Neuropsychological performance profiles in groups with harm avoidance (HA) and novelty seeking (NS) temperament trait clusters: an exploratory study

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ABSTRACT

Whilst there is a growing body of research investigating links between temperament, neuropsychological performance and psychopathology, as well as the neurophysiological aspects underlying temperament; few studies have sought to examine the neuropsychological performance profiles of different combinations of temperament trait clusters. Therefore, the aim of the study is to explore the differences in executive performance profiles within second order temperament trait clusters comprised of harm avoidance (HA) and novelty seeking (NS) as defined by Cloninger's Temperament and Character Inventory (TCI). Participants (N = 420) were evaluated using the Temperament and Character Inventory (TCI), and the PennCNP neuropsychological battery of executive functioning and abstract reasoning tasks.

The participants were clustered into four main groups evidencing impulsive (low HA and high NS; n = 121) and rigid (high HA and low NS; n = 131) traits, and those with hyperthymic (low HA and low NS; n = 75) and hypothymic (high HA and high NS; n = 93) reactive traits.

The results indicated firstly that when comparing rigid-trait individuals and impulsive-trait individuals, rigid-trait individuals reacted more slowly to both complex (executive functioning) and less complex tasks (attention and working memory) tasks. These individuals also attained fewer correct responses on complex tasks. Secondly, the results also revealed that hyperthymic-trait individuals demonstrated faster response times on the tasks, as well as performing consistently better on complex tasks (executive functioning) than hypothymic-trait individuals. These results are discussed within the psychobiological framework.

KEY TERMS

Psychobiological theory; neuropsychological performance; executive function; temperament; harm avoidance; novelty seeking; hypothymic; hyperthymic; impulsive; rigid.

CHAPTER 1
INTRODUCTION

1.1 OVERVIEW

Temperament, its biological basis and how it influences both personality and behaviour including related disorders, has enjoyed widespread attention dating as far back as 350 BC with the contributions of the Greek philosophers Hippocrates and Galen (Oakland, Pretorius & Lee, 2008). More recently, facilitated by developments in the fields of neurophysiology, neuropsychology and neuroimaging, various studies have focused on investigating the links between temperament (viewed as largely heritable) and psychiatric disorder, and more specifically the relationship between temperament, neuropsychological performance and psychopathology (Aigner, Sachs, Bruckmüller, Winklbaur, Zitter, Kryspin-Exner, *et. al*., 2007; Boeker, Kleiser, Lehman, Jaenke, Bogerts & Northoff, 2006; Guillem, Pampoulova, Rinaldi & Stip, 2008). Further to this, research has also set out to elucidate the neurophysiological aspects underlying and contributing toward temperament (Henderson & Wachs, 2007; O'Gorman, Kumari, Williams, Zelaya, Connor, Alsop, *et al*., 2006; Whittle, Allen, Lubman & Yücel, 2006) as well as related neuropsychological performance, and more specifically executive function – all of which have been aimed at the detection and diagnosis of sub-clinical putative risk factors for psychopathology, which continues to present a clinical challenge.

Thus whilst the results of these research endeavours have shown that various temperament traits and executive function performance share common neurotransmitter and neuroanatomical systems, with each individually implicated in the development of various psychopathologies, few studies have been conducted exploring specific temperament clusters and their accompanying executive function correlates. It is believed that these results may emerge as a valuable factor in the pursuit of identifying predictive attributes in the development of psychopathology.

The temperament clusters selected for this study constitute combinations of harm avoidance (HA) and novelty seeking (NS), two of the four temperament scales comprising the seven dimensions of personality assessed by the Temperament and

Character Inventory (TCI), an instrument derived from Cloninger's psychobiological theory of personality (Cloninger, Svrakic & Przybeck, 1993; Cloninger, Przybeck, Svrakic & Wetzel, 1994).

What follows is a brief explanation of the research problem and motivation for conducting the study. The chapter will then conclude with an overview of the structure the thesis will follow.

1.2 RESEARCH PROBLEM

This study, which forms part of a larger research initiative funded by the National Research Foundation (NRF) and the University of Pretoria Research and Development Fund, seeks to explore neuropsychological performance specifically in the area of executive functioning and abstract reasoning of the following HA (associated with the behavioural inhibition system or BIS) and NS (associated with the behavioural activation system or BAS) temperament clusters:

- Impulsive (low HA - high NS) and Rigid (high HA – low NS)
- Hyperthymic (low HA – low NS) and Hypothymic (high HA – high NS)

The data used was collected over a two-year period, the details of which are discussed later in the methodology section.

A thorough literature review revealed that whilst some research on the neuropsychological performance of temperament clusters has been done, such as the study by Meyer and Deckersbach (2005) which explored the neuropsychological performance associated with the hypomanic (hyperthymic) and rigid temperament clusters, more research is required to investigate the neuropsychological performance profiles of different combinations of the first order traits of HA and NS.

1.2.1 Harm avoidance (HA) and novelty seeking (NS) clusters, and neuropsychological performance

Previous research findings have linked HA, NS and neuropsychological performance, specifically executive function tasks requiring accuracy and speed. The explanation for these findings is the growing research that supports the notion that executive functioning and temperament share similarities in their neuroanatomical sites as well as neurotransmitter functions (Cassimjee & Murphy, 2010). For example, higher scores on HA (which involves neuromodulation associated with behavioural inhibition), are associated with the ability to delay responses for a longer period of time as tested by the Spatial Delayed Response and Finger Tapping exercises (Cloninger, *et. al.*, 1994). Higher scores on NS (involving neuromodulation associated with behavioural activation) are in turn, associated with poor attention or learning lists of words as tested by the Rey Auditory List Learning test. Thus, the first order temperament traits HA and NS have, as predicted, been associated with specific neuropsychological performance deficits.

With this in mind, differences in executive functioning and abstract reasoning between HA and NS were analysed. The executive function and abstract reasoning tests were selected from The University of Pennsylvania Computerised Neuropsychological Test Battery (PennCNP). Performance indices comprised accuracy scores (number correct) and speed (median reaction time for correct responses).In order to derive the temperament clusters, the participants were divided into two groups (due to the data exhibiting a relatively normal distribution) in terms of the HA and NS scores (Low and High):

- **Low:** total score <= mean score
- **High:** total score >= mean score

A further categorisation was conducted where participants were classified in terms of four a priori groups based on their combination scores for HA and NS as defined in the typology above.

1.2.2 The research instruments employed in the study

As stated above, this study forms part of a larger research initiative funded by the National Research Foundation (NRF) and the University of Pretoria Research and Development Fund and uses data collected over a two-year period. The instruments used include the Temperament and Character Inventory (TCI) based on Cloninger's psychobiological theory of personality, and the Executive Function and Abstract Reasoning test battery from The University of Pennsylvania Computerised Neuropsychological Test Battery (PennCNP). The TCI comprises a questionnaire that assesses normal and abnormal behaviour patterns based on seven dimensions comprised of four temperament scales and three character scales. Combinations of the temperament scales HA and NS are used for the purposes of this study. The specific neuropsychological tests used include the MPRAXIS general sensory-motor test; the Penn Abstraction, Inhibition and Working Memory Task (AIM); the Letter-N-Back (LNB2); the Penn Conditional Exclusion Task (PCET); the Penn Short Logical Reasoning Test (SPVRT); and Short Raven's Progressive Matrices (SRAVEN).

1.3 MOTIVATION

The theoretical motivation rests on the basis that the HA and NS traits and executive function performance have been shown to share common neurotransmitter and neuroanatomical systems. Whilst existing research supports the link between neuropsychological performance and temperament dimensions, little research has been conducted to determine whether deficits in executive functioning and second order temperament clusters (rigid, impulsive, hypothymic and hyperthymic) present independent risk factors for the development of psychopathology. As such, both the detection and diagnosis of sub-clinical putative risk factors for psychopathology remains a clinical challenge. It is believed that the categorisation of premorbid temperament clusters and the exploration of accompanying executive function correlates may emerge as a valuable factor in this area of inquiry.

This study attempts to identify specific temperament clusters and their related executive functioning performance profiles, thereby contributing to knowledge regarding specific neurobiological features that increase vulnerability for psychopathology. Therefore, the aims are firstly to establish the executive performance profiles associated with the above-mentioned second order clusters; and secondly, to identify significant differences between and within these clusters.

1.4 THESIS STRUCTURE

The literature review provides a detailed summary of research conducted in the fields of temperament and executive functioning including neuroanatomical aspects as well as personality models underlying current understandings of the above-mentioned. This is followed by the methodology which elucidates the relevant areas of exploration; the sampling and instruments used; and the research design and process. A discussion of the results then follows which includes the statistical analyses employed. The results for each test relative the specific temperament cluster is described including the relationships between the variables. The thesis then proceeds with a discussion of the findings in which the theory, results, and literature reviewed are integrated. This is then followed by a final conclusion and recommendations.

1.5 CONCLUSION

Whilst a number of studies have been conducted which have reported findings that support the link between neuropsychological performance and temperament dimensions, few studies have been conducted to determine whether differences in executive functioning and second order temperament clusters comprising combinations of harm avoidance (HA) and novelty seeking (NS) (rigid, impulsive, hypothymic and hyperthymic) present independent risk factors for the development of specific psychopathologies. Based on the premise that temperament traits HA and NS and executive function performance have been shown to share common neurotransmitter and neuroanatomical systems, it is believed that this investigation may contribute to knowledge regarding specific neurobiological features that may increase vulnerability for psychopathology, thereby aiding in the detection and diagnosis of sub-clinical putative risk factors for this.

