	129	-0.002 (1.00)
WASI Vocabulary (raw)	132	60.52 (7.53)
WASI Block Design (raw)	132	55.39 (11.03)
ANT Alerting (ms)	128	28.55 (31.26)
ANT Orienting (ms)	128	44.14 (42.77)
ANT Executive (ms)	128	91.93 (39.68)
Stroop Conflict (ms)	132	27.91 (10.82)
Δ (Good – Bad) (cards)	132	11.89 (12.82)

Note. PPI-R: Psychopathic Personality Inventory-Revised; WASI: Wechsler Adult Intelligence Scale; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task.

Table 2.3

Regression Analyses for Δ (Good – Bad), Stroop Conflict and ANT Executive

Step in Regression Model	ΔR^2	$F\Delta R^2$	*df*	β's in Final Model	*p*-value for β
		Δ (Good – Bad)			
Step 1: Age	0.012	0.797	2, 126	-0.090	0.31
Block Design				0.124	0.169
Step 2: Fearless Dominance	0.013	1.695	1, 125	-0.084	0.35
Step 3: Self-Centered Impulsivity	**0.044**	**5.908***	**1, 124**	**-0.216***	**0.017**
		Stroop Conflict			
Step 1: Age	0.038	2.508	2, 126	-0.005	0.958
Block Design				**-0.226***	**0.012**
Step 2: Fearless Dominance	0.005	0.653	1, 125	0.052	0.566
Step 3: Self-Centered Impulsivity	0.017	2.196	1, 124	0.133	0.141
		ANT Executive			
Step 1: Age	**0.139**	**9.853****	2, 122	**0.169***	**0.050**
Block Design				**-0.277****	**0.001**
Step 2: Fearless Dominance	0.012	1.735	1,121	-0.103	0.241
Step 3: Self-Centered Impulsivity	0.002	0.246	1,120	-0.043	0.621

Note. ΔR^2 is the change in variance accounted relative to the previous step in the regression. By definition ΔR^2 for Step 1 is just R^2 for the predictors at this step. $F\Delta R^2$ is the *F* ratio for the test of significance of the change in variance accounted for with each new step in the regression model. β's are standardized partial regression coefficients from the model fit with all predictors in Step 3. Bold entries indicate a significant effect. Reaction time for ANT is reported from cases with no more than 20% errors on all trials. PPI-R measures are sex-corrected *z*-scores. PPI-R: Psychopathic Personality Inventory-Revised; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task.
*$p \leq 0.05$;
** $p \leq 0.01$

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CHAPTER 3. STUDY 2: PSYCHOPATHIC PERSONALITY TRAITS AND EXECUTIVE FUNCTION IN INDIVIDUALS WITH A FAMILY RISK FOR FRONTOTEMPORAL LOBAR DEMENTIA[14]

Frontotemporal Lobar dementia (FTLD) is a disease characterized by profound personality and behavioural changes. These changes include loss of empathy, insight and interpersonal warmth, emotional blunting and declines in personal and social conduct such as decreased tactfulness and manners, violation of interpersonal space, overtly sexual comments or advances, shoplifting and verbal or physical aggression (Passant, Elfgren, Englund & Gustafson, 2005; Boxer & Miller, 2005; Mendez & Cummings, 2003; Eslinger et al., 2005). Cognitive dysfunction, including poor decision making ability and executive dysfunction are also present in this disorder (Kramer et al., 2003; Torralva et al., 2007). Because these changes resemble many of the emotional, interpersonal and behavioural sequelae of psychopathy, these changes have been referred to in the literature as "acquired sociopathy" (Mendez, Chen, Shapira & Miller, 2005). In relation, a recent study by Rankin and colleagues (2008) found that individuals with FTLD were more likely to be endorsed by clinicians as displaying conduct consistent with psychopathic behaviour compared to individuals with other neurodegenerative or psychiatric disorders. Psychopathy, however, is a heterogeneous construct, thought to reflect two dissociable personality traits: Fearless Dominance (emotional and interpersonal deficits) and Self-Centered Impulsivity (rebellious and disinhibited behaviour) (Lilienfeld & Andrews, 1996; Benning, Patrick, Hicks, Blonigen & Krueger, 2003). Furthermore, several theorists believe these traits are the result of two etiologically unrelated processes which,

[14] A version of this chapter is currently being prepared for publication. LaMarre, A. K., Hallam, B. J., Mackenzie, I. R, & Feldman, H. H. (2009).

when they occur simultaneously, result in psychopathy (Patrick & Bernat, 2009; Fowles & Dindo, 2006). Because these traits are theoretically unrelated, relative levels of each trait predict differences in phenotypic expression of the personality and behavioural sequelae associated with each (Benning et al., 2003; Sellbom & Verona, 2007; Sadeh & Verona, 2008; Carlson, Thái and McLarnon, 2009). Aside from the one study which has investigated clinician-rated psychopathic behaviours in individuals with FTLD, there has been no research conducted investigating the two dissociable dimensions of psychopathic personality in individuals with or at-risk for FTLD, nor how each of these two factors might relate to the personality and behavioural changes seen in FTLD.

FTLD is the second most common cortical degenerative disorder in individuals under the age of 65 (Ratnavalli, Brayne, Dawson & Hodges, 2002). The usual duration of FTLD ranges from 8-11 years (Mendez & Cummings, 2003), although genetic forms such as FTLD-17 tend to have a younger onset and faster course of deterioration (Pasquier & Delacourte, 1998). FTLD is a heterogeneous disorder with three main variants (Neary et al., 1998). The frontal variant, which is most common, accounts for approximately 70% of the phenotypic expression of the disease (Pickering-Brown, 2007). The frontal variant results in disinhibited social conduct, impulsive behaviours and dysexecutive symptoms (Neary et al., 1998). The other two variants are characterized by aphasic syndromes. The temporal variant is associated with the loss of the semantic structure of language, while the progressive non-fluent aphasia variant is characterized by the progressive loss of the grammatical structure of language (Neary et al., 1998). Like many other neurodegenerative diseases, FTLD is a complex, multi-factorial disease. However, vulnerability to FTLD appears to be at least partially genetic, as 30-40% of cases of FTLD have a family history of the disease (Sikkink, Rollinson & Pickering-Brown, 2007).

Investigation of the neuroanatomical staging of FTLD has demonstrated that in its earliest stages, the disease begins with mild atrophy of the orbital and superior medial prefrontal cortex, including the anterior cingulate cortex (Broe et al., 2003). It then moves anterior in the prefrontal cortex and posterior to the temporal pole, inferior temporal cortex, hippocampus and basal ganglia. In the end stages of the disease, there is severe global atrophy of the prefrontal and inferior temporal cortex with further degeneration of the hippocampus and basal ganglia (Broe et al., 2003). These stages are consistent across histopathological subtypes (e.g., FTLD-Tau; FTLD-U) suggesting a common pathway for neurodegeneration in FTLD (Broe et al., 2003; Mann & South, 1993).

As mentioned previously, the earliest signs of disease onset are frequently subtle personality and behavioural changes such as apathy, emotional blunting, disinhibition and loss of personal and social awareness (Boxer & Miller, 2005; Mendez & Cummings, 2003; Passant, Elfgren, Englund, & Gustafson, 2005; Shingawa, Ikeda, Fukuhara, & Tanabe, 2006). These changes are often dramatic, resulting in the dissolution of the individual's former self to the point where partners and families no longer recognize the person they have become. Mendez and colleagues (2005) have likened the changes to "acquired sociopathy" due in large part to the combination of increased disinhibited and impulsive behaviour, along with superficial emotionality and decreased interpersonal warmth and empathy demonstrated by some individuals with FTLD. Interestingly, investigations of informant ratings of patient's personalities pre/post FTLD onset demonstrate significant increases in personality traits important in the conceptualization of psychopathic personality (Cleckley, 1941; 1976; Cooke, Michie & Hart, 2006; Ross, Benning, Patrick, Thompson & Thurston, 2009) such as cold-heartedness and aloofness (Rankin, Baldwin, Pace-Savitsky, Kramer & Miller, 2005), and lower levels of Agreeableness (Rankin et al., 2004) after disease onset. Furthermore, a recent investigation by Rankin and colleagues (2008) explored

aspects of psychopathy related to interpersonal coldness and lack of empathy using the Interpersonal Measure of Psychopathy (IMP) in FTLD patients. This scale consists of 18 behaviours which the observer rates the participant on with respect to degree to which a particular behaviour typified their interaction (e.g., "ignores professional boundaries"). The IMP also has a 32 item checklist of behaviours which could be endorsed if they occurred during the interview (e.g., "patient touched interviewer"). While they did not differ significantly from control subjects with respect to frequency of endorsement of checklist items, individuals with the frontal variant of FTLD were rated higher on the behaviour "perseverated" and "exhibits unusual calmness or ease" (Rankin et al., 2008). This is the first study to systematically investigate psychopathy in individuals with FTLD. However, as mentioned previously, psychopathy is comprised of two, unrelated factors associated with both affective and interpersonal deficits (Fearless Dominance) and impulsive, socially deviant behaviours (Self-centered Impulsivity). As Rankin and colleagues (2008) did not distinguish between these two factors, it is unclear which aspect of psychopathic personality is most strongly related to FTLD.

Cognitively, deficits are thought to occur broadly in the domain of executive function, with relative preservation of episodic memory and visuospatial function (Kramer et al., 2003). However, investigations of this cognitive domain have lead to inconsistent findings. These discrepancies are likely the result of a number of issues, including the lack of application of a single, universally applied diagnostic criteria agreed upon by all research groups, the lumping together of all three clinical variants of the disease as a way to improve small sample sizes and the lack of reporting of disease severity or symptom duration (Wittenberg, et al., 2008). Nevertheless, evidence suggests that subtle deficits in the areas of attention and executive function are present, even in individuals who are experiencing the earliest signs of FTLD. For example, Torralva and colleagues (2007) investigated neuropsychological test

performance in individuals in the early stages of the frontal variant of FTLD (mean clinical dementia rating scale score = 0.62, mean mini-mental status exam score = 27.9). Compared to age and education-matched controls, individuals exhibited significantly poorer performance on traditional tasks of attention and working memory such as Trail Making Test A and Letter-Number Sequencing (Torralva et al., 2007) and on the impulsive decision making task, the Iowa Gambling Task. Furthermore, cognitive deficits may be present in individuals prior to any overt signs of disease onset in individuals with familial forms of FTLD. For example, Geschwind and colleagues (2001) investigated the performance of individuals who were pre-symptomatic, but at-risk for FTLD-17 on standard neuropsychological measures in the domains of executive function, attention, memory, visuospatial skills and language. It was found that individuals who carried the genetic mutation for FTLD-17 performed significantly worse on tasks of attention and executive function compared to family members who did not carry the mutation. Given that the two groups did not differ on memory, language or visuospatial skills, it suggests that the difference between the two groups was likely the result of focal frontal lobe deficit rather than global cognitive deficits (Geschwind, et al., 2001).

Despite significant gains in knowledge made in the past ten years, early identification of FTLD remains clinically challenging. For example, in one study, misrecognition of initial symptoms by a primary health care provider contributed to diagnostic delay (median = 2 years) in 85% of frontal variant patients and 60% of temporal variant patients (Pijnenburg, Gillissen, Jonker & Scheltens, 2004). Early diagnosis of FTLD is complicated by a number of factors, including its early age of onset, mischaracterization of symptoms as psychiatric disorder or other neurodegenerative disorders such as Alzheimer's disease (Wittenberg, et al., 2008), overly restrictive diagnostic criteria which are poorly defined and insensitive to early stages of the disease (Rascovsky et al., 2007), few longitudinal studies, low base

rates of known familial forms in community samples (Gass et al., 2006) and lack of availability of genetic testing (Goldman et al., 2004). Given the emotional, social and economic burdens which arise from this disorder, it is imperative that research efforts focus on the early characterization of this disease.

In order to better characterize the initial stages of FTLD, researchers should focus their attention on individuals at-risk for the disease in addition to individuals who already meet clinical diagnosis for FTLD. Despite many university-based memory and aging centers having large data bases of individuals with a family history of the disease to draw from, there is a paucity of research conducted with this population. Studies in which these individuals are followed longitudinally, prior to any potential symptom-onset is an important area of research that could aide our understanding. In addition to targeting research efforts to high-risk populations, more care should be utilized in choosing measures that might have better sensitivity to detect changes in these individuals. For example, current behavioural and cognitive assessments utilize tools which have been developed to assess fully manifested dementia such as the Clinical Dementia Rating Scale or the Mini-Mental Status Examination (which are also biased towards dementias with a primary symptom of memory loss and visuospatial dysfunction). Investigation of the earliest signs of FTLD should utilize measures that will be able to detect subtle personality and cognitive changes in individuals who, on a surface level, may appear similar to the normal population. Furthermore, choice of measures should also focus on tools that are known to assess areas of early neuroanatomic degeneration in this population.

As such, the purpose of the following study is to extend the results of previous investigations that utilized clinical populations by investigating personality and cognitive changes in individuals from the community who have been recruited for participation due to a history of family risk for FTLD. As these individuals did not

present at a primary-care physician or dementia clinic, these individuals will either be asymptomatic or exhibit symptoms that are arguably at an earlier stage in disease course than those typically utilized in research paradigms. For example, very few studies report mean disease duration for their participants at time of study. In those that do, disease stage of individuals is arguably in the mid to late stage of the disease. For example, Rosen et al's (2004) FTLD cohort's mean disease duration was 6.4 years at time of participation. Furthermore, this may actually be an underestimate of actual duration given that it has been shown that diagnosis of FTLD can take a median time of 2 years before formal diagnosis (Pijnenburg, et al., 2004). We are also extending previous research paradigms by utilizing several computerized cognitive measures in addition to traditional neuropsychological tests of attention and executive function. We believe these may be more sensitive to subtle changes in cognition due to their specificity in patient populations with frontal deficits and greater precision of measurement. Similarly, a self-report measure of psychopathic personality traits which measures both factors of psychopathy was chosen given its a) specificity to personality traits which have been proposed to change over the disease course of FTLD and b) ability to measure individual differences in these traits in the normal population. Given that very few studies have investigated individuals at such an early stage of the disease, alongside our use of novel cognitive and personality trait measures, this study should be considered exploratory in nature. It is our hope that the data obtained from this study will provide us with important information regarding the feasibility of conducting a larger scale study.

Based on previous research that suggests that cognitive dysfunction in the early to middle stages of FTLD is limited to difficulties with tasks of basic attention, various domains of executive function such as working memory, error monitoring, and impulsive decision making (Torralva et al., 2007; Kramer et al., 2003), a comprehensive battery of tasks targeting those areas of cognition was conducted. It

was hypothesized that individuals neurologically diagnosed as symptomatic (displaying at least some FTLD symptomatology) will perform significantly worse on each task of attention and executive function. It is also proposed that individuals who are symptomatic will have significantly higher levels Self-Centered Impulsivity compared to individuals diagnosed as neurologically asymptomatic. This hypothesis is based on the fact that the neuroanatomical systems proposed to be impaired in Self-Centered Impulsivity relate to frontal-subcortical circuits, while limbic structures associated with fear conditioning are thought to be involved in Fearless Dominance (Patrick & Bernat, 2009). As our sample is argued to be at an early stage of disease onset and the earliest areas of degeneration in FTLD tend to be within the orbital and superior medial prefrontal cortical areas with limbic structures being affected later in the disease process (Broe et al., 2003) this hypothesis makes sense. Moreover, on behavioural scales relating to frontal dysfunction such as the Frontal Systems Behaviour Scale (FrSBe; Grace & Malloy, 2001), individuals with FTLD have elevated scores on all three scales: apathy, disinhbition and executive control (Mioshi, Kipps & Hodges, 2009). Interestingly, research suggests that Self-Centered Impulsivity, but not Fearless Dominance is positively associated with all three scales on the FrSBe as well (Ross, Benning & Adams, 2007), further indicating that Self-Centered Impulsivity is likely to be elevated in the symptomatic group.

In addition, as research indicates a differential relationship may exist between the two factors of psychopathic personality traits and performance on attention and executive function tasks (Sellbom & Verona, 2006; Sedah & Verona, 2008; Carlson, et al., 2009), we also chose to examine whether this might be the case in our sample as well. It was believed that individuals with higher levels of Self-Centered Impulsivity will perform significantly worse on these tasks while individuals with higher levels of Fearless Dominance may perform significantly better on these tasks. A similar differential relationship was also proposed for the two factor's relationship

to state and trait anxiety and depressive symptoms (referred to as internalizing symptoms). It was hypothesized that individuals with high levels of Fearless Dominance would exhibit lower levels of internalizing symptoms, while individuals with high levels of Self-Centered Impulsivity would experience higher levels of internalizing symptoms (Hicks & Patrick, 2006; Patrick & Bernat, 2009)[15].

Method

Participants

Participants were 26 (17 female) individuals recruited from twelve families with pathology confirmed FTLD from a large existing database at the Alzheimer's Disease and Related Disorders Clinic at the University of British Columbia. These individuals were recruited as part of a larger, ongoing study investigating the genetic, neuroanatomical and phenotypic expression of individuals who are at-risk for familial forms of Frontotemporal Lobar dementia. Participants were between 22 and 81 years old, with a mean age of 50.35 (*SD* = 10.27) years and mean number of years of education of 14.00 (*SD* = 2.69). All participants were of European decent. Ninety-six percent were right handed and 96% were native English speakers. A provisional diagnosis was provided by three neurologists, who were not provided any information regarding the neuropsychological performance of the participant. Participants were classified as either asymptomatic (no symptoms suggestive of FTLD), clinically symptomatic, not demented (CSND; some symptoms suggestive of FTLD) or affected (meeting Neary criteria for FTLD). Based on these diagnoses, participants were assigned to one of two groups: asymptomatic (*n* = 15) or symptomatic, which combined those with a CSND (*n* = 7) or Affected diagnosis (*n* = 4) in order to increase the *n* to a comparable level with those diagnosed as

[15] These relationships were discussed comprehensively in Chapter 2. Please refer to this chapter for clarification, if needed.

asymptomatic (*n* = 11). All participants provided written informed consent prior to participating. All procedures were approved by the relevant institutional behavioural research ethics board.

Measures

Given the frontal variant of FTLD is the most common phenotypic expression of FTLD (Pickering-Brown, 2007), personality and cognitive measures were chosen to reflect areas of known degeneration in this variant, especially those sensitive to areas which degenerate early on in the disease such as the orbital and superior medial prefrontal cortex and the anterior cingulate cortex (Broe et al., 2003).

Personality measure. Participants completed the Psychopathic Personality Inventory-Revised (PPI-R), which is a 154 item self report measure of psychopathy (Lilienfeld & Widows, 2005). The PPI-R consists of eight content scales, 7 of which load on two main orthogonal factors: Fearless Dominance and Self-Centered Impulsivity. A third factor, Coldheartedness is comprised of one content scale, which does not correlate with any of the other content scales. The PPI-R also includes three validity scales to detect positive impression management, malingering and careless or random responding. Standardization and validation was based on a normative community sample of men and women ranging from age 18-86 matched to 2002 United States census data, undergraduate university students from various universities across the United States, and a sample of male correctional inmates from ages 18-57. As abnormalities in prefrontal cortex function have been posited to play a role in the etiology of psychopathy (Patrick & Bernat, 2009; Pridmore, Chambers & McArthur, 2006), especially the orbitofrontal cortex (Birbaumer, et al., 2005) we

believe this measure will be sensitive to personality characteristics which may be indicative of disease in these individuals.

In our sample, 3 participants missed one item when completing the questionnaire. Their score for this item was pro-rated by taking their mean response for the content scale the item belonged to. Content scales were computed by totaling the raw scores for each item in each scale. Factor scores were then computed by summing the content scale raw scores that belong to each Factor score (as per instructions in Lilienfeld and Widows, 2005). Scores were calculated in this manner so as to be able to compare the scores of our participants to the normative data provided by the PPI-R Professional Manual (Lilienfeld & Widows, 2005).

The zero-order correlation between the two PPI-R Factor Scores, Self-Centered Impulsivity and Fearless Dominance was non-significant (r = -0.03, p > 0.05) similar to Lilienfeld and Widows (2005). Cronbach's (1951) alpha was also computed in order to ascertain the reliability of the content scales which comprise the PPI-R Factor Scores. Three participants were dropped from these analyses because their scales had been pro-rated due to a missing item. High levels of internal consistency were obtained for the PPI-R Scales, ranging from α = 0.71 (Carefree Nonplanfulness) to α = 0.88 (Stress Immunity). The internal consistency of the two Factor scores was α = 0.79 (Self-Centered Impulsivity) and α = 0.92 (Fearless Dominance). Finally, PPI-R data was available for 7 participants from a second time point, approximately one year after the initial assessment. Test-retest reliability was computed for both Factor Scores and the scales comprising the Factor Scores. Test-retest reliability ranges from r = 0.71 (Coldheartedness) to r = 0.96 (Stress Immunity) for the content scales. Test-retest reliability for the Factor Scores was r = 0.93 for Self-Centered Impulsivity and r = 0.94 for Fearless Dominance.

Cognitive measures. As data being used in this study are part of a larger ongoing project, participants were administered a sizeable neuropsychological test battery which included tests selected to assess multiple domains of cognition such as memory, language, visuospatial function, attention and executive function. However, given the specific hypotheses of this study, we restricted our analysis to selected tasks of attention and executive function which may be associated with impulsivity and superficial emotion. Measures presented below were grouped into specific areas of executive function for which they are theoretically thought to assess (Lezak, Howieson & Loring, 2006)[16]. However, given the fact that executive functions (in general) are higher level cognitive processes influenced by multiple sources, these groupings should not be considered definitive.

Attention

California verbal learning test II short form (CVLT-II-SF). In this task (Delis, Kramer, Kaplan & Ober, 2000) participants were asked to recall 9 words from 3 semantic categories (fruits, clothing and tools) over several immediate recall trials, a short delay recall trial and a long delay recall trial. They were also given a semantic prime trial and a forced choice yes/no recognition trial at the end. This task is a measure of verbal/auditory learning and memory (Delis, et al., 2000). The CVLT-II has been shown to demonstrate very good test-retest reliability (Woods et al., 2006). In this study, total number of words recalled on Trial 1 (CVLT 1) was investigated as it may be conceptualized as a measure of immediate auditory attention span (Delis, et al., 2000).

Digits span forward. In this task (Wechsler, 1997a) participants were read aloud strings of digits of varying lengths, starting with 2 to a maximum of 9. The

[16] Please refer to Chapter 1 for further clarification regarding the theoretical and neuroanatomical groupings for these measures

participant's job in the Digits Forward task is to repeat the numbers back to the examiner in the same order presented. Digits forward is considered to be a test of auditory attention (Wechsler, 1997a; Lezak, et al., 2006). Reliability coefficients range from .75-.99 (Iverson, 2001). The participant's longest span which they could accurately recall was chosen as the variable of interest.

Trail making test a. This task requires an individual to draw a line connecting 25 encircled numbers as fast as they can without making mistakes. Trail Making Test A is generally considered a measure of visual attention and psychomotor speed (Mitrushina, Boone, Razani & D' Elia, 2005). Test-retest reliability scores for Trail Making Test A range from adequate to excellent for (r = .46 to .98) (Lezak et al., 2006). The participant's speed of completion of the task was used as the variable of interest.

Monitoring/updating (working memory)

Digits span backward. This task is the same as Digit Span Forward except the participant repeats the digits back to the examiner in the reverse order of presentation (Wechsler, 1997a). Digits Backward is considered a working memory task (Wechsler, 1997a; Lezak, et al., 2006). Reliability coefficients range from .75-.99 (Iverson, 2001). The participant's longest span which they could accurately repeat backwards was chosen as the variable of interest.

Spatial span forward & backward. This test is a non-verbal analogue to Digit Span Forward/Backward, measuring attention and working memory (Wechsler, 1997b). In Spatial Span Forward, the examiner points to a series of blocks on a three-dimensional board and the participant must point to the blocks in the same sequence. In Spatial Span Backward, the participant must complete the sequence of block taps in the reverse order to the one presented by the examiner. Lezak, Howieson and Loring (2006) suggest that the total score for both tasks (forward and

backward) is a more reliable measure of working memory than spatial span backward alone. As such, this score was used as the variable of interest.

Conflict resolution

Resistance to interfering stimuli. The Color-Word Stroop task (Kramer et al., 2003) was chosen for use in this study as it is one of the oldest and most widely used techniques to examine attention and resistance to interfering stimuli (Strauss, Sherman & Spreen, 2006). In addition, it has adequate test-retest reliability (Delis, Kaplan & Kramer, 2001; Dikmen, Heaton, Grant & Temkin, 1999; Graf, Uttl & Tuokko, 1995) and good construct validity with other tasks of conflict resolution such as the stop-signal task (Miyake et al., 2000) and omission errors on continuous performance tasks (Weinstein, Silverstein, Nader & Turnbull, 1999). Increased interference has also been demonstrated in a number of patient groups such as schizophrenia (Moritz, et al., 2002), Huntington's disease (Snowden, Craufurd, Griffiths, Thompson & Neary, 2001) and ADHD (Homack & Riccio, 2004). In addition, the interference trial of the Stroop task activates areas of the mid-dorsolateral prefrontal cortex and the inferior frontal junction (located more inferior and posterior in the DLPFC) (Derrfuss, Brass, Neumann & von Cramon, 2005). As such, the Stroop task is relatively sensitive to DLPFC function. In this task, the variable of interest was the number of incongruent colour words correctly spoken in 60 seconds, defined as Stroop Interference.

Behavioural inhibition. Participants completed the Attention Networks Task (ANT; Fan, McCandliss, Sommer, Raz & Posner, 2002), which is a computerized reaction time task designed to measure three uncorrelated aspects of attention – alerting, orienting and executive attention (Fan, et al., 2002). In this task, participants are seated in front of a computer screen and given a response box. The experimental stimuli consist of a series of 5 black arrows against a white background.

Participants are instructed to press the left most button when the center arrow points to the left and the right most button when the center arrow points to the right. They are instructed to respond to the center arrow only, as quickly and accurately as possible. They are also instructed to keep their attention focused at all times on a fixation cross in the center of the screen in between trials. Based on the participant's reaction time, the three aspects of attention are computed for the participants.

The ANT has been shown to have good test-retest reliability for each aspect of attention, with executive attention having the highest correlation (r = .77) and to show independence between the three aspects of attention (Fan et al., 2002). Furthermore, twin studies investigating the heritability of the three networks indicate strong heritability for the executive attention network, some for the orienting network and no apparent heritability of the alerting network (Fan, Wu, Fossella & Posner, 2001). As executive attention involves the monitoring and resolving of conflict among thoughts, feelings and responses (Posner & Rothbart, 2007) it is therefore the attention network most related to behavioural inhibition. As such, only this aspect of the ANT's three attentional networks was investigated in this study.

The ANT was chosen for this study because it allows for greater precision of measurement than more traditional non-computerized measures of attention and conflict resolution. Reaction time is measured in milliseconds, and tallied by the computer which eliminates experimenter error. Furthermore, Fan, McCandliss, Fossella, Flombaum and Posner (2005) demonstrated that executive control was related to activation of the anterior cingulate cortex and the lateral and ventral prefrontal cortex, important areas of neurodegeneration in early FTLD (Broe et al., 2003). Please refer to Chapter 2, Study 1 for additional details.

Shifting mental set

Wisconsin card sorting test-64 card version. In this task (Kongs, Thompson, Iverson & Heaton, 2000), four stimulus cards are placed in front of the participant, the first having a red triangle on it, the second having two green stars, the third having three yellow crosses and the fourth having four blue circles. Participants are handed a deck of cards with similar designs on it and are told to begin by matching a card from their deck with one of the four stimulus cards. Participants are given no instructions on how to match the cards; rather, they are told each time whether they are correct or incorrect. Based on these responses, the participant must figure out what rule the matching is based on. These rules are colour, form (type of geometric shape) and number (in this order). Once the participant has matched the cards according to the rule 10 times straight, the sorting rule is switched to the next one (i.e., from colour to form). The task continues until the participant has matched all the cards in their deck. The purpose of this task is to assess the ability to form abstract concepts, to shift and maintain set, and to utilize feedback (Mitrushina, Boone, Razani & D'Elia, 2005). While the WCST-64 is the short form of the task and as such, has reduced reliability, scores on this version correlate highly with those on the 128 card WCST (Axelrod, Henry & Woodard, 1992). Total number of perseverative errors was investigated in this study as this is the most common measure used to assess executive function on the WCST (Strauss, et al., 2006).

Delis-kaplan executive function system design fluency test. This test measures novel design generation under time constraints (mental flexibility and monitoring of previous responses) (Delis, et al., 2001). Only condition one is used in this study. In this task, participants are presented with a page that has 35, five dot matrices on it. Participants must make as many different designs as they can in one minute, by connecting the dots using only four straight lines. They must not repeat any designs. The total number of unique designs and rule violations are recorded.

Impairment on this task has been demonstrated in individuals with frontal lobe lesions compared to normal control participants (Baldo, Shimamura, Delis, Kramer & Kaplan, 2001). Total number of unique designs was the variable of interest in this study.

Trail making test b. This task requires the individual to draw a line connecting 25 encircled numbers and letters, switching back and forth as fast as they can without making mistakes. Trail Making Test B is generally considered a measure of mental flexibility (Mitrushina et al., 2005). Test-retest reliability scores for Trail Making Test B range from adequate to excellent r = .44 to .90 (Lezak, et al., 2006). The Trail Making Test B has been shown to be sensitive to a range of conditions leading to neurocognitive deficits including alcoholism (Ratti, Giardini & Soragna, 2002), lead exposure (Stewart, et al., 1999), and closed head injury (Iverson, Lange, Green & Franzen, 2002). The participant's speed of completion of the task was used as the variable of interest.

Verbal fluency

Letter fluency. In this task, participants are asked to say as many words as they can, as fast as they can, that begin with a certain letter in sixty seconds. They must not give proper nouns or the same word with different endings. Factor analytic findings in adults suggest that attentional control/working memory play an important role in task performance (Elias, Elias, D'Agostino, Silbershatz & Wolf, 1997). Test-retest reliability is good, r = 0.74 (Ruff, Light, Parker & Levin, 1996). Total number of unique words for three letters (C, F, L) was used as the variable of interest.

Impulsive decision making

Participants completed The Iowa Gambling Task (IGT; Bechara, Damasio, Damasio & Anderson, 1994), which is a measure of impulsive decision making.

Participants were presented with four decks of cards (A, B, C, D) on the same computer monitor used during the ANT. From these four decks, they were instructed to pick one card at a time using the computer mouse, and that they may switch from one deck to another, as often as they wish. They were informed that the objective of the game is to win as much money as possible and to avoid losing as much money as possible. They were also informed that some decks of cards are worse than others, and to be able to win the game, they must avoid choosing cards from the "bad" decks. The "bad" decks (A and B) are financially disadvantageous as they give larger payouts, but higher losses, eventually resulting in a net loss of money. The "good" decks (C and D) are financially advantageous because although they give smaller rewards, they also give smaller losses, resulting in a net gain of money. For example, in 10 straight trials, if decks A and B are chosen consistently, participants will lose $250; if decks C and D are consistently chosen, they win $250.

Participants completed 100 trials (or 5 "blocks" of 20 trials). In this study, participant's ability to adopt an advantageous decision making strategy on the IGT was of most interest. As such, "ability to improve response strategy" (Δ (Good - Bad)) was defined as the difference between the number of "good" decks vs. "bad" decks selected in the final block (Block 5) of trials minus the difference between the number of "good" decks vs. "bad" decks selected in the first block of trials (Block 1). Operationally speaking: Δ (Good - Bad) = [Block 5 (C + D) – (A + B)] – [Block 1 (C + D) – (A + B)]. The difference score between Block 5 and Block 1 was chosen as several other studies investigating impulsive personality traits have found that the biggest differences in response choice appear to occur in the final block of the task (Miranda et al., 2009; Sweitzer, Allen & Kaut, 2008; Franken, van Strien, Nijs & Muris, 2008).