CHAPTER 2
LITERATURE REVIEW

2.1 OVERVIEW

This literature review provides the contextual backdrop against which the current study is set. The aim of this research is to explore executive function and abstract reasoning abilities of participants grouped according to combinations of temperament clusters harm avoidance (HA) and novelty seeking (NS). These groupings are referred to as Impulsive, Rigid, Hyperthymic, and Hypothymic, with Impulsive comprising low HA and high NS scores; Rigid comprising high HA and low NS scores; Hyperthymic comprising low HA and low NS scores; and Hypothymic comprising high HA and high NS scores.

Substantial evidence exists suggesting a genetic link to temperament and personality (Auerbach, Faroy, Ebstein, Kahana & Levine, 2001; Gillespie, Cloninger, Heath & Martin, 2003; Moore, Aitken Schermer, Paunonen & Vernon, 2010; Shiner & Caspi, 2003), with personality evolving from the interaction between temperament and environment, or what Tackett (2006, p. 585) refers to as "cognitive and emotional stages that increasingly allow [children] to interact with, experience, and respond to the world in more complex ways". Temperament speaks to individual differences in both self-regulation or self-constraint and reactivity. This includes the propensity toward being inhibited or uninhibited in response to possible reward or punishment; as well as skills such as delaying gratification, planning responses to situational demands, and inhibiting impulsive behaviour (Berger, Kofman, Livneh & Henik, 2007; Olson, Bates, Sandy & Schilling, 2002; Shiner & Caspi, 2003). In addition, temperament is believed to influence how children learn, retain and retrieve information, how they form values, how they relate to both superiors and peers, and how they are motivated (Oakland, Alghorani & Lee, 2007). It is postulated that these qualities provide the foundation for the development of the personality (a more encompassing and pervasive manifestation of the interaction between temperament and the environment as noted above) as well as potential predisposing factors in the development of psychopathology (Richter & Brändström, 2009; Whittle, *et al.*, 2006).

A number of studies point to the contribution temperament makes in the development of various physical and psychological problems identified in both adult and child populations (Baum, Byars, deGrauw, Dunn, Bates, Howe, *et al.*, 2010; Neppl, Donnellan, Scaramella, Widaman, Spilman, Ontal, *et al.*, 2010; Ortiz & Gándara, 2006; Shiner & Caspi, 2003; Sovio, King, Miettunen, Ek, Laitinen, Joukamaa, *et al.*, 2007). According to these studies, physical abnormalities include metabolic syndrome markers and cardiovascular disease; and psychological manifestations such as behaviour disorders, personality disorders and problematic social skills, cognitive abilities, aggression and anger – all of which are implicated in the development of psychopathology.

Having said this however, little research has been done investigating the influence of more specific dimensions of temperament which has necessitated further research in this area. Similarly, whilst a number of studies have explored the link between neuropsychological performance and various disorders, very little research exists which examines the link between neuropsychological performance, and more specifically executive function and abstract reasoning, and temperament dimensions/traits. Hence, the aim of this research is to explore combinations of the temperament dimensions harm avoidance (HA) and novelty seeking (NS) as per Cloninger's Temperament and Character Inventory (TCI), an instrument derived from his psychobiological[1] model of personality, and their related neuropsychological performance.

2.2 TEMPERAMENT AND PERSONALITY AS CONSTRUCTS

Interest in temperament and personality dates back thousands of years, underpinned by the need to understand the human psyche or explain some aspect of human nature and the development of psychopathology (McRae & John, 2001; Oakland *et al.*, 2008; Tackett, 2006). As constructs, temperament and personality are seen as both separate and overlapping, with current agreement that temperament "emerges prior to and remains a component of personality" (Oakland, *et al.*, 2008, p. 628).

[1] Throughout this document, the terms psychobiological, biosocial and biopsychosocial are used interchangeably.

Personality in turn, is defined as an integrated pattern of feeling, thinking and behaving that differs between individuals but that remains relatively stable over time (Papageorgiou, Beratis, Rabavilas, Nanou, Hountala, Maganioti, *et al*., 2010; Suslow, Kugel, Reber, Bauer, Dannlowski, Kersting, *et al*., 2010)

Carl Jung contributed significantly to more contemporary theories of temperament by suggesting that individual differences in temperament are a result of the mediation between physiological or genetic qualities and the environment (Oakland, *et al*., 2008; Oakland, Alghorani & Lee, 2007*)*, providing the premise on which the biosocial theories of personality are built. These theories define temperament as heritable and biologically based differences in thought, emotion, and behavioural proclivities that are identified early in life and remain relatively stable across situation and time, even transcending nations (Baum, *et al*., 2010; Berger, *et al*., 2007; Henderson & Wachs, 2007; Oakland & Lu, 2006; Whittle, *et al*., 2006).

Current thinking also espouses that temperament reflects behavioural tendencies rather than specific behaviours and its expression is influenced by social, cognitive, and motivational developmental qualities (Oakland, *et al*., 2008; Tackett, 2006); and conversely, that many developmental outcomes are the result of the influence played by individual differences in temperament (Neppl, *et al*., 2010) However, it is also accepted that temperament traits can fluctuate as a function of social and cultural experiences (that is, environmental influences), personal choices, age, gender, and personality (Light, Joyce, Luty, Mulder, Carter, Frampton, *et al*., 2007; Oakland, *et al*., 2007; Shiner & Caspi, 2003). A recent study by Al-Halabí, Herrero, Saiz, Garcia-Portilla, Corcoran, Bascaran *et al*. (2010) underpins this with results that show that NS decreases with increasing age in men, whilst HA increases with increasing age in both men and women with women scoring higher in general on HA than men. After controlling for age, Al-Halabí *et al*. (2010) further showed that demographic variables which include education level, civil status, employment status, and place of residence were all strongly associated with NS and HA in both men and women.

A number of biosocial models of personality exist which have sought to describe the relationship between biology, genetics, and personality (Ha, E. Kim, Abbey & T. Kim, 2007; McRae & John, 2001; Oakland, *et al*., 2007; Oakland, *et al*., 2008); and similarly, the relationship between personality and psychopathology (Matsudaira, 2006; Trull, 2000). Within this context, various theorists have explored the biological underpinnings of temperament given its heritable and relatively stable nature, including Jung, Eysenck, Gray, and Cloninger, whose models share theoretical links (Mardaga & Hansenne, 2007). What follows is a brief overview of these prominent theorists' models, culminating in a more detailed discussion of Cloninger's psychobiological theory of personality, which provides the theoretical framework encompassing this study.

2.2.1 Biosocial models of personality

There is general agreement amongst the various biosocial theories that certain temperament dimensions are heritable, linked to neurobiological markers, and relatively stable over time (Cho, Hwang, Lyoo, Yoo, Kin & Kim, 2008; Gardini, Cloninger & Venneri, 2009; Park, Kim, Lee, Kim & Chae, 2009; Wahba & McCroskey, 2005). These temperament dimensions have also been shown to be universal across culture and ethnicity, exhibiting a normal distribution, and which are identifiable in early childhood (Ha, *et al*., 2007; Kantojärvi, Miettunen, Veijola, Läksy, Karvonen, Ekelund, *et al*., 2008; Ravaja, Keltikangas-Järvinen & Kettunen, 2006). Biosocial theories posit that personality (and associated disorders) is the product of an interaction between genetic, biological, and social factors (Bond, 2001; Cho, *et al*., 2008; Kemp & Center, 2003; White, 1999). For example, impulsivity and inattention (directly linked to self-regulatory competence) are influenced by the early infant-primary caregiver relationship, infant/toddler temperament traits and cognitive functioning, specifically executive competence (Olson, *et al*., 2002).

2.2.1.1 Jung's three-part temperament theory

Carl Jung's three-part temperament model laid the foundations for what can be considered contemporary personality theory (Oakland, *et al*., 2007; Oakland, *et al*., 2008). He proposed that the way a person experiences the world is influenced by two dominant attitudes. The first concept is Extroversion, which reflects a tendency toward social conformity and a dependence on the environment and others as a source of energy. The second concept is Introversion, which reflects the tendency toward more personal independence combined with internal thoughts and representations as their source of energy. These concepts were elaborated on further by Eysenck and Gray respectively, who sought to explore their biological underpinnings and establish an empirical basis from which to understand personality.

2.2.1.2 Eysenck's extraversion, neuroticism and psychoticism theory

Eysenck's biosocial model proposed that personality is the result of the interaction between social experience and temperament (Kemp & Center, 2003; White, 1999). He researched the relationship between temperament and cortical arousability positing that differences in introverts and extraverts were the result of differences in the ascending reticular activating system (ARAS), which involves the activation and deactivation of the cerebral cortex (Robinson, 2001; Tsanadis, 2005). The ARAS originates in brainstem reticular formation in the medulla oblongata, extending to the cortex via the thalamus, caudate nuclei, and limbic cortex (Suslow, *et al.*, 2010).

Eysenck believed that introverts have an overactive ARAS and as a result, they seek low-stimulation settings to keep their heightened levels of arousal under control. In fact, research has shown that introverts require greater levels of sedative drugs to reach a required level of sedation than extraverts. This arousal differentiation may result from a threshold approximation where introverts have a higher "basal level of cortical arousal" than extraverts (Center, Jackson & Kemp, 2005; Hagemann, Hewig, Walter, Schankin, Danner & Naumann, 2009; Robinson, 2001; Tran, Craig, Boord, Connell, Cooper & Gordon, 2006). Extraverts on the other hand, have an underactive ARAS and as such, engage in sensation seeking behaviours in an attempt to increase their arousal levels. Eysenck's theory evolved into a three-factor model referred to as the ENP model, which describes temperament in terms of three personality dimensions, namely extraversion (E), neuroticism (N), and psychoticism (P) (Wahba & McCroskey, 2005). N is characterised by heightened sensitivity to negative or punishment cues in the environment, whereas E is associated with a more optimistic social and cooperative stance, where contact with others is sought rather than avoided (Gioia, Cerasa, Valentino, Fera, Nisticò & Liguori, 2009).

2.2.1.3 Gray's Reinforcement Sensitivity Theory

Another influential biosocial theory is that of Jeffrey Gray's called the Reinforcement Sensitivity Theory (RST). This theory focuses on the interactions between three hypothesised biological brain systems (the behavioural inhibition system [BIS], the behavioural activation system [BAS] and the flight-flight system [FFS]), which Gray believed accounted for the individual differences in temperament (Corr & Perkins, 2006; Erdle & Rushton, 2010; Mardaga & Hansenne, 2007; Park, *et al*., 2009; Tsanadis, 2005; White, 1999). The BIS/BAS model is based on the individual's predilection to avoid punishment or pursue reward, respectively (Mitchell & Nelson-Gray, 2006). These tendencies are linked to Eysenck's neuroticism (N) and extraversion (E) as well as Cloninger's temperament dimensions of harm avoidance (HA) and novelty seeking (NS) discussed below (Zuckerman & Cloninger, 1996).

According to this model, the BIS is associated with anxiety and a conditioned response when an individual is confronted with potential punishment or non-reward triggered by exposure to novel stimuli; whereas the BAS is associated with impulsivity and a conditioned response to the possibility of reward or relief from punishment (Rafiena, Azadfallah, Fathi-Ashtiani & Rasoulzadeh-Tabatabaiei, 2008).

The septohippocampal system is considered as the neural substrate underlying BIS (Corr & Perkins, 2006). This includes the noradrenergic and serotinergic pathways linking the locus coeruleus and the raphe nuclei to the system respectively, as well as the neocortical structures including the prefrontal cortex linked to the system (Tsanadis, 2005). The BIS in turn, has been linked to activity in the anterior cingulate, right amygdala, and the thalamus (Corr & Perkins, 2006).The BAS is said to predominantly involve the dopaminergic (DA) pathways with evidence suggesting that the neural substrate underlying reward sensitivity or incentive motivation involves excitability of the mesocorticolimbic DA pathway (Alcaro, Huber & Panskepp, 2007; Davis, Patte, Tweed & Curtis, 2007; Tsanadis, 2005; Zellner & Ranaldi, 2010). This pathway ascends in the ventral tegmental area, through to the nucleus acumbens and the ventral striatum, incorporating the basal nuclei, the neocortical regions that connect to the basal nuclei, and the thalamic nuclei. Gray concluded that the BIS/BAS shared significant similarities with Eysenck and

Eysenck's ENP model, linking BIS to neuroticism (N) and BAS to extraversion (E) in terms of shared attributes, neurobiological functioning, and neurobiological circuitry (Wahba & McCroskey, 2005). Research has also added a great deal of support to Eysenck's theory that both anxiety and depressive disorders are correlated with high scores on N (similar to Cloninger's HA) and even more so when combined with low E scores (Cloninger's NS dimension) thereby underpinning the belief that high N and low E are the best predictors for the development of emotional disorders (Kemp & Center, 2003), with N being strongly related to coping choices and cognitive appraisals when confronted with anxious situations (Shoji, Harrigan, Woll & Miller, 2010).

2.2.1.4 Summary

All three models have therefore been shown to be relatively consistent with one another, with Eysenck and Eysenck's extraversion (E) linking to Cloninger's NS and Gray's BAS; and similarly, Eysenck and Eysenck's anxiety proneness of neuroticism (N) linking to Cloninger's HA and Gray's BIS (Bond, 2001; Park, *et al.*, 2009; Fukuda, Kuratsune, Tajima, Takashima, Yamagutchi, Nishizawa, *et. al.*, 2010; Tsanadis, 2005). Findings by both Eysenck and Eysenck and Cloninger using twin studies and a genome-wide scan, have shown significant heritability of these traits (Bond, 2001; Gillespie, *et. al.*, 2003). Personality traits, specifically extraversion (E) and neuroticism (N) have been found to influence information processing, bearing in mind that mood states have a moderating affect on interpretation and judgement (Rafiena, *et al.*, 2008). E entails attributes such as stimulus responsiveness, energy, dominance, positive emotionality, cooperativeness, and sociability (similar to those in NS); and N incorporates aspects such as emotional instability, vulnerability to anxiety, depression, shyness or self-consciousness, and avoidance, all of which are similar to the attributes found in HA (Jylha, Melartin & Isometsä, 2009). Individuals with high N have been shown to be at risk for developing anxiety disorders, whilst individuals with high E have shown a vulnerability to developing addiction disorders (Hooker, Verosky, Miyakawa, Knight & D'Esposito, 2008). Further, high N has been identified as a risk factor in the development of anxiety and depressive disorders, psychosomatic disorders such as chronic fatigue syndrome (CFS) as well as being positively associated with PDs; whilst E had been linked to the presence of histrionic and narcissistic PDs (Jylha, *et al.*, 2009; Fukuda, *et al.*, 2010).Psychoticism on the other hand is linked to a lack of impulse control which includes aggressive and hostile tendencies.

2.3 CLONINGER'S PSYCHOBIOLOGICAL THEORY OF PERSONALITY

C. Robert Cloninger proposed a psychobiological model describing personality in terms of the interaction between temperament and character (Cloninger, *et. al.*, 1993). Cloninger's theory suggests that temperament develops prior to character, and the development of personality is the result of an "iterative epigenetic process" wherein temperament and character interact with one another (Gillespie, *et. al.*, 2003, p. 1933). This model is a product of years of investigation integrating information gathered from a number of sources including longitudinal studies of development, twin and family studies, psychometrically tested aspects of personality structure, neuroanatomical and neuropharmacologic aspects of learning, and behavioural conditioning in both animals and humans (Gillespie, *et al.*, 2003; Miettunen, Lauronen, Kantojärvi, Veijola & Joukamaa, 2008). From this, Cloninger's seven-factor biosocial model of personality evolved. This model is comprised of three character traits (self-directedness [SD], co-operativeness [C] and self-transcendence [ST]); and different combinations of four basic temperament dimensions or traits which he postulates govern habits and automatic emotional responses. These traits are harm avoidance (HA), novelty seeking (NS), reward dependence (RD) and persistence (P) (Gillespie, *et al.*, 2003; Ha, *et al.*, 2007; Kantojärvi, *et al.*, 2008; Lundqvist, 2008). A number of studies have consistently found that low scores on self-directedness (SD) and cooperation (C) are essential features of personality disorders, confirming the validity of the TCI as a diagnostic instrument in establishing the absence or presence of personality pathology (Bond, 2001; Fukuda, *et al.*, 2010); however, the temperament traits of HA and NS are pertinent for the purposes of this study and will therefore be the focus of the discussion.

2.3.1 Novelty seeking (NS) and harm avoidance (HA)

NS is an individual's tendency to action behaviours and is associated with the genetic bias to impulsivity, quick loss of temper, and exploratory activities cued by the possibility of reward or the relief from punishment (Roussos, Giakoumaki & Bitsios, 2009). HA is associated with a tendency to inhibit behaviours, and is associated with a fearful, cautious, pessimistic, and shy approach, cued by the need to avoid novelty or punishment (Gardini, *et al*., 2009; Ha, *et al*., 2007; Kantojärvi, *et al*., 2008; Lundqvist, 2008; M. Mazza, O. Mazza, Pomponi, Di Nicola, Padua, Vicini, *et al*., 2009; Park, *et al*., 2009). Conversely, low NS is linked to orderly, unsocial and frugal behaviour; whilst low HA tends to be more social and carefree. These are related to independent yet "interactive neurobiological systems", namely the behavioural inhibition system (BIS) and the behavioural activation system (BAS) in the central nervous system (Henderson & Wachs, 2007; Ravaja, *et al*., 2006, p. 288). Cloninger also postulates that "temperament implies individual differences in procedural memory" (Du Preez, Cassimjee, Ghazinour, Lauritz, & Richter, 2009, p. 542) or perceptual memory, whereas the development of an individual's character is a consequence of developments in the propositional or conceptual memory system (Gillespie, *et al*., 2003).

2.3.2 Links to psychiatric and personality disorders

Cloninger's theory further suggests that temperament, as a significant component underlying the personality structure, influences various manifestations of psychopathology such as alcoholism, anorexia nervosa, and anxiety and mood disorders (Di Nicola, Tedeschi, Mazza, Martinotti & Harnic, Catalano, *et al*., 2010; Lochner, Hemmings, Seedat, Kinnear, Schoeman, Annerbrink, *et al*., 2006; Matsudaira, 2006). The temperament dimensions harm avoidance (HA) and novelty seeking (NS) have been strongly implicated in a number of psychopathologies, including major depressive disorder (MDD) and various anxiety disorders (Celikal, Kose, Cumurcu, Erkomaz, Sayar, Borckardt, *et al*., 2009; Lundqvist, 2008; Nery, Hatch, Nicoletti, Monkul, Najt, Matsuo, *et al*., 2009; Matsudaira, 2006; Richter, Polak & Eisemann, 2003).

Mazza *et al*. (2009) found strong links between high HA (and low SD) and the presence of fibromyalgia (FM), an illness characterised by chronic, pervasive pain whose aetiology is still relatively unknown but which shows pathophysiological links to depression. They note that neurotransmitter studies conducted on patients diagnosed with FM, show abnormalities in their serotinergic, dopaminergic, and opioidergic systems thereby adding to evidence linking the neurotransmitter system to various temperament dimensions.