Functional imaging studies in healthy control subjects indicate that the ventromedial prefrontal cortex is activated during participation in the IGT (Northoff et

al., 2006). As such, the IGT may be a sensitive measure in our sample owing to the fact that the earliest areas of degeneration in FTLD are thought to occur in the OMPFC (Broe et al., 2003; Rosen et al., 2002). Please refer to Study 1 for additional details.

Behavioural quantification of disinhibition

The ability to follow rules is an important aspect of executive function that has been shown to be disrupted in individuals with FTLD (Thompson, Stopford, Snowden & Neary, 2005; Kramer et al., 2003, Possin et al., 2009). As such, the following errors were quantified and summed to create the variable Total Rule Violations: total intrusions in CVLT-II SF, total sequencing errors on Trail Making Test A & B, Letter Fluency rule violations, Design Fluency rule violations and total perseverative errors on the WCST-64.

Control variables

Wechsler test of adult reading (WTAR). In order to control for intellectual ability, the WTAR (The Psychological Corporation, 2001) was administered to participants. This task requires the participant to pronounce aloud, 50 irregularly spelled words. This task is used as a measure of pre-morbid intellectual functioning, as it relies on the relatively strong correlation between reading ability and intellectual functioning in asymptomatic people (Strauss, et al., 2006). The WTAR has excellent internal consistency and very good test-retest correlations. It also correlates highly with WAIS III Verbal IQ scores (r = .75) and Full Scale IQ scores (r = .73) (The Psychological Corporation, 2001).

Internalizing symptom measures. Participants completed the State-Trait Anxiety Inventory Form Y (STAI; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983), a 40 item self-report inventory for measuring anxiety in adults. The STAI

differentiates between the temporary condition of "state anxiety" and the more general and long-standing quality of "trait anxiety." The STAI has been demonstrated to have adequate internal consistency and construct validity (Spielberger, et al., 1983). Much research on psychopathy has focused on the hypothesis that individuals with psychopathy possess low levels of trait anxiety (Lykken, 1995; Hicks & Patrick, 2006, Patrick & Bernat, 2009). However, measuring state anxiety is also important due to the fact that high levels can affect executive function performance (Castaneda, Tuulio-Henriksson, Marttunen, Suvisaari & Lönnqvist, 2008; Zarantonello, Slaymaker, Johnson & Petzel, 1984). As such, both state and trait anxiety were investigated in this study.

Participants also completed the Beck Depression Inventory – Second Edition (BDI-II), a 21 item self-report inventory of depressive symptoms (Beck, Steer & Brown, 1996). The BDI-II has been demonstrated to have good internal consistency (Beck, et al., 1996) and factor-analytic structure (Arnau, Meagher, Norris & Bramson, 2001; Norris, Arnau, Bramson & Meagher, 2003). It also has strong convergent and divergent validity with other instruments (Sprinkle et al., 2002; Osman, Kopper, Barrios, Gutierrez & Bagge, 2004) and high sensitivity to the presence and severity of depression (Beck, et al., 1996; Arnau, et al., 2001; Sprinkle et al., 2002). Like anxiety, depressive symptoms may affect cognitive performance (Castaneda, et al., 2008) and have also been associated with the factors underlying psychopathy (Hicks & Patrick, 2006).

Other. Demographic information was also collected regarding participant's age, sex, and years of education in order to control for these variables.

Procedure

On the day of testing, participants were welcomed and given a short introduction regarding the nature of testing and what to expect. The study then proceeded in two stages.

In the first stage, participants completed half of the neuropsychological test battery with the psychometrist, and then completed the two computerized tasks of cognitive function: IGT and ANT. Participants were then given a half hour break in order to allow them time to rest. This portion of the testing took approximately one and a half hours to complete.

In the second stage, participants completed the second half of the neuropsychological testing with the psychometrist. At the end of testing, they then completed the PPI-R. This portion of the testing took approximately two hours to complete.

Statistical analysis

Stage 1. Raw scores on the executive function tasks and the WTAR were converted to standardized z scores based on normative reference group means and standard deviations. Because the IGT, ANT Executive Attention and Total Rule Violations do not have acceptable normative data, these were left as raw scores. Raw scores on the PPI-R Factor Scales were converted to *t* scores based on normative data. Please note *n*'s are not equal to overall group *n* for a number of tasks. This is due to administration error, patient inability to complete tasks and computer errors which made some data unusable.

Next, histograms for each variable were visually inspected for departures from normality. Due to the small sample size, most distributions appeared skewed. Transformation of the variables using either log or square roots failed to normalize the distributions. As such, Blom Transformations were applied to each variable. The

Blom Transformation is the inverse cumulative asymptotic function of the rank score adjusted for the number of observations. These asymptotic scores are approximations to the exact expected order statistic for the asymptotic distribution (Blom, 1958). Because this transform rank orders scores, outliers are generally eliminated.

Because a number of variables such as gender, age, number of years of education, predicted intelligence, state and trait anxiety and depression symptoms had been identified earlier as potential confounding variables, *t*-tests (in the case of gender) and zero-order correlations were computed between these variables and the executive function tasks. Age, number of years of education, predicted intelligence, state anxiety, trait anxiety and depression symptoms were associated with one or more of these variables. As such, regressions were computed for each executive function task and domain score using these control variables as predictors. From these analyses, the unstandardized residuals were saved and subsequently used in all further analyses as the scores for each individual.

Stage 2. Performance on individual executive function tasks and Self-Centered Impulsivity was explored between asymptomatic and symptomatic individuals using one-tailed *t*-tests[17]. One-tailed *t*-tests were chosen given that symptomatic individuals were expected to perform significantly worse on all cognitive measures and the behavioural quantification of disinhibition (rule violations) and have higher levels of Self-Centered Impulsivity. Two-tailed *t*-tests were used to explore demographic variables, state anxiety, trait anxiety, depression symptoms and

[17] An alternate way to investigate group differences is to divide the pariticipants into those whose age at assessment is below the mean age of onset for the disease for their family (for pathologically confirmed cases), and those who are above the mean age. When this was performed, 21 participants were below the mean age of onset, while 5 were above. Statistical analysis of between group differences using *t*-tests did not reveal any significant differences. Thus, these analyses were not explored further.

Fearless Dominance between asymptomatic and symptomatic individuals as there were no a priori predictions regarding group differences for these variables. Given the exploratory nature of this study, Type-I error correction was not employed to adjust for the number of separate analyses conducted. In an attempt to control for the lack of independence created due to sampling subjects from the same families, the *t*-tests were analyzed a second time while adjusting the degrees of freedom to the number of families in the study (12), rather than using the number of participants.

Stage 3. In order to explore the relationship between the PPI-R Factor Scores and executive functioning, impulsive decision making, state and trait anxiety and depression symptoms, Pearson Product-Moment bivariate correlations and partial correlations (partialing out each PPI-R Factor Score) were conducted (due to the fact that our n will be too small to utilize hierarchical regression). Correlations were examined as one-tailed tests due to our hypothesis that higher levels of Fearless Dominance would correlate with better performance on the neuropsychological tests and less internalizing symptoms while higher levels of Self-Centered Impulsivity would correlate with poorer performance on the tests and more internalizing symptoms. In addition, partial correlations were conducted as it has been suggested that suppressor effects can occur when examining the relationship between psychopathic personality factors and other variables (Hicks & Patrick, 2006).[18]

[18] Suppression occurs when two correlated measures have opposing relationships with a variable, such that when they are both included in a regression equation, they exhibit stronger relationships with the criterion variable than when each is entered on its own (Paulhus, Robins, Trzesniewski & Tracy, 2004). Because our *n* was not large enough to use regression, we addressed this problem by calculating partial correlations. Partial correlations allow us to remove the common variance between the two PPI-R factors which may have concealed a potential relationship between the PPI-R Factor Score and the neuropsychological measure.

As a matter of interest, Steiger's (1980) *t*-test for dependent correlations was also computed to discern whether any of the significant zero-order and partial correlations was significantly different between the two PPI-R Factor scores. All statistical analyses were conducted using SPSS Version 16.0.

Results

Table 3.1 lists the means and standard deviations for both the asymptomatic and symptomatic groups on demographic, personality and emotional variables for the two groups. Table 3.2 lists the means and standard deviations for individual neuropsychological tests, domain scores, total rule violations and total repetitions for the two groups. Raw score, *z*-score or *t*-score form scores are presented in Appendix A.10.

As can be seen from Table 3.1, the asymptomatic and symptomatic groups did not differ significantly from one another with respect to age [t (24) = -1.34, p = 0.19], years of education [t (24) = 0.69, p = 0.50], state anxiety [t (24) = -.08, p = 0.93], trait anxiety [t (24) = -.48, p = 0.64] or depressive symptoms [t (24) = -0.44, p = 0.66]. An unanticipated finding was that predicted intelligence (WTAR score) differed significantly between the two groups [t (24) = 2.24, p = 0.03], wherein the asymptomatic group's predicted intelligence was higher than that of the symptomatic group. Contrary to our prediction, the two groups did not differ significantly with respect to the PPI-R Factor Score Self-Centered Impulsivity [t (21) = -1.22, p = 0.24] nor did they differ on Fearless Dominance [t (21) = -0.42, p = 0.68].

With respect to the individual executive function tasks, the asymptomatic and symptomatic groups differed significantly from one another on a total of four tests: CVLT Trial 1 [t (24) = 2.32, p = 0.01], Spatial Span Total [t (23) = 1.83, p = 0.04], Design Fluency [t (23) = 1.89, p = 0.04] and ANT Executive Attention [t (21)

= 2.02, p = 0.03] such that the symptomatic group performed significantly poorer on each of these tasks in comparison with the asymptomatic group. There were no significant differences between the two groups on any of the other individual executive function tasks: Trail Making Test A [t (24) = 1.42, p = 0.08], Trail Making Test B [t (23) = 0.15, p = 0.44], Digit Span Forward [t (24) = 1.60, p = 0.06], Digit Span Backward [t (24) = 1.27, p = 0.11], WCST Perseverative Errors [t (24) = 1.69, p = 0.05] and Stroop Interference [t (24) = 0.57, p = 0.29]. There was also no significant difference between the two groups with respect to the behavioural quantification of disinhibition: Total Rule Violations [t (24) = -1.24, p = 0.11]. Finally, contrary to our hypothesis, the symptomatic group did not perform significantly worse on the IGT (Δ (Good - Δ Bad)) compared to the asymptomatic group [t (13) = 1.23, p = 0.12][19]. Please refer to Table 3.2 for all t-test results for neuropsychological measures.

Zero-order and partial correlations were calculated between the PPI-R Factor Scores and the neuropsychological measures, as shown in Table 3.3. Contrary to our hypothesis, none of the neuropsychological measures were significantly correlated with either of the PPI-R Factor Scores (all $p > 0.05$; lowest p value = 0.26). When partial correlations were computed for Self-centered Impulsivity and the neuropsychological measures holding Fearless Dominance constant, Self-Centered Impulsivity and Trail Making Test B were significantly negatively associated

[19] As mentioned previously, in order to partially account for the non-independence of our sample, the t-tests were re-computed adjusting each one's degrees of freedom to 12, based on the number of families participating in the study. Adjustment of the degrees of freedom did not significantly alter the outcome of the results. In addition, the t-tests were also re-analyzed by randomly assigning one member from each multi-person family to either group. The result was 6 participants per group, none of which were related. Upon re-analysis, there was a significant difference between the two groups with respect to performance on CVLT Trial 1, Spatial Span, WCST Perseverative Errors and Total Rule Violations in the predicted direction. However, the significant difference for Design Fluency and ANT Executive Attention dropped out. As such, these results should be interpreted with caution.

with one another (r= -0.70, p = 0.03) and Self-Centered Impulsivity and Total Rule Violations were significantly positively associated with one another (r = 0.82, p = 0.01). It appears that higher levels of Self-Centered Impulsivity are associated with faster performance on Trail Making Test B and the likelihood of committing a greater number of rule violations. All other partial correlations between Self-centered Impulsivity and the other neuropsychological measures were non-significant (all p > 0.05; lowest p value = 0.054). In addition, when partial correlations were computed for Fearless Dominance and the neuropsychological measures holding Self-centered Impulsivity constant, Fearless Dominance and Stroop Interference and Fearless Dominance and ANT Executive Attention were significantly negatively correlated with one another (r = -.72 , p = 0.02; r = -.64 , p = 0.04, respectively). Higher levels of Fearless Dominance appear to be associated with less interference in conflict resolution tasks. All other partial correlations between Fearless Dominance and the other neuropsychological measures were non-significant (all p > 0.05; lowest p value = 0.09).

As a follow-up to the four significant partial correlations, Steiger's (1980) t-test was computed in order to ascertain whether the correlation between the two Factor Scores and the neuropsychological measure were significantly different from one another. With respect to Self-centered Impulsivity, Fearless Dominance and Trail Making Test B, the difference between the two correlations was not significantly different [t (20) = 0.64, p = 0.53], indicating that Self-Centered Impulsivity may not be uniquely associated with Trail Making Test B independent of Fearless Dominance's association. Similarly, Self-Centered Impulsivity was not uniquely associated with Total Rule Violations, independent of Fearless Dominance (t (20) = 0.46, p =0.65]. With respect to Fearless Dominance, Self-Centered Impulsivity and Stroop Interference, the difference between the two correlations was also not significantly different [t (20) = 0.04, p = 0.97], indicating Fearless Dominance may not be

uniquely associated with Stroop Interference independent of Self-Centered Impulsivity. Similarly, Fearless Dominance was not uniquely associated with the ANT Executive Attention independently of Self-Centered Impulsivity [t (17) = 0.97, p = 0.35].

Zero-order and partial correlations were also computed between the two PPI-R Factor Scores and State anxiety, Trait Anxiety and BDI scores as previous research has shown that the PPI-R Factor Scores are differentially related to depressive and anxiety symptoms, such that Fearless Dominance may be a protective factor for these emotional symptoms, while Self-Centered Impulsivity may be associated with greater levels (Hicks & Patrick, 2006; Falkenbach et al., 2007). As can be seen from Table 3.4, contrary to previous research, there were not any significant zero-order correlations between Self-centered Impulsivity and BDI Scores (r = 0.25, p = 0.24), State Anxiety (r = 0.08, p = 0.71) or Trait Anxiety (r = 0.22, p = 0.31). Similarly, when holding Fearless Dominance constant, partial correlations were also non-significant between Self-Centered Impulsivity and the BDI (r = 0.27, p = 0.23), State Anxiety (r = 0.08, p = 0.73) and Trait Anxiety (r = 0.24, p =0.29). However, consistent with previous research, Fearless Dominance was significantly negatively correlated with both the BDI (r = -.41, p = 0.05) and Trait Anxiety (r = -0.47, p = 0.02). It was not, however, significantly correlated with State Anxiety (r = -0.20, p = 0.37). When holding Self-centered Impulsivity constant, the partial correlations remained significant between Fearless Dominance and the BDI (r = -0.42, p = 0.05) and Trait Anxiety (r = -0.47, p = 0.03) and non-significant with State Anxiety (r = -0.20, p = 0.39). Once again, Steiger's (1980) t-test was computed in order to determine whether the correlations between Fearless Dominance and the BDI and Fearless Dominance and Trait Anxiety were significantly different from their correlations with Self-Centered Impulsivity. For both the BDI and Trait Anxiety, the difference between the two correlations was significantly different

from one another [t (23) = 2.36, p =0.03] and [t (23) = 2.50, p =0.02], respectively. This indicates that Fearless Dominance is uniquely associated with both depressive symptoms and trait anxiety, such that higher levels of the personality trait Fearless Dominance are associated with lower levels of depressive symptoms and trait anxiety.

Discussion

The primary purpose of this study was to investigate attention, executive function and psychopathic personality traits in symptomatic and asymptomatic individuals with a familial risk for FTLD. Results of the study demonstrate that individuals diagnosed as clinically symptomatic exhibit significant deficits on tasks related to several domains of executive function, including attention, working memory, shifting mental set and behavioural inhibition compared to asymptomatic family members. However, contrary to our hypothesis, the two groups did not significantly differ from one another in their performance on verbal fluency or total rule violations. Furthermore, they did not differ in their performance on impulsive decision making or in trait levels of Self-Centered Impulsivity.