Specific temperament traits have also been shown to indicate *types* of personality disorders (PD) that may affect an individual, with several studies supporting this finding (Black, Forbush, Langer, Shaw, Graeber, Moser, *et al*., 2009; Ravaja, *et al*., 2006). For example, cluster A PDs which includes paranoid, schizoid and schizotypal personality disorders, have been found to be associated with low reward dependence (RD), cluster B PDs which includes borderline, antisocial, histrionic and narcissistic personality disorders, with high NS, and cluster C PDs which includes avoidant, dependent and obsessive compulsive personality disorders with high HA (Bond, 2001; Ha, *et al*., 2007; Joyce, McKenzie, Luty, Mulder & Carter, 2003; Kantojärvi, *et al*., 2008). Jylha *et al*. (2009) had similar results in their study which showed a positive relationship between neuroticism (linked to HA) and the prevalence of co-morbid axis I and II disorders, specifically in individuals diagnosed with MDD; and a negative relationship between extraversion (linked to NS) and the prevalence of social phobia and Cluster C PDs. Further, Maser, Akiskal, Schettler, Scheftner, Mueller, Endicott *et al*. (2002) found links between the temperament attributes of impulsivity and assertiveness (both implicated in HA/N and NS/E) and attempters and completers of suicide. Calati, Giegling, Rujescu, Hartmann, Möller, De Ronchi *et al*. (2008) reported similar findings with suicide attempters showing higher scores on HA (and lower scores on SD and C) than controls.

These findings modestly suggest that temperament may be a putative risk factor for the development of certain psychiatric and personality disorders, however they also emphasise the need for more research in this regard.

2.3.3 Neural substrates of novelty seeking and harm avoidance

Growing evidence exists pointing to associations between deviations in temperament and neurobiological markers, both structural and functional (Lundqvist, 2008). Strong links have been found between some dimensions of temperament and perfusion in localised areas of the brain (O'Gorman, *et al*., 2006); with NS associated with perfusion in the cuneus, cerebellum and thalamus; and HA with perfusion in the cuneus, medial frontal gyrus and cerebellar vermis. The neurotransmitter system, specifically dopamine and serotonin, has also been implicated with research suggesting that HA (involving behavioural and emotional inhibition) is linked to the serotonin system, and NS (involving the exploration and pursuit of novel stimuli) linked to the dopamine system (Auerbach, *et al*., 2001; Carver & Miller, 2006; Gardini, *et. al*., 2009; Henderson & Wachs, 2007; Kantojärvi, *et al*., 2008; Ravaja, *et. al*., 2006).

Roussos *et al*. (2009) found in their study that less efficient functioning of the dopamine D4 receptor (L-DRD4 VNTR polymorphism) – found in large quantities in prefrontal and limbic regions of the brain such as the amygdala and hippocampus and associated with high levels of NS – is linked to increased reward-related ventral striatum reactivity, and self-reports on impulsivity. In this study, they also found a positive correlation between high NS (and associated L-DRD4 VNTR) and potentially harmful and risky behaviour. They established that L-DRD4 does not affect problem-solving in cognitive decision-making per se, but does affect performance negatively when motivational or emotional feedback is required in the decision-making process. They further suggest the importance of noting the different brain areas implicated in this finding, with the former involving the dorsolateral prefrontal cortex (DLPFC), and the latter involving the ventrolateral prefrontal cortex (VLPFC) and orbitofrontal cortex (OFC), which is in accordance with their findings regarding the distribution of DRD4 in the fronto-limbic regions as well as the connectivity of the OFC and the medial PFC regions with the limbic areas. Munafò, Yalcin, Willis-Owen and Flint (2008) in turn found moderate associations between the DRD4 gene and measures of impulsivity and NS in a meta-analysis of research conducted on non-clinical adult samples. In three independent functional magnetic resonance imaging (fMRI) studies conducted on a non-clinical sample, Britton, Ho, Taylor and Liberzon (2007) found a positive correlation between individuals scoring high on neuroticism (associated with high levels of anxiety and Cloninger's HA) and dorsomedial prefrontal cortex (dMPFC) activation when exposed to positive emotional stimuli. They postulate that this is linked to high NS individuals' tendency to introspection, self-rumination and self-association with emotional stimuli, or with what they refer to as "internally driven emotional states" (Britton, *et al*., 2007, p. 255) making their responses to emotional stimuli more easy to detect. Similarly, Most, Chun, Johnson and Kiehl (2006) found that individuals who scored high on HA showed decreased ability for attentional modulation of emotion-related amygdala activity – the amygdala being involved in emotional processing. Davis, *et al*. (2007) further argue that individual variance in punishment sensitivity (linked to HA), could arise from fluctuations in the excitability of the extended amygdalial circuitry, where over-activity is linked to an enhanced fear response to unfamiliar, novel or threatening stimuli.

Advancements in neuroimaging techniques have added further evidence that structural differences in specific brain areas may also account for individual differences in temperament dimensions NS and HA, amongst other. NS has been shown to correlate positively with the volume of grey matter in the frontal and posterior cingulate gyrus; with HA correlating negatively with grey matter volume in the orbito-frontal, occipital, and parietal structures (Gardini, *et al*., 2009). This possibly contradicts findings by Davis *et al*. (2007), where impulsivity was seen to be associated with orbitofrontal dysfunction which they felt could be related to lower levels of activity or smaller cortical volume. They argued that decision-making is significantly impaired by impulsivity, a trait defined by Lewis, Scott and Frangou (2009) as "a predisposition towards rapid, unplanned actions without regard to consequences" (p. 464), and as such is often linked to a variety of addictive behaviours; as well as frequent aggressive and potentially self-harming behaviour (Carli, Jovanović, Podlešek, Roy, Rihmer, Maggi, *et al*., 2010). However, in the same study noted above, Davis *et al*. (2007) found that effective decision-making was impaired in individuals exhibiting sensitivity to punishment, that is, those scoring high on BIS (or HA) who show a tendency for greater anxiety, low self-esteem, social withdrawal, and negative affect – all of which are strongly associated with most forms of psychopathology. It was hypothesised that high levels of anxiety are counterproductive when an "assessment of stimuli and an evaluation of outcome" is required which are two important stages in the decision-making process (Davis, *et al*., 2007, p. 288). The conclusion therefore is that decision-making is a complex process incorporating different psychological mechanisms which are difficult to isolate, and which thus requires further investigation. The implications of this are relevant in the section which follows, which explores the links between executive function (involving complex decision-making processes) and temperament.

According to Bond (2001), various clinical studies have shown that character and temperament dimensions improve with pharmacological treatment, specifically drugs targeting different neurotransmitters. For example, research has consistently revealed a decrease in HA in depressed patients when antidepressants targeting the serotinergic system are administered (Bond, 2001). Both Bond (2001) and Berger *et al*. (2007) also found that selective serotonin reuptake inhibitors (SSRIs) decrease impulsivity, a subscale on the NS dimension. Regulation of self-control involves intricate interactions between dopamine (DA), serotonin (SA) and noradrenalin (NA), with research revealing significant correlations between DA and NA and novelty seeking but not with harm avoidance. Research has also shown correlations between low levels of tryptophan, a precursor for serotonin, with vulnerability to anxiety and increased aggression or hostility and low self-determination (Bond, 2001). Deficits in self-control are core features of psychiatric disorders, and attention deficits are linked to hypofunctioning of the prefrontal cortex (PFC) DA circuits and hyperfunctioning of the striatal DA circuits (Berger, *et al*., 2007). According to Suslow, *et al*. (2010), the thalamus and striatal nuclei are integral parts in the dopaminergic reward system and have been found to be involved in the neurobiology of extraversion. They cite several studies that made use of functional neuroimaging of individual's at rest, with consistent findings positively correlating extraversion with metabolic processes in the striatum, the posterior and anterior cingulate cortex, the amygdala, and both the orbitofrontal and temporal cortices. It is argued that there is competition between two separate neural systems responsible for delayed and immediate reward in the BIS/BAS interplay. Delayed reward is associated with the lateral PFC and posterior parietal cortex activation, as opposed to the limbic area activation linked to a bias for immediate reward. Similarly, serotonin is an inhibitory neurotransmitter involved in both delay and constraint (Bond, 2001). Research has also shown that deficits in self-regulation are implicated in the development of ADHD-type behaviours which incorporate aggression and hyperactivity and which involve both the dopamine receptor gene (D4) and the dopamine transporter gene (DAT1) (Berger, *et al*., 2007; Olson, *et al*., 2002). Similarly, hyperactive-impulsive ADHD-related symptoms have been found to correlate directly with BAS, extraversion and higher NS (Cho, *et al*., 2008; Mitchell & Nelson-Gray, 2006). A study involving a forensic clinical sample of violent offenders conducted by Nilsson, Bromander, Anckarsäter, Kristiansson, Forsman, Blennow *et al*., (2010) supports this finding wherein they reported that increased dopaminergic neurotransmission relative to serotinergic neurotransmission, was related to increased irritability, and negatively correlated with inhibited aggression and co-operativeness. Hirshfeld-Becker, Biederman, Calltharp, E. Rosenbaum, Faraone and J. Rosenbaum (2003) found substantial evidence supporting this with their results showing links between behavioural inhibition and behavioural disinhibition with disruptive behaviour disorders.

As noted earlier, various temperament attributes such as impulsivity, aggression, lack of cooperativeness and heightened fear responses amongst other play a critical role in decision-making (or responding appropriately to the demands of a new situation) – a complex process involving executive function and abstract reasoning ability. The section which follows seeks to explore the links between temperament and executive performance in more detail.

2.4 EXECUTIVE FUNCTION

Executive functioning involves the integration of higher order processing comprising motivational, affective, cognitive, and behavioural components necessary for decision-making which is essential for planning and goal-oriented behaviours (Cassimjee & Murphy, 2010; Lezak, Howieson & Loring, 2004; Morasch & Bell, 2010; Whitney, Jameson & Hinson, 2004). Similarly, Guillem *et* al., (2008) describe executive function as a "multifaceted construct involving various sub-processes such as cognitive inhibition, set shifting or flexibility, maintenance and manipulation or monitoring" (p. 176), and which Best, Miller and Jones (2009) further describe as "goal-oriented control functions of the PFC [prefrontal cortex]" (p. 180). Berger *et al.* (2007) explain that these effortful self-monitoring and self-regulatory processes entail moving toward or away from stimuli (NS or HA) and depends heavily on executive function as a whole, incorporating the executive facets of attention and working memory.

Self-regulation is a critical component of positive adaptation and adjustment to the demands of the environment. In exploring the relationship between self-regulation and executive function, V. Molfese, P. Molfese, D. Molfese, Rudasill, Armstrong and Starkey (2010) suggest that self-regulation is the product of temperament (or more specifically effortful control) and executive function (specifically working memory and inhibitory control). Working memory is the ability to keep information in the mind and use it as needed to guide current and future behaviour. Inhibitory control in turn is the ability to prevent distracting, unimportant information from interfering with performance, and is a critical component of executive function associated with frontal lobe development (Molfese, *et al*., 2010; Morasch & Bell, 2010). Abdullaev, Posner, Nunnally and Dishion (2010) found links between increased activation of the right frontal and bilateral parietal areas in a sample of cannabis using adolescents, when confronted with executive attention tasks that require the inhibition of conflicting information. This is related to effortful control and self-regulation where deficits in this are linked to anti-social and addictive behaviour. Self-regulation incorporates approach, avoidance and attentional processes involved in the modulation of an individual's reactivity or responsiveness of their activation, arousal, and emotional systems (González, Fuentes, Carranza & Estévez, 2001).

Spielberg, Miller, Engels, Herrington, Sutton, Banich *et al*. (in press) explored the effects of approach (reward) and avoidance (punishment) motivation on neural activation associated with executive functioning required for goal-directed behaviour, using the color-word Stroop Task[2]. Whilst their study did not focus on the specific performance aspects of executive functioning per se, they were able to identify certain brain areas (using fMRI) linked to executive performance which were activated when given the task, and which differed for approach and avoidance. They

[2] This test was used as it enlists executive control on a multitude of levels which include directing attention, semantic concept selection, and selecting behavioural responses to different stimuli (Spielberg, *et al*., in press).

found that approach motivation (BAS and NS) was associated with activation of two regions of the left middle frontal gyrus (MFG) and avoidance motivation (BIS and HA) was associated with one region of the right MFG. The implications are that the temperament traits of approach (BAS and NS) and avoidance (BIS and HA) moderate executive functioning competence. Another aspect worth mentioning is that hyperactivity in the amygdala or impulsive system, could reduce the control of the reflective system (located in the ventromedial prefrontal cortex), thereby undermining effective decision-making and enhancing addictive behaviours or those offering immediate reward (Ko, Hsiao, Liu, J. Yen, Yang & C. Yen, 2010). Interestingly in Ko, *et al.*'s (2010) study, they also found the above was related to higher scores on NS (associated with the dopaminergic system), reflecting the brain's activation system. It can therefore be assumed that executive functioning competence is a result of the interaction between complex cognitive processes and temperament (Olson, *et al.*, 2002). As a result of this complexity, various areas in the brain are implicated which includes orbital and medial structures in the frontal lobes, cortical and sub-cortical areas including limbic structures and their components such as thalamic nuclei (Lezak, *et al.*, 2004).

This therefore establishes the fundamental premise underlying this research, which seeks to explore performance and temperament cluster correlates to ultimately pinpoint common brain anatomical sites and shared neuronal circuitry.

2.4.1 Temperament traits and executive performance

As noted above, it has been found that both temperament and character dimensions share a common underlying neural base with several executive functioning tasks (Bergvall, Nilsson & Hansen, 2003), and that temperament may influence executive function (Guillem, *et al.*, 2008; Rueda, Posner & Rothbart, 2005). Similarly, research findings suggest that neuropsychological functioning has a potential moderating effect on both temperament and behaviour (Baum, *et al.*, 2010). For example, high scores on NS have been associated with decreased performance on verbal memory tasks (Bond, 2001).

Investigations of neuropsychological performance and specific temperament traits have yielded some promising results, with executive function performance correlating with impulsiveness ratings (Keilp, Sackeim & Mann, 2005), as well as NS, HA, SD and C (Cloninger, *et al*., 1994). Guillem *et al*. (2008) in turn conducted a study examining the correlation between temperament traits and executive performance using the Auditory Digit Span of the Wechsler Memory Scale (WMS) (to assess maintenance and manipulation performance) and the Wicken's test for proactive interference and release (to assess ability to withstand interference and flexibility or set-shifting capacity). Their findings revealed a direct correlation between executive function performance and both HA and NS, with high HA favouring cognitive flexibility and high NS revealing greater interference sensitivity and poorer manipulation. Correlations between executive function performance and HA were also found by McNamara, Durso and Harris (2008), with higher HA scores correlating with poorer verbal fluency performance. In terms of linking personality disorders to temperament and executive function performance, Black *et al*. (2009) found that individuals diagnosed with borderline personality disorder (BPD), a cluster B personality disorder, revealed high scores on both NS and HA, and performed poorly in the areas assessing decision-making, working memory, cognitive inhibition, and perseveration.

2.5 SUMMARY

The purpose of this study is to explore the neuropsychological performance profiles on measures of executive functioning and abstract reasoning associated with clusters comprised of NS and HA. The clusters being investigated are Rigid (high HA, low NS), Impulsive (high NS, low HA), hyperthymic (low HA, low NS), and hypothymic (high HA, high NS). The motivation for conducting this investigation rests on the basis that the HA and NS traits and executive function performance have been shown to share common neurotransmitter and neuroanatomical systems. Whilst various inquiries have reported findings that support the link between neuropsychological performance and temperament dimensions, few studies have been conducted to determine whether deficits in executive functioning and second order temperament clusters (rigid, impulsive, hypothymic and hyperthymic) present independent risk factors for the development of psychopathology. For example, correlational studies such as those conducted by Britton *et al*. (2007) who found a positive relationship between high neuroticism and dMPFC activation, thereby suggesting a high level of self-relatedness processing in these individuals, could yield benefits in terms of improving our understanding of the ways in which individuals diagnosed with psychiatric disorders process emotions. Similarly, by examining the ways in which individuals whose personality traits score at extreme ends of the spectrum process emotional stimuli, we could establish mechanisms that identify vulnerabilities for the development of psychiatric disorders.

Thus, it is believed that this investigation may contribute to knowledge regarding specific neurobiological features that increase vulnerability for psychopathology, thereby aiding in the detection and diagnosis of sub-clinical putative risk factors for this. Therefore, the aims are firstly to establish the executive performance profiles associated with the above-mentioned second order clusters; and secondly, to identify significant differences between and within these clusters.

CHAPTER 3
METHODOLOGY

3.1 OVERVIEW

This study employed an exploratory, non-experimental, comparative design to investigate the relationship between clusters comprised of combinations of the temperament dimensions harm avoidance (HA) and novelty seeking (NS), and neuropsychological performance. Participants grouped in the identified clusters of rigid and impulsive, and hypothymic and hyperthymic were compared on executive function and abstract reasoning performance.

As mentioned earlier, the original study comprised data collection over a period of 2 years. This initiative was funded by the National Research Foundation and the University of Pretoria Research and Development Fund (Grant No:TTK2006042400049). For the original study, the administration of the computerized neuropsychological test battery was approved and implemented in collaboration with the University of Pennsylvania, Brain Behaviour Center. The choice of a computerized battery facilitated the group administration of tests (Gur, Ragland, Moberg, Turner, Bilker, Kohler, *et al.*, 2001). With the technical support of researchers at the Brain-Behavior Laboratory at the University of Pennsylvania, a web-interface was set up between the South African site and the USA site. The University of Pennsylvania Computerized Neuropsychological Test Battery (PennCNP) comprises four computerized neuropsychological test batteries (Emotions, Memory, Executive Function and Abstract Reasoning and a full battery comprising all the tests from the 3 batteries).

3.1.1 Sample

The data was collected from a sample comprising first year psychology students registered for the biological and cognitive psychology modules at a residential university in South Africa. Six hundred and thirty students from the 1124 registered students invited to participate in the study, agreed to take part. For the purpose of this study, processing of the data yielded a realised sample of 430 after participants with incomplete neuropsychological test and TCI data as well as those with a past medical and psychiatric history were omitted from the final data analyses.

3.1.2 Measuring instruments

A socio-demographic questionnaire was administered to each participant at the commencement of the battery yielding data on age, gender, home, and schooling language, parental education level, handedness and past and current medical and psychiatric history.

3.1.2.1 The Temperament and Character Inventory (TCI)

The Temperament and Character Inventory (TCI) derived from Cloninger's psychobiological personality model was administered. The TCI assesses seven factors comprised of four independent, largely genetically determined temperament and three character dimensions predominantly determined by socialisation processes during the life-span, through a 238 item forced choice true-false standardised self-administered questionnaire. The different temperament dimensions are Novelty Seeking (NS), Harm Avoidance (HA), Reward Dependence (RD), and lastly Persistence (PS). The character dimensions are Self-Directedness (SD), Cooperativeness (CO), and Self-Transcendence (ST) (Cloninger, Przybeck, Svrakic & Wetzel, 1994). Each of the dimensions measured, with the exception of Persistence, is defined by what Rushton and Irwing (2009) refer to as facet traits which are totalled to generate a total score for each dimension. Internal consistency coefficients range from .70 to .89 for the seven factors in a non-clinical sample (Cloninger, et al., 1994). The TCI is widely used internationally and has been used before in different groups in South Africa (du Preez, *et al.*, 2009; Lochner, Simeon, Niehaus & Stein, 2002; Peirson & Heuchert, 2001; Rushton & Irwing, 2009).