Neuropsychological test scores

Comparison of neuropsychological task performance between family members diagnosed as either symptomatic for FTLD or asymptomatic indicates that symptomatic participants perform more poorly on tasks thought to assess various aspects of executive function. For example, performance on the auditory attention task CVLT-II-SF Trial 1 was significantly worse for symptomatic versus asymptomatic individuals with a family history of FTLD. These results are consistent with previous findings that basic attention is compromised in individuals with FTLD (Torralva et al., 2007). It is also in line with Geschwind and colleague's (2001) report of attention

deficits in individuals who possess the genetic mutation for FTLD-17, but were asymptomatic at the time of testing. Taken together, it appears that basic attention processes may be one of the first aspects of cognition to become compromised in FTLD.

Symptomatic individuals also experienced greater conflict when performing a task of behavioural inhibition (ANT executive control) compared to asymptomatic individuals. To the best of our knowledge, this is the first study to examine ANT executive attention in individuals at-risk for FTLD. These findings converge with those of O'Keeffe and colleagues (2007) who found that individuals with FTLD were impaired on several computerized tasks which required them to monitor errors (e.g, go/nogo task and continuous performance task). This finding highlights the fact that computerized measures such as the ANT may be more sensitive to detecting early deficits in this domain compared to more traditional neuropsychological measures.

When performance was compared between symptomatic and asymptomatic group members on a test of working memory (Spatial Span Total score), symptomatic individuals performed significantly worse. A recent study by Giovagnoli, Erbetta, Reati and Bugiani (2008) also found deficits in spatial span in individuals in the early stages of FTLD (mean disease duration was three years) compared to caregiver controls, though others have not found such deficits (O'Keefe et al., 2007). However, other investigations using alternate measures of working memory such as Letter-Number Sequencing and Digit Span Backwards have also demonstrated similar deficits in individuals with FTLD (Torralva et al., 2007; O'Keefe et al., 2007; Xie et al., 2008).

Symptomatic group members also perform significantly worse on a task of cognitive set shifting (Design Fluency), an aspect of executive functioning which is neuroanatomically and conceptually related to working memory (Ravizza & Ciranni, 2002). This finding extends previous research which has demonstrated a relationship

between frontal lobe hypoperfusion, brain volume and impaired performance on design fluency in FTLD (Kramer et al., 2007; Boone, et al., 1999). While we did not find significant differences between the two groups on any other measures of set shifting, Wicklund, Rademaker, Johnson, Weitner and Weintraub (2007) found that individuals with FTLD exhibited the poorest performance on the Trail Making Test B compared to both normal controls and individuals with Alzheimer's disease.

The above results are important as they may shed light on how alterations in cognition could relate to behavioural features of FTLD. For example, deficits in each of these domains of executive function (i.e., attention, working memory, set shifting and behavioural inhibition) in individuals with early FTLD may manifest themselves as the development of "difficult" personality features, such as appearing distracted, having difficulty following conversations or the inability to resist cutting others off mid-sentence. In relation, research on other populations with known executive dysfunction such as ADHD, indicates that these individuals have greater relational problems than others (Canu & Carlson, 2007; Hoza, 2007).

There were no other significant differences in task performance between the asymptomatic and symptomatic groups. While these findings are contrary to several previous studies (Kramer et al., 2003; Rosen et al., 2004; Nedjam, Devouche & Dalla Barba, 2004; Gregory & Hodges, 1996), our cohort is arguably in a much earlier stage of the disease process than those in other studies whose participants have all been diagnosed with FTLD. As such, deficits in cognition are likely to manifest themselves much more subtly in our population; thus compromised ability on every executive function task is unlikely in our sample. However, it should be noted that when we examine the means and standard deviations for performance for both groups, it appears that the symptomatic group is consistently exhibiting lower scores on almost all tasks compared to the asymptomatic group.

Another explanation for non-significant findings between groups is due to the nature in how they were classified. At this time, we do not have the data to allow us to separate the individuals into those with a known genetic mutation versus those without. Therefore, at this point, all individuals need to be considered at-risk. As such, even if they are currently asymptomatic, they may still have the genetic mutation and therefore have potential deficits. However, because almost all the neuropsychological test scores were transformed into *z*-scores from normative data, this explanation is less likely. The asymptomatic group's means on most neuropsychological tests is at the mean, or slightly above, suggesting that as a whole, the group is cognitively normal.

Contrary to previous findings (Thompson et al., 2005; Kramer et al., 2003; Rosen et al., 2004, Nedjam, et al., 2004; Possin et al., 2009), we did not find group differences in total rule violations or on the IGT (Torralva et al., 2007). Given the symptomatic groups difficulties with behavioural inhibition, it is surprising that they were not significantly worse at resisting violating rules on the neuropsychological tasks compared to the asymptomatic group. However, given that the means for both groups are in the predicted direction, it may be that the high level of variability in the symptomatic group obscured this difference. Similarly, the lack of group differences on the IGT may have been the result of a low n coupled with high levels of variability within each group.

The finding that asymptomatic individuals had higher predicted intelligence than symptomatic individuals was an unexpected result. However, this may be an artifact of the disease process as the WTAR is also a measure of irregular word pronunciation ability. Language disturbance can be an early indicator of FTLD in the non-behavioural variants of the disorder (Neary et al., 1998), such that the difference between the two groups may reflect symptomatology rather than lower

intelligence. Regardless, the variance associated with predicted intelligence was removed from all neuropsychological variable scores before analysis between groups.

Psychopathic personality traits

Contrary to the previous finding by Rankin et al. (2008) investigating impulsive/interpersonal facets of psychopathy, we did not find evidence to suggest that individuals who are symptomatic possess differential levels of psychopathic personality traits compared to individuals who are asymptomatic. Specifically, symptomatic individuals did not possess higher levels of Self-Centered Impulsivity compared to asymptomatic individuals, nor was there any difference between the groups with respect to Fearless Dominance. One issue which may have contributed to this finding is method of measurement. Previous studies have used informant ratings of patients, either individuals who share a close relationship with the patient or psychometrists trained to assess these traits (Rankin et al., 2004; Rankin et al., 2005; Rankin et al., 2008).

In addition, the PPI-R measures psychopathic personality traits – long standing characteristic patterns of thought and behaviour, rather than one-time reflections of behaviour such as a clinician rating scale. Given that any psychopathic personality traits these individuals might evince is likely a reflection of change due to cortical degeneration, rather than being a constitutional risk factor, these traits may not be endorsed by individuals from our population as characteristic of themselves. Rather, behaviours associated with psychopathy, such as impulsivity and interpersonal coldness are thought to result once the disease process begins (Mendez et al., 2005). As such, exploring whether specific behaviours associated with psychopathy (similar to Rankin et al., 2008) were present in our sample of individuals with early FTLD rather than personality traits may have been more sensitive to changes occurring in our sample. For example, a recent study by Hoeffer

and colleagues (2008) which examined fear conditioning in individuals with FTLD (a paradigm which has been investigated extensively in individuals with psychopathy; for a review, please see Lynam & Derefinko, 2006), found they exhibited a blunted electrodermal response to aversive stimuli, similar to individuals with psychopathy (Hoeffer, et al., 2008). Finally, differences could also be obscured because of the groupings we imposed based on neurological diagnosis and sample size, rather than separating them into mutation and non-mutation carriers.

Relationship between psychopathic personality traits and executive function

The results of this study are partially concordant with previous studies which demonstrate a differential relationship between the two factors of psychopathic personality, Fearless Dominance and Self-Centered Impulsivity and performance on neuropsychological tasks of attention and executive function (Sellbom & Verona, 2007; Carlson, et al., 2009). For example, Sellbom and Verona (2007) found that individuals high on Fearless Dominance performed better on the overall domain of Executive Function than individuals low on Fearless Dominance. This was also the case for several individual neuropsychological measures of executive function (Digits Backward and WCST Perseverative errors) when controlling for Self-Centered Impulsivity. Furthermore, individuals with high levels of Self-Centered Impulsivity performed worse on the Response Inhibition domain and total Flanker Commission Errors than individuals low on Self-Centered Impulsivity. This was also the case for the overall Executive Function domain when controlling for Fearless Dominance. While we did not demonstrate any significant bivariate correlations between the PPI-R Factor scores and our neuropsychological measures as Sellbom and Verona (2007) did, partial correlations revealed several interesting findings. For example, when we examine the partial correlation between Fearless Dominance and Stroop Interference and Fearless Dominance and ANT Executive Attention, we find that when we take out

the variance associated with Self-Centered Impulsivity, individuals who have higher levels of Fearless Dominance are actually better at ignoring conflicting information and inhibiting incorrect responses than those who have lower levels of this trait. This is consistent with the suggestion that psychopathic individuals may have a better ability to focus their attention and resist interference from competing stimuli than other individuals (Forth & Hare, 1989; Hiatt, Schmitt & Newman, 2004). In addition, when we remove the variance associated with Fearless Dominance and examine the relationship between Self-Centered Impulsivity and Trail Making Test B we find that individuals with high levels of this trait tend to perform the task more quickly than those low on this trait. This is in contrast to previous literature that suggests that individuals with high levels of impulsivity are more inefficient (and therefore slower) at switching their attention back and forth between disparate stimuli (Dolan, Bechara & Nathan, 2008; Leshem & Glicksohn, 2007; Friedman et al., 2007). However, it has been suggested that there is a trade-off in timed tasks, where one must choose between speed of completion and accuracy of responses (Dickman & Meyer, 1988). When total number of errors on Trails B was examined, analysis did not indicate a significant positive relationship between high levels of Self-Centered Impulsivity and errors; however it is possible that the task is sufficiently easy enough in this population for a floor effect to have occurred. Nevertheless, when we sum total errors (rule violations) across several tests we find that individuals with higher levels of Self-Centered Impulsivity make more rule violations than individuals who are low on this trait. This is consistent with the literature suggesting that individuals with high levels of impulsivity have difficulty with error detection and monitoring of performance (Stahl & Gibbons, 2007; Dikman & Allen, 2000). Overall, the above findings highlight the importance of addressing the possibility of suppressor effects when examining correlations among associated traits.

Given that individuals in our sample share a common potential for development of a neurodegenerative disease (and some come from the same family) the range of variance associated with both personality and cognitive measures may have been somewhat restricted due to the homogeneity of individuals. This may have affected our ability to detect significant correlations between psychopathic personality traits and executive function ability. Thus, it is possible that these results may underestimate the true strength and magnitude of these relationships in this sample. However, upon examination of the means and standard deviations of the two groups on both personality and cognitive measures (Table 3.1, 3.2), it appears that there is enough variability within groups to suggest analysis of correlations is worthwhile and that the results presented here are interesting preliminary findings.

Relationship between psychopathic personality traits and internalizing symptoms

The results of this study partially support previous investigations of the differential relationship between the two factors associated with psychopathy and internalizing symptoms (Verona, Patrick & Joiner, 2001; Hicks & Patrick, 2006). While our study demonstrated that individuals with high levels of Fearless Dominance exhibit lower levels of trait anxiety and depressive symptoms, contrary to previous research we did not find that individuals with high levels of Self-Centered Impulsivity displayed higher levels of these traits. However, high levels of negative affect in this population may be the result of accumulated negative repercussions related to engaging in impulsive and antisocial behaviours (Patrick & Bernat, 2009). Given those individuals in our study are functional, community-dwelling individuals, this may not apply. Our results however, support long standing conceptualizations that high levels of the trait Fearless Dominance are related to having lower levels of negative emotional adjustment, especially with regards to anxiety (Cleckley, 1941; 1976; Lykken, 1995; Hicks & Patrick, 2006; Patrick & Bernat, 2009). Previous

research demonstrates that individuals with FTLD are less prone to developing depression than other dementias such as Alzheimer's disease (Levy, Miller, Cummings, Fairbanks & Craig, 1996). One possibility is that those individuals who become more emotionally cold are protected from such symptoms, much like individuals who possess high levels of Fearless Dominance.

Limitations, implications & future directions

There are a number of limitations to this study. To begin, like many other investigations of individuals with FTLD, due to the very low base rate of the disease in the general population (approximately 81/100 000 in individuals between the ages of 45-65; Ratnavalli et al., 2002), the number of participants was very small, limiting our ability to detect differences between individuals. Moreover, despite being able to invite individuals with a family history of the disease, many of these individuals were not interested in participating in a study in which highlights the possibility of their developing such a devastating disease. In addition, given the exploratory nature of our study we performed a large number of statistical tests, which resulted in a small number of positive results. It is possible that findings may be due to inflation of Type I error rate. However, our results are consistent with the few previous studies of early FTLD, which suggest that neuropsychological tests which measure aspects of attention and executive function are most sensitive to detecting cognitive deficits in this population of individuals (Geschwind et al., 2001; Torralva, et al., 2007). There is also the potential that individuals with different clinical variants of the disease were grouped together, thereby diluting our sample as well. Furthermore, because histological analysis is the only way to definitively know whether an individual has FTLD, we can not be sure that those individuals we grouped in the symptomatic group have FTLD, nor can we be assured that any of the individuals in the asymptomatic group won't eventually go on to develop the disease either. A more

accurate way to have grouped these individuals would have been to divide them based on whether they did or did not carry one of the known genetic mutations for FTLD. Unfortunately, we were not able to access any genotyping data for the participants.

Despite these limitations, several important findings emerge from this exploratory study. The first is that the domains of Attention, Working Memory, Set Shifting and Conflict Resolution are important areas of cognition to focus on in individuals at-risk and/or in the earliest stages of FTLD. Future research should concentrate on breaking down various aspects of each domain in order to discern greater specificity of dysfunction. For example, attention may be further broken down into vigilance, short-term memory capacity, divided and sustained attention. The second is that psychopathic personality traits do not appear to be elevated in individuals at familial risk for FTLD. This finding suggests that efforts to examine psychopathy in FTLD should focus on objectively quantifiable aspects of psychopathy, such as recent criminal activity or impulsive behaviours (e.g., gambling) rather than personality traits which may not be elevated until much further into the disease process. Moreover, it would be interesting to investigate whether relationships exist between executive dysfunction and overt impulsive or socially inappropriate behaviours. As the results of this study are part of a larger, ongoing project investigating the phenotypic characteristics of individuals at familial risk for FTLD, future analysis will examine cognitive changes in these participants longitudinally, over a period of five years. Furthermore, genetic analysis of all participants will also be conducted, allowing for the analysis of individuals by genetic mutation status, rather than neurological diagnosis.

Conclusion

Our study corroborates previous evidence which suggests that individuals who are at-risk for FTLD exhibit cognitive deficits in the areas of attention and executive function. It will be important for future research efforts to continue to explore cognitive deficits as early diagnostic markers in familial FTLD. In addition, this is the first study to examine the dissociable personality traits underlying psychopathy, Fearless Dominance and Self-Centered Impulsivity. We found that individuals at-risk for FTLD possessed similar levels of psychopathic personality traits compared to a community control sample. This finding suggests that individuals at-risk for FTLD do not possess a developmental predisposition for increased levels of psychopathic personality traits prior to disease onset. Furthermore, symptomatic individuals did not differ in relative levels of these traits compared to asymptomatic family members. As such, it appears that psychopathic personality trait measures do not yield useful information with respect to characterizing the early symptoms of FTLD. Overall, these findings highlight the importance of being creative when looking to find ways to accurately characterize the personality and cognitive changes that occur as a result of this disease.

Table 3.1

Descriptive and *T*-test Statistics by Diagnostic Status For Control Variables and PPI-R Factor Scores

	Asymptomatic		**Symptomatic**			
Variable	***n***	**Mean (*SD*)**	***n***	**Mean (*SD*)**	***t***	***p***
Age	15	-0.21 (0.94)	11	0.29 (0.96)	-1.34	0.19
Years of Education	15	0.13 (0.84)	11	-0.12 (1.01)	0.69	0.50
Predicted Intelligence	15	0.34 (0.88)	11	-0.46 (0.93)	**2.24**	**0.03***
PPI-R Self-Centered Impulsivity	14	-0.19 (0.85)	9	0.30 (1.08)	-1.22	0.24
PPI-R Fearless Dominance	14	-0.07 (0.86)	9	0.10 (1.14)	-0.42	0.68
State Anxiety	15	-0.01 (0.98)	11	0.02 (0.97)	-0.08	0.93
Trait Anxiety	15	-0.08 (1.05)	11	0.11 (0.86)	-0.48	0.64
BDI	15	-0.04 (0.88)	11	0.12 (0.99)	-0.44	0.66

Note. Means and standard deviations presented are Blom Transformed Scores. Two-tailed *t*-tests were computed on all of these scores except Self-Centered Impulsivity, given there were no a priori hypotheses that the two groups would differ on any of these other variables. PPI-R: Psychopathic Personality Inventory-Revised; BDI: Beck Depression Inventory.
*$p \leq 0.05$.