For the purposes of this study, only clusters comprising the temperament traits harm avoidance (HA) and novelty seeking (NS) were used. Novelty Seeking (NS) is related to the behavioural activation system and Harm Avoidance (HA) is related to the behavioural inhibition system. The facet traits defining NS are Exploratory, Excitability, Impulsiveness, Extravagance, and Disorderliness; and those defining HA are Anticipatory Worry, Fear of Uncertainty, Shyness, and Fatigability (Rushton & Irwing, 2009). According to Cloninger *et al.* (1994), combination of traits NS and HA yield different temperament clusters. For data analyses, the participants were divided into groups based on their scores on the NS and HA dimensions. The neuropsychological performance of these categorized groups was analysed and interpreted within the framework of the psychobiological theory.

3.1.2.2 Tasks of the Executive Function and Abstract Reasoning battery

The PennCNP begins with a general sensory-motor and familiarization trial (MPRAXIS) so as to allow participants to become comfortable with the computer-based testing procedure and demonstrate adeptness at using a computer and mouse. The battery of tests does not commence until the participant has successfully completed the MPRAXIS trial.

The PennCNP is comprised of five tests of abstract reasoning and executive functioning and one sensory-motor test. These are: the Penn Abstraction, Inhibition and Working Memory Task (AIM); the Letter-N-Back (LNB2), the Penn Conditional Exclusion Task (PCET); the Penn Short Logical Reasoning Test (SPVRT), and Short Raven's Progressive Matrices (SRAVEN). The tests from the Executive Functioning and Abstract Reasoning Battery are administered in a set order (MPRAXIS, AIM, LNB2, PCET, SPVRT, and SRAVEN). Below is a description of each task and the performance indicators selected for statistical analyses (http://penncnp.med.upenn.edu).

3.1.2.2.1 Motor Praxis (MPRAXIS)

The MPRAXIS is a measure of sensory-motor ability. It is also designed to familiarise the participant with the computer mouse, which is used for all of the tasks. During the MPRAXIS trial practice session, the participant needs to move the computer mouse cursor over an ever-shrinking green box and click on it once. The box appears in a different location on the test-screen every time. If participants cannot complete the MPRAXIS, it is likely they will not be able to complete any other PennCNP task. During the test session, the participant needs to move the computer mouse cursor over an ever-shrinking green box and click on it once, each time it appears on a different location on the test-screen. This is presented 20 times, in a non-randomized manner. As soon as the participant clicks on the box it will disappear and reappear at another location on the test-screen in a smaller size. This will continue until all 20 sizes/locations of the green box are presented. The participant must click on the green box within 5 seconds, otherwise the green box will automatically move to the next location on the computer screen. Total correct responses on the test trial and reaction time for correct responses were selected as performance measures.

3.1.2.2.2 Penn Abstraction, Inhibition and Working Memory Task (AIM)

The AIM assesses abstraction and concept formation with and without working memory. It is divided into two separate question types, which the participant practices before starting the task. During the first question type, the participant sees two pairs of stimuli on the top of the screen (adjusted to the left and to the right) and one single stimulus on the mid-bottom of the screen. The participant's task is to decide with which pair the stimulus on the bottom best belongs. The participant then clicks on the pair that best fits the bottom stimulus. Immediate feedback in the form of the word 'correct' or 'incorrect' is displayed on the screen, without any explanation of the rules. The task moves automatically onto the next question after the feedback is presented. In the second question type, the bottom stimulus flashes for less than a second and then the two pairs of stimuli appear on the top. This type of trial also measures working memory: the participant's ability to keep the bottom stimulus in mind so that a choice of the best fit can be made. As with the first type of question, the second trial type presents feedback and moves on to the next question. Once the task begins, the participant has 10 seconds to answer each trial. There are 60 questions in total, 30 based on the first trial type and 30 based on the second (working memory) type. The criteria for best fit must take into consideration colour and shape of all stimuli figures. Total number correct and reaction time for correct responses were selected as performance measures.

3.1.2.2.3 Letter-N-Back (LNB2)

The LNB2 assesses attention and working memory. In this task, participants are asked to pay attention to flashing letters on the computer screen, one at a time, and to press the spacebar according to three different principles or rules: the 0-back, the 1-back and the 2-back. During the 0-back the participant must press the spacebar whenever the letter X appears on the screen. During the 1-back the participant must press the spacebar whenever the letter on the screen is the same as the previous letter (i.e. in the series 'T', 'R', 'R' the participant should press the spacebar on or immediately after the second "R"). During the 2-back, the participant must press the spacebar whenever the letter on the screen is the same as the letter before the previous letter (i.e. in the series 'T', 'G', 'T', the participant should press the spacebar on or immediately after the second 'T'). In all trials, the participant has 2.5 seconds to press the spacebar (each letter flashes for 500 milliseconds and is followed by a blank screen lasting for 2000 milliseconds). The participant practices all three principles and mistakes are allowed during the practice sessions. Once all practice sessions are completed successfully, the task will begin. During the actual test trials, the participant does the 0-back, 1-back and 2-back three times each. No feedback is given in terms of correct or incorrect responses. Total number of true positive responses for each of the trails (0-Back, 1-Back, 2-Back) and the reaction time for true positive responses on 0-Back, 1-Back and 2-Back trials were selected as performance measures.

3.1.2.2.4 Penn Conditional Exclusion Task (PCET)

The PCET is a measure of abstraction in executive function related to the Wisconsin Card Sorting Test (Kurtz, Ragland, Moberg & Gur, 2004; Kurtz, Wexler & Bell, 2004). It is a computerised variant form of the 'Odd Man Out' model where participants must decide which object, out of four objects, does not belong with the other three. There are three principles/criteria for choosing an object, which change as the participant achieves 10 consecutive correct answers for each principle: line thickness, shape, and size (respectively). The participant has 48 trials to get 10 consecutive answers correct for each criterion. There is only one principle for any trial, but a response may match more than one principle. The participant is not told what the ruling principle is at any moment of the task and must make a decision by clicking with the mouse on the object that does not belong with the group. It is a forced-choice task (the question will remain on the computer screen until the participant chooses one of the answers). Feedback is given with a correct or incorrect message displayed on the screen with no explanation of the sorting principle rule. Total correct, categories achieved, perseveration errors and reaction time for correct responses were selected as performance measures.

3.1.2.2.5 Penn Short Logical Reasoning Task (SPVRT)

The SPVRT is a measure of verbal intellectual ability. It is a short version of the Penn Verbal Reasoning Test (Gur, *et al*., 2001; R.C. Gur, R. E. Gur, Obrist, Skolnick & Reivich, 1987). It is a multiple-choice task in which the participant must answer verbal analogy problems. The SPVRT has a total of 8 questions. The participant must click with the computer mouse on one of the four choices that he/she thinks best fits the analogy presented. It is a forced-choice task (the question will remain on the computer screen until the participant chooses one of the four answers). No feedback is given in terms of correct or incorrect responses. Total number correct and reaction time for correct responses were selected as performance measures.

3.1.2.2.6 Short Raven's Progressive Matrices (SRAVEN)

The SRAVEN is a measure of abstraction and mental flexibility. It is a short version of the University of Pennsylvania's RAVEN, which is a computerised version of the standard paper and pencil task published in 1960 (Gur, *et al*., 2001; Raven, 1960). It is a multiple-choice task in which the participant must conceptualise spatial, design and numerical relations that range in difficulty from very easy to increasingly complex (Gur, *et al*., 2001). During the SRAVEN task, the participant must click with the mouse on the pattern that best fits the visual analogy of non-representational designs displayed on the page. The SRAVEN has a total of 9 questions drawn from the regular RAVEN, which has 60 questions. Of the 9 questions, questions 1 and 2 have 6 responses to choose from and questions 3-9 have 8 choices. It is a forced-choice task (the question will remain on the computer screen until the participant chooses one of the alternatives). No feedback is provided in terms of correct or incorrect responses. The SRAVEN stimuli were created by scanning and digitalising the original stimuli cards from the paper and pencil RAVEN task (Gur, *et al*., 2001). Total number correct and reaction time for correct responses were selected as performance measures.

3.1.3 Procedure

The data to be used for this study was gathered from the responses obtained from the 630 participants following the administration of the University of Pennsylvania Computerized Neuropsychological Test Battery (PennCNP). A web-interface between the computer laboratory at the University of Pretoria and the Brain-Behavior Laboratory at the University of Pennsylvania was established which facilitated the group administration of tests and large scale data collection. Participants were given the opportunity to select a session from 30 group sessions scheduled. A maximum of 25 participants comprised each group session, which was facilitated by three attending researchers and eight research assistants each of whom were trained in the administration of the battery. The research assistants were each tasked with monitoring 4 participants, and upon completion of the battery, were required to submit in electronic format the test status code (C-complete, I-incomplete) and the number 1 (good data), 2 (questionable data) or 3 (bad data) for each of the tests comprising the battery.

3.1.4 Analysis of data

As noted above, this study sought to explore neuropsychological performance specifically in the area of executive functioning of the following HA (associated with the behavioural inhibition system or BIS) and NS (associated with the behavioural activation system or BAS) temperament clusters:

- Impulsive (low HA - high NS) and Rigid (high HA – low NS)
- Hyperthymic (low HA – low NS) and Hypothymic (high HA – high NS)

In order to derive the above-mentioned clusters, the participants were divided into two groups (due to the data exhibiting a relatively normal distribution) in terms of the HA and NS scores (Low and High):

- **Low:** total score <= mean score
- **High:** total score >= mean score

A further categorization was conducted where participants were classified in terms of four a priori groups based on their combination scores for HA and NS as defined in the typology above.

Descriptive statistics was used to report on the sample characteristics and indicate the sample performance on the executive function and abstract reasoning battery and the TCI. The independent group *t*-tests were used given that only two variables or groups (rigid versus impulsive, and hyperthymic versus hypothymic) were being compared to one another.