Table 3.2

Descriptive and *T*-test Statistics by Diagnostic Status For Neuropsychological Variables

Variable (*z*-score)	Asymptomatic *n*	Asymptomatic Mean (*SD*)	Symptomatic *n*	Symptomatic Mean (*SD*)	*t*	*p*
CVLT Trial 1	15	0.31 (0.78)	11	-0.42 (0.81)	**2.32**	**0.01***
Digit Span Forward	15	0.18 (0.73)	11	-0.24 (0.56)	1.60	0.06
Trail Making Test A	15	0.19 (0.56)	11	-0.25 (1.01)	1.42	0.08
Digit Span Backward	15	0.17 (0.76)	11	-0.23 (0.79)	1.27	0.11
Spatial Span Total	14	0.21 (0.47)	11	-0.26 (0.74)	**1.83**	**0.04***
WCST Perseverative Errors	15	0.25 (0.77)	11	-0.34 (0.99)	1.69	0.05
Design Fluency	14	0.26 (0.78)	11	-0.33 (0.76)	**1.89**	**0.04***
Trail Making Test B	15	0.02 (0.66)	10	-0.03 (1.02)	0.15	0.44
Stroop Interference	15	0.08 (0.79)	11	-0.11 (0.87)	0.57	0.29
ANT Executive Attention	12	-0.31 (0.74)	11	0.33 (0.77)	**2.02**	**0.03***
Letter Fluency	15	0.07 (0.69)	11	-0.10 (0.80)	0.58	0.28
Δ (Good – Bad)	7	0.18 (0.54)	8	-0.16 (0.54)	1.23	0.12
Total Rule Violations	15	-0.15 (0.76)	11	0.20 (0.61)	1.24	0.11

Note. All scores for the neuropsychological test variables are both Blom Transformed and the Unstandardized Residual computed by extracting the variance associated with each score by age, years of education, predicted intelligence, state anxiety, trait anxiety and depression symptoms. Please see Appendix A.9 for table of raw, *z*-score and *t*-score means and standard deviations. One-tailed *t*-tests were computed on these scores given there was an a priori hypothesis that symptomatic individuals would perform significantly worse than asymptomatic individuals on each of these variables. CVLT: California Verbal Learning Test-II-Short Form; WCST: Wisconsin Card Sorting Task-64; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task.
*$p \leq 0.05$.

Table 3.3

Correlations and Partial Correlations Between PPI-R Factor Scores and Neuropsychological Variables

Neuropsychological Test	*n*	Self-Centered Impulsivity		Fearless Dominance	
		r	partial *r*[a]	*R*	partial *r*[b]
CVLT Trial 1	23	0.14	-0.42	-0.11	-0.22
Digit Span Forward	23	0.10	0.29	0.06	0.16
Trail Making Test A	23	0.09	0.05	-0.004	0.04
Digit Span Backward	23	0.13	-0.21	-0.03	-0.26
Spatial Span Total	22	0.22	-0.45	-0.13	-0.23
WCST Perseverative Errors	23	-0.17	-0.59	0.12	-0.20
Design Fluency	22	0.10	0.001	-0.12	-0.34
Trail Making Test B	23	-0.07	**-0.70***	0.12	-0.28
Stroop Interference	23	-0.17	-0.55	-0.15	**-0.72***
ANT Executive Attention	20	-0.26	-0.35	0.10	**-0.64***
Letter Fluency	23	-0.10	0.23	0.09	0.28
Δ (Good – Bad)	12	0.03	-0.04	-0.20	-0.23
Total Rule Violations	23	-0.01	**0.82***	0.15	0.31

Note: correlations and partial correlations were computed on the Blom Transformed Factor Scores and Blom Transformed/Unstandardized Residual Neuropsychological Variable Scores. One-tailed correlations and partial correlations were computed on these scores given there was an a priori hypothesis that individuals with high levels of Self-Centered Impulsivity would perform poorly on the neuropsychological variables while individuals with high levels of Fearless Dominance would perform well. CVLT: California Verbal Learning Test-II-Short Form; WCST: Wisconsin Card Sorting Task-64; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task.
a: variance associated with Fearless Dominance and the task is being partialed out.
b: variance associated with Self-Centered Impulsivity and the task is being partialed out.
*$p \leq 0.05$.

Table 3.4

Correlations and Partial Correlations Between PPI-R Factor Scores and Internalizing Symptoms

		Self-Centered Impulsivity		Fearless Dominance	
Internalizing Symptoms	***n***	***r***	**partial *r*[a]**	***r***	**partial *r*[b]**
State Anxiety	23	0.08	0.08	-0.20	-0.20
Trait Anxiety	23	0.22	0.24	**-0.47***	**-0.47***
BDI (Depressive Symptoms)	23	0.25	0.27	**-0.41***	**-0.42***

Note. Correlations and partial correlations were computed on the Blom Transformed scores. One-tailed correlations and partial correlations were computed on these scores given there was an a priori hypothesis that individuals with high levels of Self-Centered Impulsivity would exhibit higher levels of state and trait anxiety and depressive symptoms while individuals with high levels of Fearless Dominance would exhibit lower levels of state and trait anxiety and depressive symptoms. BDI: Beck Depression Inventory.
a: variance associated with Fearless Dominance and the task is being partialed out.
b: variance associated with Self-Centered Impulsivity and the task is being partialed out.
*$p \leq 0.05$.

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CHAPTER 4: GENERAL DISCUSSION

The primary goal of my dissertation was to investigate whether varying levels of impulsive personality traits are related to executive function ability. This goal was accomplished by investigating these traits and abilities in two different samples of individuals, undergraduate university students and community members at familial risk for the neurological disorder, Frontotemporal Lobar dementia (FTLD). The results from both studies partially support the main hypothesis that higher levels of impulsive personality traits are related to poorer performance on tasks of executive function.

The following chapter provides a summary of key findings, discusses the strengths and limitations of this research, highlights questions that arise and how the findings relate to the overall field of study. The significance of the research is discussed, as are potential applications for future research and final conclusions.

Summary of Key Findings

In Study 1 (Chapter 2), undergraduate students were asked to complete several different measures of executive function ability along with a questionnaire designed to assess psychopathic personality traits related to both impulsivity and fearlessness, the Psychopathic Personality Inventory-Revised (PPI-R). It was demonstrated that, consistent with our hypothesis, the psychopathic personality trait, Self-Centered Impulsivity predicted inability to improve one's response strategy on a task of impulsive decision making, the Iowa Gambling Task (IGT). However, Self-Centered Impulsivity did not predict performance on the other executive function tasks. In addition, the trait, Fearless Dominance did not predict performance on any of the executive function tasks.

Study 2 (Chapter 3) investigated these same personality traits and executive function ability in a group of individuals who are at-risk for FTLD due to a family history of the disease. As predicted, symptomatic individuals performed more poorly on several measures of attention and executive functioning (California Verbal Learning Test-II, Short

Form, Trial 1; Spatial Span Total; Design Fluency; ANT Executive) compared to asymptomatic individuals. However, the hypothesis that symptomatic individuals would possess higher levels of the trait, Self-Centered Impulsivity compared to asymptomatic individuals was not supported. The two groups also did not differ on the personality trait Fearless Dominance.

Similar to Study 1, the relationship between PPI-R Factor Scores and executive function ability was also explored. While zero-order correlations between the two factor scores and the neuropsychological measures were non-significant, partial correlations controlling for overlapping variance in factor scores revealed several significant relationships, generally in the predicted direction. For example, when the variance associated with Self-Centered Impulsivity is removed, Fearless Dominance was significantly negatively associated with reaction time on the interference trial of the Stroop Task and on ANT Executive, suggesting that individuals with higher levels of Fearless Dominance experience less cognitive interference on these two tasks. When the variance associated with Fearless Dominance is removed, Self-Centered Impulsivity was significantly positively associated with total rule violations and negatively associated with time taken on Trail Making Test B. While we might predict that individuals with high levels of Self-Centered Impulsivity are more likely to make mistakes due to not following rules, we would not expect them to perform well on Trail Making Test B. Rather, we would expect individuals with high levels of impulsivity to perform slowly on a task requiring them to switch their attention between two different types of stimuli (Dolan, Bechara & Nathan, 2008; Leshem & Glicksohn, 2007; Friedman et al., 2007).

Finally, the relationship between psychopathic personality traits and internalizing symptoms such as anxiety and depression was explored. Results are consistent with previous findings (Hicks & Patrick, 2006) that individuals with high levels of Fearless Dominance experience lower levels of depression and trait anxiety symptoms than individuals with lower levels of this trait. However, the positive relationship between Self-

Centered Impulsivity and internalizing symptoms which has been demonstrated previously (Hicks & Patrick, 2006) was not corroborated.

Overall, it appears that, consistent with the main hypothesis, impulsive personality traits are associated with executive function ability. In both studies, Self-Centered Impulsivity was shown to be related to poorer performance on specific measures of executive function. In Study 1, Self-Centered Impulsivity negatively predicted ability to adopt a monetarily advantageous decision making strategy on the IGT. In Study 2, Self-Centered Impulsivity was related to making a greater number of rule violations across several measures of executive function, a result which has not been demonstrated previously. Results from Study 2 also suggest that the psychopathic personality trait Fearless Dominance is associated with enhanced executive function performance on a task related to resistance to interfering stimuli (Stroop task, Interference trial) and a task of behavioural inhibition (ANT Executive Attention). In addition, the same relationship was demonstrated in Study 1 between Fearless Dominance and ANT Executive when Age and Block Design were removed from the regression analysis.

Contributions to the literature on psychopathic personality traits

These studies add valuable information to our understanding of psychopathic personality traits and executive function ability for several reasons. To begin, they add to the growing evidence that psychopathic personality traits are not only relevant to incarcerated populations; rather, non-clinical subgroups of individuals appear to possess these traits (Lilienfeld & Andrews, 1996; Blonigen, Carlson, Krueger & Patrick, 2003; Maesschalck, Vertommen & Hooghe, 2002). In addition, while one population was screened for self-reported neurological problems (Study 1: undergraduates) the other population was a subset of individuals who are at-risk for neurological degeneration of the prefrontal cortex (Study 2: individuals at-risk for FTLD), an area hypothesized to be important in the development of impulsive personality traits (Patrick & Bernat, 2009). Investigating both

groups allowed us to see whether being at-risk for neurological deficits in relevant brain areas made it more likely that these individuals would develop higher levels of these traits. We found that the at-risk group did not appear to display significantly higher levels of these traits (compared to a normative reference sample). Moreover, though not the same between the two studies, both groups exhibited some of the hypothesized relationships between psychopathic personality traits and executive functions. These findings highlight the fact that our approach to investigating this topic is one which can be used in diverse populations. Furthermore, it is consistent with the suggestion that there may be a common neurological substrate between certain domains of executive functions and impulsivity.

Another important aspect of both of these studies that has previously been overlooked by many researchers is the inclusion of both basic and more non-traditional measures of executive function which attempt to assess more complex aspects of controlled behaviour (e.g., the IGT). Basic measures of executive function tend to measure simpler, more discrete, de-contextualized aspects of executive function, such as inhibition or working memory (Miyake et al., 2000; Friedman et al., 2008) which are generally thought to be mediated by more dorsal lateral aspects of the prefrontal cortex (DLPFC; Owen, McMillan, Laird & Bullmore, 2005; Buschbaum, Greer, Chang, & Berman, 2005; Derrfuss, Brass, Neumann, & von Cramon, 2005); non-traditional measures of executive function are designed to capture more emotionally-driven aspects of learning and decision making in response to reward/punishment contingencies (Bechara, Damasio, Damasio & Anderson, 1994; Reynolds, Patak & Penfold, 2008) and are believed to be mediated by orbito-medial aspects of the prefrontal cortex (OMPFC; Bechara, 2004; Clark, Cools & Robbins, 2004). Inclusion of both types of tasks has allowed us to simultaneously examine how psychopathic personality traits relate to both emotional ("hot"; OMPFC) and de-contextualized ("cool"; DLPFC) aspects of executive function (Zelazo & Müller, 2002). Including both types of measures allows us to gain a broader perspective about which particular prefrontal cortex

regions might relate to psychopathic personality traits, based on the interaction between these traits and executive functions specific to each brain region.

How do they relate to the field of study more generally?

It appears that Self-Centered Impulsivity is associated with an inability to adopt an advantageous decision making strategy. Furthermore, the results suggest that despite being told explicit rules, individuals with high levels of this trait have difficulty following through with them. The idea that impulsive individuals seem to have difficulty reflecting on previous mistakes and learning from them has been a topic of interest in the field for some time (Gorenstein & Newman, 1980; Patterson & Newman, 1993). This pattern of responding to situations has been described as one of "forging ahead" versus "stopping to check it out" (Patterson & Newman, 1993), implying that impulsive individual's do not take the time to think about why a mistake or punishment occurred; but rather respond in a perseverative fashion by continuing to use the same strategy time and again. Inability to modulate responses has also been attributed to other neurobiological reasons, such as oversensitivity to signals of reward (Gray, 1987; Gray & McNaughton, 2000) in relation to low levels of the neurotransmitter, serotonin (Carver & Miller, 2006, Zuckerman, Kuhlman, Joireman, Teta & Kraft, 1993). While the exact mechanisms are not clear, research does indicate that impulsive personality traits are linked to real world difficulties related to inhibiting appetitive responses in favour of behaviours that reduce the likelihood of negative outcomes, such as substance abuse (Slutske et al., 2002; Dom, Hulstijin & Sabbe, 2006) and chronic criminal recidivism (Waite et al., 2005; Hiscoke, Långström, Ottosson, & Grann, 2003).

In addition, it appears that the trait Fearless Dominance is related to enhanced ability to ignore irrelevant stimuli while focusing on the primary task at hand. This relationship has been found in a previous study by Sadeh and Verona (2008). One theory that has been posited as to why this might occur suggests that, due to deficiencies in limbic

structures associated with fear processing (Patrick & Bernat, 2009), individuals with high trait levels of Fearless Dominance do not experience negative emotions to the extent that others do (Patrick & Bernat, 2009; Hicks & Patrick, 2006). Therefore, their cognitive functioning is likely affected to a lesser degree by interference of negative emotions, thereby enhancing executive functioning (Ochsner, 2007). Indeed, in Study 2, we found that a negative relationship existed between Fearless Dominance and internalizing symptoms such that individuals with higher levels of this trait appeared to experience lower levels of depression and trait anxiety. Moreover, Fearless Dominance was associated with better performance on a task of resistance to interfering stimuli (Stroop task, Interference trial) and a task of behavioural inhibition (ANT Executive Attention). While enhancement of attentional focus by exclusion of irrelevant stimuli appears to be a benefit to cognitive performance, it is easy to see how this bias could have negative social implications should it interfere with appropriate responding. For example, if an individual with high levels of Fearless Dominance was having a serious discussion with another individual but ignored stimuli from the adjacent room (someone crying), this might be perceived by the other individual as cold and insensitive because they did not seem concerned by the other person's obvious distress.

Overall, the findings of these studies add further evidence that particular personality traits (impulsivity and fearlessness) are related to both emotional and de-contextualized aspects of executive function. Moreover, these relationship's neurological substrate may be via the prefrontal cortex and its reciprocal connections to lower-level limbic structures important to emotion and motivation.

Summary of Strengths and Limitations of the Research Presented

Strengths

There were a number of strengths and limitations to each of the studies, some common to both and some unique to one or the other. Two common strengths have been touched on already. One is the investigation of psychopathic personality traits in two separate, non-incarcerated populations, and the other is the use of measures of executive functions which purportedly tap different prefrontal brain regions (e.g., DLPFC vs. OMPFC).