This test is used to determine the presence of any significant differences between the two independent groups' means (rigid versus impulsive and hyperthymic versus hypothymic) on the same dependent variables (accuracy of performance and median reaction time) on the neuropsychological tests (Coolidge, 2000). When using *t* tests, the assumptions are that the population variances are homogenous and that they follow a normal distribution. This was determined using the Levene test (Field, 2005; Hays, 1973). Important to note however, is that as expected, the larger sample sizes (greater than 30) used in this research has helped to minimize unequal variances (Hinton, 1995).

T-tests tell us how likely the observed effect is real as opposed to being the result of random or chance differences between the two temperament clusters being compared. The *t*-test, being parametric statistics, focuses on partitioning or dividing the variance in the dependent variable scores (the neuropsychological performance) into two pieces – the variance caused by the temperament cluster (the independent variable) and the variance caused by everything else in the research situation. In other words, the purpose is to measure the error variance which is any variance in performance that is not a result of the effect of temperament. The treatment variance is the variance that is a result of the effect of temperament on the performance. Statistical significance increases as treatment variance increases and error variance decreases (Hinton, 1995; Whitley, 2001). A *p*-value of 0.05 was used to determine statistical significance.

Statistical significance is not necessarily an indication of meaningfulness or lack thereof – sometimes small differences can be statistically significant (Olejnik & Algina, 2000) and it is for this reason that the "practical significance" or effect size (eta-squared values or η^2 from analysis of variance [ANOVA]) was calculated. The η^2 value provides an indication of the magnitude or strength of difference or association between the independent and dependent variables (Pierce, Block & Aguinis, 2004). The reporting of effect sizes facilitates the interpretation of the substantive, as opposed to the statistical, significance of a research result. A η^2 score of 0.01 is considered low, a score of 0.06 is considered medium, and 0.14 is considered high (Olejnik & Algina, 2000). When using *t*-tests, equality of variance between the two independent variables' means is of importance and this is measured by the Levene test. If the variances are equal, the p-value is used. If the Levene test finds the variances are unequal, the p 2-sided value is used.

The STATISTICA software package was used for the t-tests, SAS was used for the descriptive statistics, and the Statistical Package for the Social Sciences (SPSS) was used to calculate the η^2 values (effect sizes).

The Department of Statistics at the University of Pretoria (UP) provided assistance and oversight of the data analysis. More detail on the analyses and interpretation is provided in the chapter which follows.

3.1.5 Ethical considerations

The original study (the grant project No:TTK2006042400049) providing the data to be used in this project was approved by the dean of students, the dean of the faculty of Humanities, the head of the Department of Psychology, and the faculty Research and Ethics Committee. The data set utilised for this study comprises the raw scores on relevant measuring instruments and no personal identifiers are included in the data files.

The collected data has not been analysed previously. As part of the NRF grant initiative, students received postgraduate bursaries/grant-holder linked student support to work on this study.

Ethical approval for this study was granted by the Ethical Committee of the Faculty of Humanities at the University of Pretoria.

3.2 CONCLUSION

As noted above, this study sought to investigate the relationship between clusters comprised of combinations of the temperament dimensions harm avoidance (HA) and novelty seeking (NS), namely: rigid, impulsive, hypothymic and hyperthymic; and compare their neuropsychological performance on tests assessing executive function and abstract reasoning. The methodology employed was therefore selected to address these objectives using data previously collected.

CHAPTER 4
RESULTS

4.1 OVERVIEW

The chapter commences with a discussion of the sample used, with an overview of the demographics data obtained by the questionnaire administered to each participant. This is then followed by a discussion of the results of the statistical analyses conducted. The results for each of the tests are presented separately, including a table outlining the findings.

4.2 SAMPLE DESCRIPTION

As mentioned in the methodology chapter, the sample was comprised of 630 first year psychology students registered for the biological and cognitive psychology modules at a residential university in South Africa. For the purpose of this study, those participants with incomplete neuropsychological test and TCI data as well as any past medical and psychiatric history were omitted from the final data analyses. This yielded a realised sample of 430 comprised of 364 females (84.65%) and 66 males (15.35%).

4.2.1 Age

Most participants (95%) fell within the age group of 18-22 years, with the majority (195) being 19 years-old. The youngest participant was 17, and the oldest was 49 years.

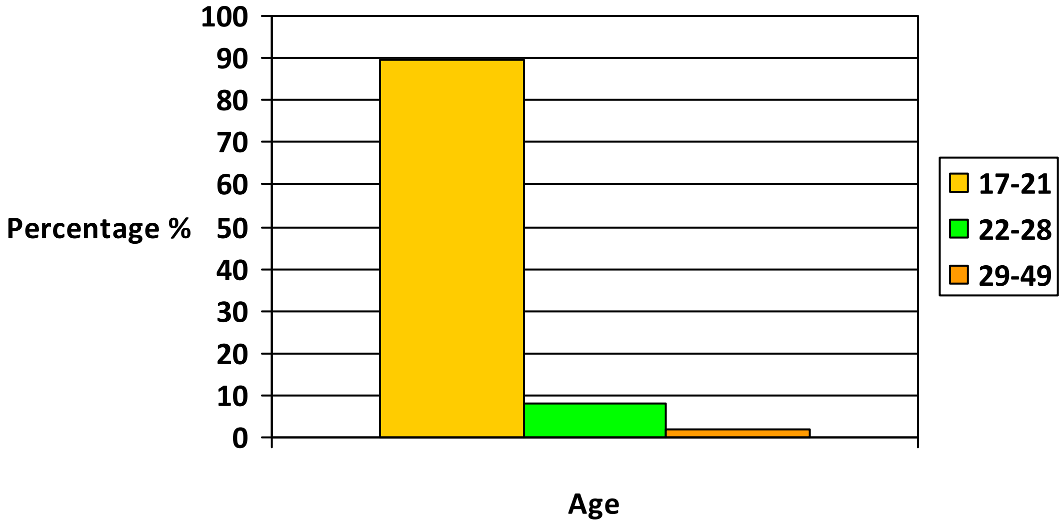

Figure 4.1: Age distribution

4.2.2 Home language

All eleven official home languages were represented in the sample, with the majority (199) selecting Afrikaans, followed by English (119), Setswana (20), Zulu (19), and Sepedi (18).

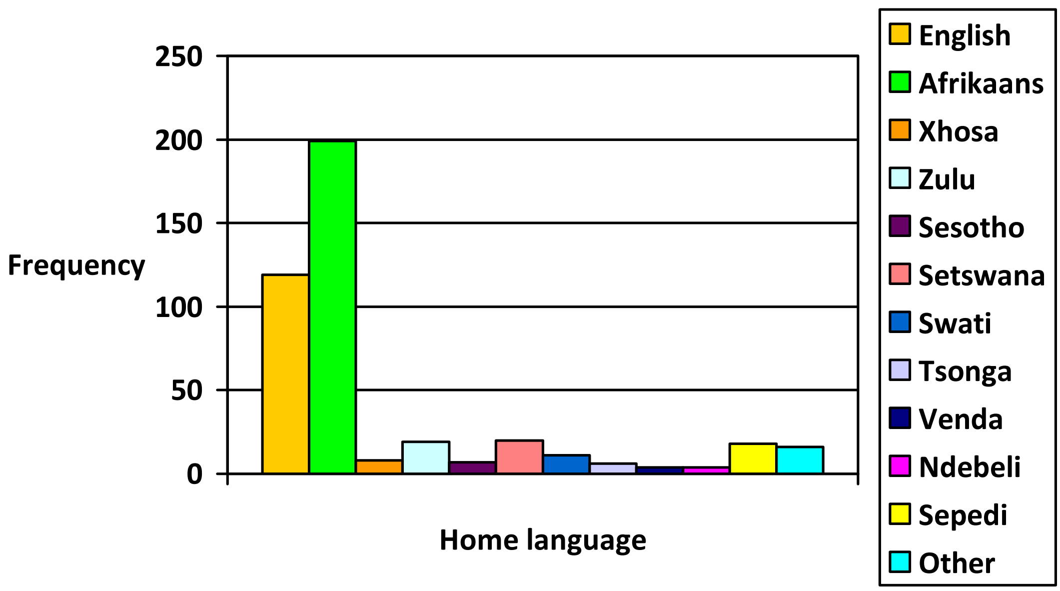

Figure 4.2: Home language

4.2.3 Level of education

The majority of participants (83%) were registered as first year students, with 12.79% registered as second year students, 2.09% registered as third year students, and 1.4% having completed a Bachelor's degree.

4.2.4 Parents' level of education

Most of the participants' parents (mothers and fathers) had achieved a grade 12 qualification, with the spread of qualifications falling between grade one (0.7% of mothers and 0.47% of fathers) and PhD level (1.16% of mothers and 2.79% of fathers). 33.49% of participants' mothers had a minimum of a grade 12, followed by 28.37% having completed a bachelor's degree. 30% of participants' fathers had a minimum of a grade twelve qualification, with 22.33% having completed a bachelor's degree.

4.2.5 Handedness

The majority of participants were right-handed (93.26%, with 5.12% being left-handed and 1.63% ambidextrous).

4.3 TCI DESCRIPTORS

A comparison of the means of HA and NS of this student sample to control group data (n= 471) from Pierson and Heuchert (2001), yielded no statistical differences between the means. This comparison is justifiable due to the lack of South African norms for the TCI and the control group sample having a similar average age and being from a university context.