Another strength of these studies relates to the variable derived to measure IGT performance. Because failure to learn from mistakes is a key component of psychopathic personality specifically, (Cleckley, 1941; 1976) as well as impulsivity generally (Gorenstein & Newman, 1980; Patterson & Newman, 1993), measuring the ability to adopt an advantageous response strategy is an important approach to take in the investigation of executive function and psychopathic personality traits. Surprisingly, our variable "ability to improve response strategy" is a unique approach meant to capture learning of advantageous response strategies that was not undertaken by the one other group of researchers (Miranda, MacKillop, Meyerson, Justus & Lovallo, 2009), who have investigated psychopathic personality traits and IGT performance.

Inclusion of computer administered tasks of executive function, rather than relying on traditional, paper and pencil tasks administered by a psychometrist is also a strength of this research. Computer administered tasks have been argued to exhibit greater precision and sensitivity than human experimenters (Wild, Howieson, Webbe, Seelye, & Kaye, 2008). For example, they are more reliable given that they are administered exactly the same way, with the same instructions each time and are able to take more precise measurements (e.g., measuring response latencies in milliseconds vs. seconds) (Wild, et al., 2008). This precision is especially important when conducting research with healthy adults who are less likely to exhibit large magnitude deficits. It should also be mentioned that while the ANT has been investigated in a number of previous studies on healthy adults, children, and

individuals with psychopathology, such as post-traumatic stress disorder and borderline personality disorder (Fan, McCandliss, Sommer, Raz & Posner, 2002; Fan, McCandliss, Fossella, Flombaum & Posner, 2005; Rueda et al., 2004; Leskin & White, 2007; Posner et al., 2002), until now, its relationship with psychopathic personality traits has not been examined. The ANT is designed to measure three aspects of attention – alerting, orienting and executive attention (Fan, Fossella & Posner, 2001). An advantage of the ANT is that it allows for the independent examination of each of these three aspects of attention. As such, unlike other versions of the Flanker Task, we are able to examine executive attention independent of any influence of alerting and orienting attention. Finally, both studies examined a number of potential confounding variables such as relative levels of intelligence, language abilities, education level, and previous neurological insult which help to ensure that, as much as possible, the results obtained were the result of true relationships with the construct of interest, rather than due to noise created by potential relationships with these other variables.

A specific strength of Study 2 compared to most other research in the field is the recruitment of a sample of individuals who are at at-risk for FTLD, rather than individuals who have already presented with cognitive complaints to their family physician or dementia clinic. Despite the paucity of sensitive and specific predictors for this neurodegenerative disease (Rascovsky et al., 2007; Wittenberg, et al., 2008), very few research investigations of early disease markers have been undertaken in this subset of individuals (Geschwind, et al., 2001; Torralva et al., 2007). In addition, Study 2 is only the second study to investigate features of psychopathy in this population and is the first study to use a measure of psychopathic personality traits.

Limitations

Both studies also share several common limitations. To begin, both samples consisted largely of female participants, which limit the generalizability of our findings.

Moreover, as men are thought to have higher levels of psychopathic personality traits compared to females (for reviews, see Cale & Lilienfeld, 2002; Verona & Vitale, 2006) the gender distribution of our sample may have adversely affected our ability to detect the hypothesized relationships due to a restricted range of variance in the traits examined. However, in Study 1, we tried to account for this by applying sex-correction in order to account for differing mean levels of traits. In Study 2, we calculated T-scores for each participant based on gender-stratified normative data. Another limitation common to both studies was the inability to use an experimental design to examine causal relationships among our variables. Unfortunately, because we are studying individual difference variables such as cognitive abilities, personality traits and risk for a genetic disease, it is impossible to assign subjects to conditions which would allow us to manipulate these constructs of interest.

The use of an undergraduate sample in Study 1 could be considered to be a weakness due to the argument that undergraduates do not fit the criteria of the "normal" population due to differences in a number of demographic, emotional and intellectual variables such as age, ethnicity and IQ (Gordon, Slade & Schmitt, 1986). However, a case can also be made that these individuals are unlikely to have experienced many of the negative effects of the lifestyles which are adopted by many incarcerated individuals such as substance abuse and violence (Patterson & Newman, 1993). Though not a "community" sample per se, individuals enrolled in Study 2 may be thought of as off-setting some of the difficulties with using an undergraduate sample. For example, they are more likely to have a broader intellectual range, as well as representing a different age group (middle age versus young adult). In relation to age, the sample from Study 2 may have found the cognitive tasks more challenging given that fluid intellectual abilities decline as we age (Salthouse, Pink & Tucker-Drob, 2008). This may have accounted for the fact that a relationship between psychopathic personality traits and executive function ability was established in several tasks in Study 2 versus only one (the IGT) in Study 1.

A weakness specific to Study 2 relates to the fact that we were forced to separate participants into groups based on neurological status rather than genetic diagnosis. Moreover, as FTLD is comprised of several clinical variants (frontal, temporal, progressive non-fluent aphasia), it is possible the ability to demonstrate differences between symptomatic and asymptomatic individuals was weakened by lumping phenotypically heterogenous groups together. Unfortunately, these difficulties are almost universally encountered in research investigating FTLD (Wittenberg, et al., 2008), given that a) these individuals are in the very earliest stage in the disease process and b) diagnosis and subtype can not be confirmed until autopsy. Another weakness associated with the FTLD study is the small number of participants that again, significantly compromises our ability to detect differences between groups. Again, this problem is common to most studies of FTLD given its low base rate for both sporadic and familial cases of the disease (Gass et al., 2006; Sikkink, Rollinson & Pickering-Brown, 2007). Importantly, Study 1 was able to account for this problem by recruitment of a much larger sample of individuals who were independent of one another. Moreover, low power due to small sample size (n = 12 for "ability to improve response strategy" on the IGT) may have been a reason why a similar finding as that obtained in Study 1 between Self-Centered Impulsivity and IGT performance was not demonstrated in Study 2.

Evaluation of Current Knowledge and Proposals For New Research

Self-centered impulsivity and impulsive decision making

Consistent with Miranda and colleagues (2009), high levels of Self-Centered Impulsivity predict poorer performance on the IGT. Moreover, these results extend Miranda et al.'s findings because they indicate that these individuals have difficulty improving their response strategy. In addition, studies investigating the broader trait, impulsivity and IGT performance also demonstrate a negative relationship between levels of impulsivity and performance on the IGT (Sweitzer, Allen & Kaut, 2008; Franken, van Strien, Nijs & Muris,

2008). While this finding was not replicated in Study 2, low power to detect differences may have been a factor. Importantly, this finding, along with Miranda et al. (2009) might account for previous null results regarding the relationship between psychopathy and IGT performance (Lösel & Schmucker, 2004), as it appears that only one of the two main factors which constitute psychopathic personality significantly predict performance on tasks of reward/punishment-based decision making. Based on these results and those of other studies (Miranda et al., 2009; Sweitzer et al., 2008; Franken et al., 2008; Davis, Patte, Tweed & Curtis, 2007) which demonstrate that impulsive personality traits relate to difficulty learning advantageous decision making strategies, future studies should investigate whether other types of decision making, such as reversal learning (reward-based learning designed to index adaptation of behavior according to changes in stimulus–reward contingencies; Clark, Cools & Robbins, 2004) also relate to Self-Centered Impulsivity. Like the IGT, reversal learning is also believed to be mediated via the orbital-medial prefrontal cortex (OMPFC) (Clark et al., 2004; Rolls, 2004). Should Self-Centered Impulsivity also negatively predict performance on this task, this would provide additional evidence for the suggestion that the neuroanatomical pathways for reward/punishment-based decision making and Self-Centered Impulsivity (and impulsive personality traits more generally) are perhaps common to one another.

A potential alternative hypothesis however, may be that impulsive individuals simply have more trouble following rules in general. In Study 2, Self-Centered Impulsivity was negatively related to rule violations across a number of traditional executive function tasks (e.g., sequencing errors on Trail Making Test, rule violations on verbal and design fluency, perseverative errors on the Wisconsin Card Sorting Task). Rule violations have been posited to result from working memory errors given that failure to follow explicit rules could result from degradation of task-relevant information held on-line (Possin et al., 2009). And like working memory (Aron, Robbins & Poldrack, 2004; Buschbaum, et al., 2005), rule violations have been shown to be preferentially related to (right) lateral prefrontal cortex

activity rather than more orbital or medial areas of the prefrontal cortex (Possin et al., 2009). Furthermore, working memory has been demonstrated to play a role in performance of reward/punishment decision making (Hinson, Jameson & Whitney, 2002; Jameson, Hinson & Whitney, 2004; Dretsch & Tipples, 2008). For example, Hinson and colleagues (2002) found that when working memory load was increased by adding a digit string to remember in between gambling trials, IGT performance declined in normal participants. As such, it appears that performance on the IGT might be dependent on how taxed working memory is during the task. Moreover, if working memory itself is dysfunctional, then this might also lead to poor performance on reward/punishment based decision making tasks, despite intact prefrontal regions thought to be sensitive to impulsive decision making, such as the orbital-medial prefrontal cortex. Given we did not measure working memory ability directly in Study 1, and found that rule violations were positively associated with Self-Centered Impulsivity in Study 2, future research should make sure to incorporate decision making and working memory measures so as to investigate this relationship more specifically. While we did not find that Self-Centered Impulsivity was significantly related to tasks of working memory in Study 2 (e.g., Digit Span, Spatial Span), upon inspection, the correlation coefficients were of moderate magnitude and in the predicted direction (higher levels of Self-Centered Impulsivity were related to poorer performance). It would also be important for investigators to discern whether working memory potentially mediates the relationship between Self-Centered Impulsivity and decision making on the IGT.

Self-centered impulsivity and behavioural disinhibition

Despite previous research indicating that impulsive personality traits relate to poor performance on tasks of response inhibition (Asahi, Okamoto, Okada, Yamawaki & Yokota, 2004; Sellbom & Verona, 2007; Morgan & Lilienfeld, 2000), results from both Study 1 and Study 2 do not support the hypothesis that Self-Centered Impulsivity is related to poorer

performance on these types of tasks. This is consistent however, with other studies that have not found an association with trait impulsivity and response inhibition measures (Lijffijt et al., 2004; Romer et al., 2009; Cheung, Mitsis, Halperin, 2004). For example Romer, et al. (2009) investigated trait levels of impulsivity in adolescents and did not find an association between impulsivity and performance on either the Flanker task or a variation of the Stroop task.

Research in both animals and humans indicates that impulsivity is a multi-dimensional construct (Evenden, 1999; Whiteside & Lynam, 2001; Patton, Stanford & Barratt, 1995). For example, principle components analysis of a commonly used measure of trait impulsiveness (Barratt Impulsiveness Scale 11; BIS-11; Patton et al., 1995) indicates that impulsivity can be divided into three factors: Attentional Impulsiveness, Motor Impulsiveness and Non-Planning Impulsiveness. Behavioural measures of impulsiveness have also been shown to factor into separable dimensions such as impulsive decision making (tasks requiring participants to make decisions about delayed versus immediate or probabilistic versus certain outcomes such as the IGT) versus impulsive disinhibition (inhibition of pre-potent motor behaviours such as the Stroop or Flanker task) (Reynolds, Ortengren, Richards & de Wit, 2006; Reynolds, et al., 2008). Furthermore, it appears that different factors of trait impulsivity map onto different executive functions related to impulsivity. For example, poor performance on a Stop-Signal Task was related to higher scores on the Motor Impulsiveness Scale of the BIS-11 (Gorlyn, Keilp, Tryon & Mann, 2005), while the Non-planning Impulsiveness Scale of the BIS-11 is associated with slower time to completion on a maze test (Pietrzak, Sprague & Snyder, 2008).

As Self-Centered Impulsivity captures other aspects of psychopathic personality, such as egocentricity, in addition to impulsivity, it was not constructed to tease out attentional or motor aspects of impulsiveness like the BIS-11. Given that impulsive decision making and impulsive disinhibition appear to relate to cognitive versus motor aspects of impulsivity, respectively (Reynolds, et al., 2006; Reynolds, et al., 2008), perhaps Self-

Centered Impulsivity is itself related more to cognitive impulsivity, rather than motor impulsivity. Future research should address whether Self-Centered Impulsivity is related to specific facets of impulsivity by including measures of trait impulsivity such as the BIS-11 (Patton et al., 1995) or the I-7 Impulsiveness Scale (Eysenck, Pearson, Easting & Allsopp, 1985) and evaluating the relationship between them. This may help guide future research as to which behavioural measures of impulsivity are likely related to Self-Centered Impulsivity.

Fearless dominance and executive function

The results of Study 2 indicate that after removing the variance associated with Self-Centered Impulsivity, higher levels of Fearless Dominance are positively associated with faster reaction times on two tasks of response inhibition (Stroop task and ANT Executive), indicating less cognitive conflict in relation to irrelevant or incongruent stimuli. Moreover, a similar relationship emerges in Study 1 between Fearless Dominance and ANT Executive when we remove Age and Block Design score from the regression analysis. Given that both Age and Block Design are known to share common variance with executive function performance (Salthouse, 2009; Salthouse, Atkinson & Berish, 2003; Friedman et al., 2006), this may be a possible reason why similar results were not found between Study 1 and Study 2. These results support Sadeh and Verona's (2008) findings which suggest that the psychopathic personality trait, Fearless Dominance is associated with reduced processing of task-irrelevant distracters. Moreover, they provide some explanation for why the literature has been equivocal with respect to discerning whether psychopathy is associated with enhanced attentional abilities (Hiatt, Schmitt & Newman, 2004; Brazil et al., 2009). It appears that, like reward/punishment decision making, enhanced attention is significantly associated with one (Fearless Dominance) but not the other (Self-Centered Impulsivity) psychopathic personality trait. While we did not demonstrate a relationship between Fearless Dominance and any other tasks of executive function, several other studies have

demonstrated that Fearless Dominance is associated with enhanced ability on tasks related to attention and working memory (Sellbom & Verona, 2007, Carlson, Thái & McLarnon, 2009, Carlson & Thái, in submission). Nevertheless, investigations into the relationship between Fearless Dominance and executive functioning are in the early stages of development. Research efforts should focus attention on discerning what specific domains of executive function are associated with Fearless Dominance (e.g., working memory, shifting of set, fluency) as well as replicating research which suggests that it is associated with enhanced response inhibition. These investigations should be conducted not only with university students, but with community and forensic samples of individuals. This will provide a greater understanding of how Fearless Dominance relates to executive function ability in the broader population, and will also provide clues as to the neuroanatomical relationship between the two.

Neuroanatomical relationship between executive function and psychopathic personality traits

Throughout this dissertation inferences have been made regarding the neuroanatomical seat of psychopathic personality traits via their relationship with executive functions. However, research is now utilizing magnetic resonance imaging to help understand the relationship between personality traits, cognition and behaviour. For example, using functional MRI, Schwartz, Wright, Shin, Kagan and Rauch (2003) have demonstrated that adults who were rated as "inhibited" at two years of age display greater bilateral activation of the amygdala during trials depicting novel versus familiar faces than those who were rated as "uninhibited". These results indicate that those who demonstrated an inhibited temperament early on in life displayed neurological signs indicative of this temperament even in their adult life. More recently, Gardini, Cloninger and Venneri (2009) investigated the neuroanatomy of personality more specifically by comparing gray matter volume with participant's scores on the Three-Dimensional Personality Questionnaire

(Cloninger, 1987). This measure is designed to assess four "psychobiological" aspects of personality: novelty seeking, harm avoidance, reward dependence and persistence. Voxel-based analysis of gray matter volume indicated that individual differences in personality traits were associated with structural differences in brain volume. For example, novelty seeking was positively associated with grey matter volume in the right middle and superior frontal gyri and posterior cingulate regions.

Future research endeavors should focus their attention on using functional neuroimaging techniques as a way to strengthen the arguments made for the neuroanatomical underpinnings of psychopathic personality traits and impulsivity more generally. Recently, Fullam and colleagues (2009) investigated the neuroanatomical relationship between psychopathic personality traits using the Psychopathic Personality Inventory (PPI) and a task measuring deception. While they did not investigate the two main factors of psychopathic personality, Self-Centered Impulsivity and Fearless Dominance, they did evaluate the relationship between each of the PPI content scales and brain activation during the deception task. Patterns of activation were correlated with five out of eight of the PPI content scale scores. For example, the scores on the scale Fearlessness were negatively associated with responses in the right orbital frontal lobe, while lower Stress Immunity scores were associated with greater bilateral activation of the insula. Other investigations could use similar study methodologies to investigate how the two main psychopathic personality factors relate to the executive function measures presented in this dissertation. Moreover, this kind of methodology could provide information regarding how hemispheric differences might relate to these traits, given that the right hemisphere appears to play a major role in appropriate social functioning. For example, individuals with right-sided frontal lobe lesions of the ventromedial prefrontal cortex are more likely to experience abnormalities of emotional processing, have disturbed social behaviour and be diagnosed with "acquired sociopathy" compared to those with left-sided lesions (Tranel, Bechara & Denburg, 2002). Similarly, individuals with FTLD whose

degeneration favours the right frontal lobe have been shown to demonstrate more aggressive, antisocial, socially inappropriate and sexually deviant behaviours as a first symptom of disease versus left-sided patients (Mychak, Kramer, Boone & Miller, 2001). Given the relative importance the right prefrontal cortex appears to play in socially appropriate behaviour, alongside research which suggests that psychopath's display poor right hemisphere processing (Hiatt & Newman, 2006), it would be interesting to discern whether psychopathic personality traits were preferentially related to right hemispheric function.

Overall Significance and Theoretical Implications

The results of this dissertation have implications for our understanding of psychopathic personality and the preponderance of equivocal findings in the literature on the relationship between executive function ability and the clinical disorder, psychopathy. The findings are consistent with previous research (Patrick & Bernat, 2009; Patrick, Edens, Poythress, Lilienfeld & Benning, 2006; Blonigen Carlson, Krueger & Patrick, 2003; Maesschalck, Vertommen & Hooghe, 2002), which suggest that psychopathic personality traits vary in non-incarcerated samples of individuals. Moreover, differential relationships were demonstrated between tasks of executive function and the two factors of psychopathic personality. Self-Centered Impulsivity was generally associated with poorer performance, while Fearless Dominance was associated with enhanced performance. Therefore, this suggests that mixed results in previous research on executive function ability and psychopathy may have been due to the fact that they did not examine task performance in relation to both factors of psychopathy, thereby diluting their ability to detect significant relationships.

More broadly, the results have implications for our understanding of the relationship between impulsive personality traits, executive function, and their suggested neuroanatomical basis and how this might translate into real-world behaviour.

Relationship to the "two process" theory of psychopathy

The findings of Study 1 and Study 2 provide evidence for the "Two Process" theory of psychopathy (Patrick & Bernat, 2009) in two important ways. First, the "Two Process Theory" posits that the traits, Fearless Dominance and Self-Centered Impulsivity are unrelated and dissociable from one another (Patrick & Bernat, 2009). While this was the case in Study 2, there was a small, significant relationship between the two factors in Study 1. While this finding is contrary to what we might expect based on factor analytical studies of these traits (Benning et al., 2003; Lilienfeld & Andrews, 1996), one other study has also demonstrated a small, significant relationship between the two factors (Uzieblo, Verschuere & Crombez, 2007). Despite this, neither Self-Centered Impulsivity nor Fearless Dominance shared associations with any of the same variables in either study. Moreover, while Fearless Dominance was associated with enhanced executive task ability; in general, Self-Centered Impulsivity was associated with reduced executive functioning. These results are in-line with previous research which indicates that these two traits either bear no relationship to the same variables, or if they do, have opposing relationships (Benning, Patrick, Hicks, Blonigen & Krueger, 2003; Justus & Finn, 2007). Moreover, they help to explain why equivocal findings are demonstrated in previous investigations of psychopathy and executive function which do not investigate relationships between executive function ability and both factors related to psychopathy.

Second, the "Two-Process" theory of psychopathy is meant to account for the presence of psychopathic personality traits in the normal population, and how this relates to the clinical manifestation of psychopathy. Having psychopathic personality traits is not sufficient to cause the disorder (as everyone has them to some extent); rather, it is the convergence of high levels of both of these traits that results in psychopathy itself. While the exact same relationships were not demonstrated between Fearless Dominance, Self-Centered Impulsivity and executive function ability in both studies, some of the hypothesized relationships were significant in both. This suggests that the processes

underlying these traits are possibly the same in two distinct, non-clinical populations (undergraduate students and individuals at-risk for FTLD). Again, this augments the idea that psychopathic personality traits a) are found in non-clinical (non-psychopathic) populations and vary, like any personality trait (Lilienfeld & Andrews, 1996; Blonigen et al., 2003) and b) their etiology is likely the same across all populations (Patrick & Bernat, 2009). Theoretically, this adds credence to the idea that the individual psychopathic personality traits (Self-Centered Impulsivity or Fearless Dominance) in and of themselves do not unequivocally result in psychopathy.

The "Two Process" theory of psychopathy posits that the trait Fearless Dominance results from deficiencies in limbic circuitry involved in fear processing (namely, via the amygdala) while Self-Centered Impulsivity arises from dysregulation of frontal-subcortical systems underlying appetitive motivation and behavioural control (Patrick & Bernat, 2009). Because executive functioning is thought to be largely mediated by the frontal lobes (Stuss & Levine, 2002), only Self-Centered Impulsivity should be associated with deficits in executive functioning. Results of both Study 1 and Study 2 support this hypothesis. Self-Centered Impulsivity was negatively associated with tasks thought to be mediated by different aspects of the prefrontal cortex (Iowa Gambling Task/OMPFC and Rule Violations/DLPFC), suggesting that Self-Centered Impulsivity is the result of broad deficits in prefrontal cortex function. Also in line with the "Two-Process" theory was the finding that Fearless Dominance was not associated with decrements in executive function performance; rather, this trait was associated with superior task performance on some measures. This enhancement of performance has been suggested to be due to reduced interference of cognitive processes by negative emotions such as fear and anxiety, due to Fearless Dominance's proposed etiological basis (Patrick & Bernat, 2009).

Impulsivity and executive functions

The psychopathic personality trait Self-Centered Impulsivity has been shown to correlate well with the general trait, impulsivity. Studies investigating the relationship between Self-Centered Impulsivity and the Behavioural Activation System (BAS; the biological system thought to underlie impulsivity in Gray's Reinforcement Sensitivity Theory, 1987) have demonstrated a significant association between the BAS scale of Carver and White's (1994) BIS/BAS-Scales and Self-Centered Impulsivity (Ross, Benning, Patrick, Thompson & Thurston, 2009; Uzieblo, et al., 2007). Moreover, Self-Centered Impulsivity maps on to the same factors that are theorized as being related to impulsivity in several broad measures of personality, including Tellegan's Multidimensional Personality Questionnaire (1982) and the Five-Factor Model of Personality (Costa & Macrae, 1992) (Benning, et al., 2003; Ross et al., 2009). As such, broader implications regarding the nature of the relationship between impulsivity and executive function can be drawn from this research. Consistent with previous research suggesting that higher levels of impulsivity are associated with poorer decision making in reward/punishment based paradigms (Davis, et al., 2007; Sweitzer, et al., 2008; Franken, et al., 2008), higher levels of Self-Centered Impulsivity predicted inability to improve response strategy on the IGT. In addition, this trait was also associated with the likelihood making more rule violations across different measures of executive functioning. It has been suggested that trait impulsivity results when there is a break-down in executive inhibitions (cognitive processes that occur for intentional control or suppression of response in the service of higher order or longer term goals; as opposed to immediate stimulus incentives) (Nigg, 2000). The results of this dissertation support this suggestion, given that impulsive personality traits were found to negatively relate most to complex aspects of behaviour, requiring inhibition of dominant responses in favour of more desirable long term outcomes. Moreover, these results provide laboratory evidence for the observation that impulsive individuals do not seem to learn from

their mistakes and are more likely to disregard rules and make poor long-term decisions for themselves (Gorenstein & Newman, 1980; Patterson & Newman, 1993).

Finally, the results of this dissertation speak to the role of impulsivity as a key component of both personality and cognition, thereby influencing not only who we are, but how we control what we do. Moreover, this link may occur through a common neurological substrate, the prefrontal cortex. Indeed, the fact that hypothesized results were demonstrated between impulsive personality traits and executive functioning in two distinct populations, one neurologically normal, the other at-risk for frontal lobe degeneration, supports this idea. As such, it appears that the personality trait impulsivity and cognitive inhibitions are interrelated, thereby influencing the very nature of who we are, and by that token, how others in our world perceive us.

Potential Applications For Future Research

Enhanced diagnosis of FTLD

Despite the fact that FTLD is the second most common cortical dementia affecting people under the age of 65 (Ratnavalli, Brayne, Dawson & Hodges, 2002), serious research efforts to understand its etiological and phenotypic presentation are still in its earliest stages (Wittenberg, et al., 2008). As such, sensitive and specific indicators of disease onset have yet to be discovered, while screening tools for diagnosis are virtually non-existent (Wittenberg, et al., 2008). By the time diagnosis occurs, we are limited in our ability to not only help the client, but also increase our knowledge about the earliest stages of the disease. It is important that research put increased efforts into exploring the early warning signs of the disease, be they cognitive, behavioural or personological. Moreover, because treatment options are currently limited to pharmacotherapy for neuropsychiatric symptoms (Mendez & Cummings, 2003), continuing to gather knowledge about the earliest stages of the disease may pave the way for critical insights into treatment. While dementia screening

tools such as the Mini-Mental State Exam (MMSE; Folstein, Folstein & McHugh, 1975) or the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) have been developed, they were created in such a way as to pick up on early signs of dementias that primarily effect episodic memory and visuospatial function. With the rate of all dementias on the rise (Mendez & Cummings, 2003), the need to develop screening tools for other types of dementia is at a crucial point. Research that investigates the early signs of non-Alzheimer type dementia may aide in the development of these types of screening tools. For example, though more research needs to be conducted on larger samples of individuals, based on the findings of Study 2, short cognitive batteries focused on tasks of attention, working memory and inhibitory processes might provide greater accuracy in picking up subtle changes in individuals who have dementias that affect frontal lobe function.

Treatment of psychopathology

Those working in rehabilitation settings are well aware that individuals with brain injuries and strokes often have symptoms of disinhibition and impulsivity which coincide with deficits in executive functioning (Rosenthal & Ricker, 2000; Caplan & Moelter, 2000). As such, training programs have been developed that often prove helpful in remediating these individual's cognitive abilities, which in turn leads to a reduction in impulsive behaviours (Sohlberg & Mateer, 2001). As impulsivity is a prominent feature of many types of psychopathology (Flory et al., 2006; Krueger & Tackett, 2003), it seems possible that this type of training might also be of benefit in the treatment of these disorders (e.g., symptom reduction). Moreover, it may also prove beneficial to improving treatment engagement and adherence. Indeed, research indicates that individuals with schizophrenia benefit greatly from cognitive remediation programs which target executive functions (Bellack, 2004). Cognitive training has also been shown to improve psychological treatment outcome in individuals with depression and generalized anxiety disorder (Siegle, Ghinnassi & Thase, 2007; Mohlman, 2008). Moreover, research suggests that cognitive remediation

and organizational skills training can improve both academic function and symptoms of attention-deficit hyperactivity disorder in both children and adults with this disorder (O'connell, Bellgrove, Dockree, & Robertson, 2006; Shalev, Tsal & Mevorach, 2007; Langberg, Epstein & Graham, 2008). As we know that variations in executive function and impulsivity exist outside the realm of psychopathology (Pietrzak, et al., 2008; Keilp, Sackeim & Mann, 2005; Reynolds, et al., 2006; Spinella, 2004), cognitive training programs targeted for the classroom could be developed as a way to help improve executive functioning in all children and potentially reduce impulsive behaviour.

Conclusion

We are all familiar with the construct of impulsivity, be it via our own impulsive tendencies, or by watching those around us who chronically talk or behave without forethought to the consequences of their actions. This relationship is even more apparent in individuals with particular types of mental illness or neurological disorders (Krueger et al., 2002; Hicks, Krueger, Iacono, McGue & Patrick, 2004; Boxer & Miller, 2005; Rosenthal & Ricker, 2000). Impulsivity has a dual-identity as both a personality trait and a failure of cognitive control. This raises important questions regarding its etiology or neuroanatomical basis.

The research presented here was designed to increase our understanding of the interplay between impulsive personality traits and the cognitive domain of executive functions. Moreover, the neuroanatomical basis of this interplay was examined by utilizing measures which engage different areas of the prefrontal cortex. The results provide partial support for the hypothesis that individuals who possess higher levels of impulsive personality traits tend to perform more poorly on tasks of executive function than individuals with lowers levels of impulsive personality traits. These deficits appeared to be specific to impaired ability to adopt an advantageous decision making strategy in the face of reward and punishment, as well as a general inability to follow rules during task completion.

These deficits implicate both ventral-medial and dorsal-lateral aspects of the prefrontal cortex in impulsive personality.

Despite significant advances made in the past 30 years with respect to our understanding of impulsivity, we are still far from understanding its potential to impact myriad different aspects of human behavior. It is therefore likely that these and other investigations represent only a fraction of the full influence of this trait. However, these are important first steps. Given its ubiquity in our day-to-day lives, research efforts must continue to refine our understanding of impulsivity by investigating it from as many avenues as possible, be it biologically, behaviourally or cognitively.

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APPENDICES

Appendix A.1

Kendall's Tau Correlations Between Control Variables, PPI-R Factor Scores and Executive Function Tasks

	Stroop Conflict	Δ (Good - Bad)	ANT Alerting	ANT Orienting	ANT Executive
Age	-0.01	-0.03	0.04	0.06	**0.14***
Fatigue	-0.04	0.02	0.09	0.05	0.09
Substance Use	-0.06	-0.03	-0.10	0.02	-0.06
WASI Vocabulary	-0.11	0.10	-0.001	-0.08	0.05
WASI Block Design	**-0.14***	0.08	-0.01	-0.05	**-0.20****
PPI-R Fearless Dominance	0.01	-0.05	0.01	0.02	-0.10
PPI-R Self-Centered Impulsivity	0.01	**-0.14***	-0.11	-0.06	-0.08

Note. Kendall's Tau was chosen rather than Pearson-Product Moment Correlations due to the minor non-normality of the distributions of most variables. PPI-R: Psychopathic Personality Inventory-Revised (scores are sex-corrected *z*-scores); WASI: Wechsler Adult Intelligence Scale; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task. PPI-R scores are sex-corrected *z* scores; Stroop Conflict reaction time is in seconds; ANT scores are in milliseconds; Δ (Good - Bad) scores are number of cards.
*$p \leq 0.05$;
** $p \leq 0.01$

Appendix A.2

***T*-Test: Sex and Neuropsychological Tasks**

Variable	Sex					
	Female		Male			
	n	**Mean (*SD*)**	***n***	**Mean (*SD*)**	***t***	***p***
Stroop Conflict	95	28.27 (10.35)	37	27.00 (12.06)	-0.61	0.55
Δ (Good - Bad)	95	11.52 (12.39)	37	12.86 (13.99)	0.54	0.59
ANT Alerting	92	28.36 (30.64)	36	29.03 (33.23)	0.11	0.91
ANT Orienting	92	46.48 (42.23)	36	38.17 (44.13)	-0.99	0.33
ANT Executive	92	92.21 (38.53)	36	91.21 (43.06)	-.13	0.90

Note. PPI-R: Psychopathic Personality Inventory-Revised; WASI: Wechsler Adult Intelligence Scale; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task. PPI-R scores are sex-corrected *z* scores; Stroop Conflict reaction time is in seconds; ANT scores are in milliseconds; Δ (Good - Bad) scores are number of cards.

Appendix A.3

***T*-Test: ESL Status and Executive Function Tasks**

Variable	English as a Second Language Status					
	English as First Language		English as Second Language			
	n	**Mean (*SD*)**	***n***	**Mean (*SD*)**	***t***	***p***
Stroop Conflict	71	26.62 (9.83)	61	29.43 (11.77)	1.49	0.14
Δ (Good - Bad)	71	12.11 (13.48)	61	11.64 (12.10)	-0.21	0.83
ANT Alerting	69	31.83 (29.99)	59	24.71 (32.52)	-1.23	0.20
ANT Orienting	69	45.71 (43.45)	59	42.31 (42.25)	-0.45	0.66
ANT Executive	69	96.18 (38.75)	59	86.95 (40.51)	-1.32	0.19

Note. PPI-R: Psychopathic Personality Inventory-Revised; WASI: Wechsler Adult Intelligence Scale; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task. PPI-R scores are sex-corrected *z* scores; Stroop Conflict reaction time is in seconds; ANT scores are in milliseconds; Δ (Good - Bad) scores are number of cards.

Appendix A.4

ANOVA: Executive Function Task by Ethnicity

	n	Mean (*SD*)	*df* (Between Groups; Within Groups)	*F* Ratio	*p*
Stroop Conflict			2, 126	1.02	0.36
European	52	26.00 (8.38)			
East Asian	48	28.25 (12.85)			
Other	29	29.21 (9.86)			
Δ (Good - Bad)					
European	52	13.27 (13.43)	2, 126	1.07	0.35
East Asian	48	11.88 (12.41)			
Other	29	8.97 (11.69)			
ANT Alerting					
EuropeanCaucasian	51	33.19 (28.55)	2, 122		
East Asian	47	23.54 (34.35)		1.20	0.30
Other	27	30.17 (29.99)			
ANT Orienting					
European	51	52.00 (42.49)	2, 122	1.74	0.18
East Asian	47	39.25 (41.70)			
Other	27	35.24 (45.57)			
ANT Conflict					
European	51	92.40 (41.22)	2, 122	0.88	0.42
East Asian	47	87.50 (34.66)			
Other	27	100.33 (45.99)			

Note. *F* ratio is the ratio between the Mean Squares Between (an estimate of the variance of the sample means) and the Mean Square Error (an estimate of the variance associated with experimental error). PPI-R: Psychopathic Personality Inventory-Revised; WASI: Wechsler Adult Intelligence Scale; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task. PPI-R scores are sex-corrected *z* scores; Stroop Conflict reaction time is in seconds; ANT scores are in milliseconds; Δ (Good - Bad) scores are number of cards.

Appendix A.5

ANOVA: Executive Function Task by Handedness

	n	Mean (*SD*)	*df* (Between Groups; Within Groups)	*F* Ratio	*p*
Stroop Conflict			2, 127	0.99	0.38
Left	7	25.57 (5.80)			
Non-Lateralized	15	24.47 (8.06)			
Right	108	28.31 (11.24)			
Δ (Good - Bad)					
Left	7	12.86 (8.71)	2, 127	0.67	0.51
Non-Lateralized	15	8.27 (13.26)			
Right	108	12.30 (13.00)			
ANT Alerting					
Left	7	24.96 (36.30)	2, 123		
Non-Lateralized	15	27.83 (19.43)		0.08	0.92
Right	104	29.46 (32.53)			
ANT Orienting					
Left	7	69.24 (16.74)	2, 123	1.33	0.27
Non-Lateralized	15	46.23 (24.17)			
Right	104	42.17 (45.86)			
ANT Conflict					
Left	7	110.55 (44.37)	2, 123	2.54	0.08
Non-Lateralized	15	73.60 (27.73)			
Right	104	93.89 (40.31)			

Note. *F* ratio is the ratio between the Mean Squares Between (an estimate of the variance of the sample means) and the Mean Square Error (an estimate of the variance associated with experimental error). PPI-R: Psychopathic Personality Inventory-Revised; WASI: Wechsler Adult Intelligence Scale; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task. PPI-R scores are sex-corrected *z* scores; Stroop Conflict reaction time is in seconds; ANT scores are in milliseconds; Δ (Good - Bad) scores are number of cards.

Appendix A.6

Verification of Violation of Assumptions of Hierarchical Regression and Outlier Analysis

In order to ensure the validity of our findings, violation of the assumptions associated with Hierarchical Regression was evaluated (i.e., linearity, homoscedasticity and normality of residuals; Cohen, Cohen, West & Aiken, 2003). To test linearity, scatterplots of the residual vs. each independent variable, and the residual vs. the overall predicted scores (Y-hats) were examined. A lowess line was fit to the data in order to visually inspect departures from linearity. Inspection of these plots did not reveal any departures from linearity in our data. To test homoscedasticity (the variance of the residuals is constant over the linear combination of predictors), non-constant variance plots were computed, creating a scatterplot of the square root of the residuals vs. Y-hat. A lowess line was then fit to the data. A score test was also performed to check for significance. This assumption was violated for the dependent variables of ANT Orienting and ANT Executive. As such, bootstrapping of standard errors was employed when analyzing the results of these regression analyses (Andrews & Buchinsky, 2000; Efron & Tibshirani, 1993). Finally, normality of the residuals was visually examined by checking the q-q plot of the residuals (the expected versus actual residuals), where a straight line at a 45º angle is indicative of normality. This assumption was violated for the dependent variables of Stroop Conflict and ANT Executive. Again, bootstrapping of standard errors was employed when analyzing the results of these regression analyses (Andrews & Buchinsky, 2000; Efron & Tibshirani, 1993).

In addition to the assumptions of hierarchical regression, it is also necessary to complete an analysis of inappropriately influential cases and problems arising from multicollinearity in the data. Following the method suggested by Cohen, Cohen, West and Aiken (2003), leverage, distance and influence were examined to determine the existence

of inappropriately influential cases. Leverage values for the predictors (how far from the overall mean of the predictor a particular observation is) were computed. Leverage values range from 0-1, with the average value being (k+1)/n (k = number of independent variables). As a rule of thumb, a leverage value twice this has been suggested to be a high value (Keith, 2006), and any case with a value over this was inspected. Distance refers to cases in which the observed Y scores are unexpected, given their X scores. Residuals were converted to studentized (*t*) residuals and examined for very large positive or negative values (e.g., those greater then an absolute value of 2.0). These cases were further examined for potential errors in data entry. Influence is the extent to which a point actually moves the regression plane, changing the slope of the estimates. Cook's D and DfBetas for each predictor were computed, where a value greater than 1 is suggestive of a case that holds high influence. Cases that had unusually high values for leverage and distance, and those that held high influence were examined carefully to identify whether they were outliers which were justifiable for exclusion from the analysis (e.g., data entry issue, from a different population). Examination indicated there was no justifiable reason to exclude any of these cases. As such, they remained in all analyses. Outlier analysis was also performed by inspecting box plots for each variable. Outliers were identified as those cases whose scores exceeded the third quartile by 3 x the Interquartile range or those who were less than the first quartile by 3 x the Interquartile range. When using this criterion, two outliers were identified, one within Age and one within ANT Alerting. These participant's scores were removed from subsequent analyses. Multicollinearity occurs when several independent variables correlate together at an excessively high level (Keith, 2006). Collinearity statistics (Variance Inflation Factor/Tolerance) were computed. All values were well under allowable standards (VIF < 10) indicating multicollinearity is not an issue in our data. All regression diagnostics and bootstrap re-sampling methods were conducted using Arc Version 1.06. Box plot inspection was conducted using SPSS Version 16.0.

Appendix A.7

Regression Analyses For ANT Alerting and ANT Orienting

Step in Regression Model	ΔR^2	$F\ \Delta R^2$	*df*	β's in Final Model	*p*-value for β
	ANT Alerting				
Step 1: Age	0.004	0.254	2, 122	0.054	0.558
Block Design				0.010	0.915
Step 2: Fearless Dominance	0.000	0.003	1,121	0.038	0.689
Step 3: Self-Centered Impulsivity	0.021	2.634	1,120	-0.152	0.107
	ANT Orienting				
Step 1: Age	0.012	0.746	2, 122	0.108	0.241
Block Design				0.029	0.757
Step 2: Fearless Dominance	0.007	0.833	1,121	0.092	0.331
Step 3: Self-Centered Impulsivity	0.001	0.171	1,120	-0.039	0.680

Note. ΔR^2 is the change in variance accounted relative to the previous step in the regression. By definition ΔR^2 for Step 1 is just R^2 for the predictors at this step. $F\Delta R^2$ is the *F* ratio for the test of significance of the change in variance accounted for with each new step in the regression model. β's are standardized partial regression coefficients from the model fit with all predictors in Step 3. Reaction time for ANT is reported from cases with no more than 20% errors on all trials. PPI-R measures are sex-corrected z-scores. PPI-R: Psychopathic Personality Inventory-Revised; ANT: Attention Networks Task

Appendix A.8

Mean and Standard Deviation of Choice of Card by Deck For All Participants On Block 1 and Block 5 of the IGT and Correlation Between PPI-R Factor Scores and Deck Choice in Block 1 and Block 5

Block 1			
Deck	**Mean (*SD*)**	**Self-Centered Impulsivity**	**Fearless Dominance**
A	3.93 (1.89)	-0.10	-0.12
B	8.57 (3.62)	-0.07	0.01
C	3.51 (1.80)	-0.11	0.14
D	3.99 (3.76)	-0.17	-0.02
Block 5			
A	3.71 (12.06)	0.10	0.05
B	5.69 (12.37)	0.12	0.11
C	6.79 (12.63)	0.04	0.00
D	9.48 (12.50)	0.04	0.08

Note. IGT: Iowa Gambling Task; n = 134.
All $p \geq 0.05$

Appendix A.9

Mean and Standard Deviation of Good, Bad, Good Minus Bad Decks and Total IGT Score For All Participants On Blocks 1 to Block 5 of the IGT and the Correlation Between Good Minus Bad Decks, Total IGT Score and PPI-R Factor Scores

		Mean (*SD*)	**Self-Centered Impulsivity (*r*)**	**Fearless Dominance (*r*)**
Block 1				
	Good (C+D)	7.49 (3.78)		
	Bad (A+B)	12.51 (3.78)		
	Good - Bad	-5.01 (7.57)	0.12	0.04
Block 2				
	Good (C+D)	12.07 (4.21)		
	Bad (A+B)	7.93 (4.21)		
	Good - Bad	4.13 (8.43)	-0.08	0.07
Block 3				
	Good (C+D)	13.14 (4.44)		
	Bad (A+B)	6.86 (4.44)		
	Good - Bad	6.28 (8.88)	-0.10	-0.16
Block 4				
	Good (C+D)	14.87 (11.81)		
	Bad (A+B)	8.59 (19.21)		
	Good - Bad	6.28 (13.52)	-0.12	-0.09
Block 5				
	Good (C+D)	16.27 (23.18)		
	Bad (A+B)	9.40 (24.01)		
	Good - Bad	6.87 (9.41)	**-0.18***	-0.10
Total IGT Score				
	∑ Block (Good-Bad)	18.55 (30.26)	-0.13	-0.09

Note. IGT: Iowa Gambling Task; *SD*: Standard Deviation; Total IGT Score = ∑ Block (Good-Bad); *r* = correlation coefficient;
$n = 134$
$^{*}p \leq 0.05$

Appendix A.10

Raw, *Z*-score and *T*-score Means and Standard Deviations For All Variables

Variable	Asymptomatic		Symptomatic	
	n	**Mean (*SD*)**	***n***	**Mean (*SD*)**
Age (raw)	15	48.00 (9.53)	11	53.45 (10.87)
Years of Education (raw)	15	14.23 (2.89)	11	13.73 (2.49)
Predicted Intelligence	15	0.55 (0.59)	11	0.07 (0.63)
PPI-R Self-Centered Impulsivity (*t*-score)	14	45.57 (5.15)	9	48.22 (6.06)
PPI-R Fearless Dominance (*t*-score)	14	48.57 (8.23)	9	50.44 (10.10)
State Anxiety (raw)	15	34.80 (12.01)	11	34.91 (13.60)
Trait Anxiety (raw)	15	32.47 (11.17)	11	32.72 (10.00)
Beck Depression Inventory (raw)	15	4.87 (5.37)	11	6.00 (7.09)
CVLT Trial 1	15	0.27 (1.61)	11	-1.43 (1.46)
Digit Span Forward	15	-0.08 (1.07)	11	-0.45 (0.90)
Trail Making Test A	15	0.02 (0.89)	11	-0.89 (1.74)
Digit Span Backward	15	0.11 (1.06)	11	-0.23 (0.88)
Spatial Span Total	14	0.57 (0.78)	11	0.12 (1.01)
WCST Perseverative Errors	15	-0.21 (0.65)	11	-0.62 (1.22)
Design Fluency	14	0.14 (0.77)	11	-0.45 (1.05)
Trail Making Test B	15	-0.13 (0.85)	10	-1.46 (2.75)
Stroop Interference	15	-0.15 (0.62)	11	-0.76 (1.04)
ANT Executive Attention (raw)	12	99.09 (53.20)	11	155.04 (84.13)
Letter Fluency	15	0.16 (0.86)	11	-0.64 (1.21)
Δ (Good – Bad) (raw)	7	13.71 (11.04)	8	4.75 (14.69)
Total Rule Violations (raw)	15	9.23 (4.65)	11	16.55 (12.44)

Note. All scores are presented in *z*-score form unless otherwise specified. *z*-scores were computed by using the norm-referenced mean and standard deviation. *t*-scores were also computed using the norm-referenced mean and standard deviation. PPI-R: Psychopathic Personality Inventory; CVLT: California Verbal Learning Test-II-Short Form; WCST: Wisconsin Card Sorting Task-64; ANT: Attention Networks Task; Δ (Good – Bad): Ability to improve response strategy variable, Iowa Gambling Task.

Appendix B.1

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Carlson, S.	Psychology	**B06-0312**

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

UBC Campus ,

CO-INVESTIGATORS

LaMarre, Amanda, Psychology

SPONSORING AGENCIES

TITLE

Neuropsychological Correlates of Psychopathic Personality Traits in Undergraduate Students

APPROVAL DATE	TERM (YEARS)	DOCUMENTS INCLUDED IN THIS APPROVAL:
MAY 17 2006	1	May 11, 2006, Consent form / Apr. 12, 2006, Advertisement / Questionnaires

CERTIFICATION

The application for ethical review of the above-named project has been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures

Appendix B.2

The University of British Columbia
Office of Research Services,
Clinical Research Ethics Board – Room 210, 828 West 10th Avenue, Vancouver, BC V5Z 1L8

Certificate of Full Board Approval

Clinical Research Ethics Board Official Notification

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Feldman, H.	Medicine	C05-0283

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

Other, UBC Campus, Vancouver Coastal Health Authority

CO-INVESTIGATORS:

Cashman, Neil, Medicine; Christoff, Kalina, Psychology; Dwosh, Emily, ; Hallam, Bradley, Medicine; Hsiung, Robin, Medicine; Leavitt, Blair, Medical Genetics; MacKenzie, Ian, Pathology & Laboratory Med; Sadovnick, Dessa, Medical Genetics

SPONSORING AGENCIES

Canadian Institutes of Health Research

TITLE

Clinical, Pathological and Genetic Studies in Frontotemporal Dementia

APPROVAL DATE	TERM (YEARS)	DOCUMENTS INCLUDED IN THIS APPROVAL
31 August 2005	1	Protocol; Peer Review Report; Investigator's Brochure version date 01 June 2005; Subject Consent Form version date 10 August 2005; Assent Form version date 20 May 2005; Request for Release of Medical Records version date 20 May 2005; Serum and DNA Banking Consent Form version date 10 August 2005; Autopsy and Brain Donation Consent Form version date 10 August 2005; Letter of Initial Contact version date 20 May 2005; Questionnaires and Tests version date 21 April 2005; VCHA Authority for Autopsy

CERTIFICATION:

In respect of clinical trials:

1. The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations.

2. The Research Ethics Board carries out its functions in a manner consistent with Good Clinical Practices.

3. This Research Ethics Board has reviewed and approved the clinical trial protocol and informed consent form for the trial which is to be conducted by the qualified investigator named above at the specified clinical trial site. This approval and the views of this Research Ethics Board have been documented in writing.

The documentation included for the above-named project has been reviewed by the UBC CREB, and the research study, as presented in the documentation, was found to be acceptable on ethical grounds for research involving human subjects and was approved by the UBC CREB.

The CREB approval for this study expires one year from the approval date.