Table 4.1: Harm Avoidance Confidence Intervals of Means

Sample	Mean	Standard Deviation	Standard Error	95% Lower Conf. Limit of Mean	95% Upper Conf. Limit of Mean
1 = Student	15.3900	7.0600	0.3354	14.7308	16.0492
2 = Control	16.1100	7.3800	0.3401	15.4418	16.7782

Table 4.2: Two-Sided, Two-Sample T-Test (H0: M1 = M2 versus H1: M1 <> M2)

Variance Assumption	DF	T-Value	Prob Level	Conclude H1 at 5.0% Significance?	Power (Alpha=0.05)	Power (Alpha=0.01)
Equal	912.00	-1.505	0.1326	No	0.3250	0.1422
Unequal	911.74	-1.507	0.1321	No	0.3257	0.1427

Table 4.3: Equal Variance Test

Statistic	DF1	DF2	F-Value	Prob Level	Reject Hypothesis of Equal Variance at the 5.0% Significance Level?
Variance Ratio	442	470	1.093	0.3451	No

Table 4.4: Novelty Seeking Confidence Intervals of Means

Sample	Mean	Standard Deviation	Standard Error	95% Lower Conf. Limit of Mean	95% Upper Conf. Limit of Mean
1 = Student	20.4400	6.3000	0.2993	19.8517	21.0283
2 = Control	20.7000	6.0900	0.2806	20.1486	21.2514

Table 4.5: Two-Sided, Two-Sample T-Test (H0: M1 = M2 versus H1: M1 <> M2)

Variance Assumption	DF	T-Value	Prob Level	Conclude H1 at 5.0% Significance?	Power (Alpha=0.05)	Power (Alpha=0.01)
Equal	912.00	-0.634	0.5260	No	0.0972	0.0268
Unequal	903.81	-0.634	0.5264	No	0.0971	0.0267

Table 4.6: Equal Variance Test

Statistic	DF1	DF2	F-Value	Prob Level	Reject Hypothesis of Equal Variance at the 5.0% Significance Level?
Variance Ratio	442	470	1.070	0.4689	No

4.4 STATISTICAL ANALYSES

As stated above, the primary objective of the statistical analyses was to explore and compare the neuropsychological performance profiles of the temperament clusters rigid (high HA, low NS) versus impulsive (high NS, low HA); and hyperthymic (low HA, low NS) versus hypothymic (high HA, high NS). The independent group *t*-tests were used given that only two variables or groups (rigid versus impulsive, and hyperthymic versus hypothymic) were being compared to one another. This test is used to determine the presence of any significant differences between the two independent groups' means (rigid versus impulsive and hyperthymic versus hypothymic) on the same dependent variable, being performance on the neuropsychological tests (Coolidge, 2000). When using *t* tests, the assumptions are that the population variances are homogenous and that they follow a normal distribution. This was determined using the Levene test (Field, 2005; Hays, 1973). Important to note however, is that as expected, the larger sample sizes (greater than 30) used in this research has helped to minimize unequal variances (Hinton, 1995).

The η^2, a measure of practical or clinical significance, was used as the correlations were quite low given that they represent results from a single situation (that is, neuropsychological performance on specific tests taken in a single moment). Statistical significance is not necessarily an indication of meaningfulness or lack thereof – sometimes small differences can be statistically significant (Olejnik & Algina, 2000) and it is for this reason that the η^2 was calculated. The η^2 is a value judgement of the importance of the result for the hypotheses being tested and it measures the significance of the effect of the independent variable (the respective temperament clusters) on the dependent variable (the neuropsychological test performance). The rationale underlying this is that it is accepted that the effects can become increasingly significant when cumulated across time and situations as correlations will grow accordingly (Whitley, 2001). In addition, this research is still in its early stages being explorative in nature, and thus it is useful to know that the temperament clusters have an effect on performance, even if very small. A η^2 score of 0.01 is considered low, a score of 0.06 is considered medium, and 0.14 is considered high (Olejnik & Algina, 2000).

4.5 RESULTS

Only the significant results from each of the tests administered are discussed separately below. The PennCNP tests used are comprised of the Abstraction and concept formation ('complex tasks') (AIM), Letter-N-Back Attention and working memory ('simple tasks') (LNB2), Motor Praxis (MPRAXIS), Penn Conditional Exclusion Task (PCET), Short Penn Logical Reasoning Test (SPVRT), and Short Raven's Progressive Matrices (SRAVEN)

4.5.1 TCI trait clusters and neuropsychological profiles

The results for the first cluster comparison (rigid versus impulsive) are illustrated in Table 4.7 below, followed by the second cluster comparison (hypothymic versus hyperthymic) in Table 4.8. The results for rigid versus impulsive are presented first, including a brief overview of each test. This is followed by the results for the hyperthymic versus hypothymic clusters but will not include a repetition of the test overview.

As mentioned above, an independent *t*-test was conducted to compare neuropsychological performance profiles of the temperament clusters rigid versus impulsive, and hyperthymic versus hypothymic. Only the results which showed statistical and practical significance (p<0.5 and η^2) have been reported on.

Table 4.7 PennCNP Descriptive Performance data and test of difference data for Rigid (high HA, low NS) and Impulsive (high NS, low HA)

Neuropsychological Measures	**Mean Rigid (R)**	**Mean Impulsive (I)**	***t*-value**	**df**	***p***	***p* 2-sided**	**Valid N R**	**Valid N I**	**SD R**	**SD I**	**η^2**
Abstraction and concept formation ('complex tasks') (AIM)											
E23 – Median response time for incorrect items 41-50	2787.95	2445.08	2.01186	183	0.045701	-	96	89	1235.06	1069	0.01
Letter-N-Back Attention and working memory ('simple tasks')											
F5 – Mean of median response time correct responses	439.6	412.25	2.2486	249	-	0.023232	131	120	111.46	76.18	0.01
F17 – Mean of median response time correct responses 1-Back	456.55	416.83	2.69438	249	-	0.007003	131	120	127.82	103.05	0.02
MPRAXIS											
J1 – Time for mouse 1	830.8	744.64	2.41938	250	0.016261	-	131	121	319.62	235.61	0.01
J5 – Time for mouse 2	612.19	575.44	2.95134	250	0.003465	-	131	121	107.63	88.1	0.02
PCET											
G3 – Time for correct responses	1994.36	1870.77	1.97811	249	0.049019	-	131	120	518.92	466.27	0.02
SRAVEN											
I3 – Time for correct responses	18968.42	15946.11	2.85651	247	0.004648	-	130	119	8906.2	7672.59	0.02

Table 4.8 PennCNP Descriptive Performance data for Hyperthymic (low HA, low NS) and Hypothymic (high NS, high HA)

Neuropsychological Measures	**Mean Hyper**	**Mean Hypo**	***t*-value**	**df**	***p***	***p* 2-sided**	**Valid N Hyper**	**Valid N Hypo**	**SD Hyper**	**SD Hypo**	**η^2**
Abstraction and concept formation ('complex tasks') (AIM)											
E3 – Correct response on items 21-30	8.63	8.1	2.64948	166	0.008841	-	75	93	1.22	1.34	0.02
E5 – Correct response on items 41-50	8.84	8.24	3.58862	166	-	0.000292	75	93	0.9	1.21	0.04
E7 – Correct response on items 11-20	8.24	7.65	2.95659	166	0.003564	-	75	93	1.21	1.36	0.02
E13 – The median response time for correct responses on items 1-10	2174.07	2455.72	-2.22824	166	-	0.022206	75	93	655.29	922.73	0.01
E15 – The median response time for correct responses on items 21-30	2056.49	2314.25	-2.34422	166	0.020251	-	75	93	588.69	791.83	0.02
E27 – Median response time for correct responses on items 31-40	1435.91	1595.48	-2.1758	166	0.030984	-	75	93	399	524.29	0.01
E37 – Total correct responses for items 1-10, 21-30 and 41-50	24.66	22.76	3.7825	165	0.000217	-	74	93	3.12	3.3	0.04
E39 – Total correct responses for items 11-20, 31-40 and 51-60	24.86	23.71	2.3668	165	0.019102	-	74	93	2.91	3.3	0.02
E41 – Mean of median response time for correct responses on items 1-10, 21-30 and 41-50	2024.99	2295.05	-3.00876	165	0.003035	-	74	93	485.28	639.21	0.03
E43 – Mean of median response time for correct responses on items 11-20, 31-40 and 51-60	1430.62	1621.92	-2.76998	165	0.006249	-	74	93	308.22	526.43	0.03
Letter-N-Back Attention and working memory ('simple tasks')											
F9 – False positive response 0-back	0.52	0.31	2.15474	162	-	0.03662	75	89	0.68	0.54	0.02
PCET											
G3 – Time for correct responses	1955.56	2156.85	-2.0749	166	-	0.031345	75	93	463.77	729.4	0.03
SPVRT											
H1 – Total correct	15.77	13.88	2.40501	165	-	0.014649	74	93	4.39	5.5	0.02

4.5.1.1 Rigid versus impulsive

4.5.1.1.1 Abstraction and concept formation ("complex tasks") – AIM

There was significant difference between the performance of rigid (M=2787.95, SD=1235.06) and impulsive individuals (M=2445.08, SD=1069) on the abstraction and concept formation ("complex tasks") (AIM) test, with the median response time for incorrect items 41-50 being slower for rigid than for impulsive. The η^2 was 0.01 and *t df* (183) = 2.01186, p = 0.045701. This test assesses abstraction and concept-formation both with and without working memory. The test is divided into blocks of trials, and the scores are an indication of the number of correct and incorrect responses, as well as the median response time for each.

4.5.1.1.2 Letter-N-back attention and working memory ("simple tasks") – LNB2

On the letter-N-back attention and working memory ("simple tasks") (LNB2) test, the mean of median response times for correct responses was slower for rigid (M=439.6, SD=111.46) than for impulsive (M=412.25, SD=76.18). The LNB2 measures attention and working memory and is scored according to the total number of true/false positives, the median reaction time for correct responses, and the number of true/false positives with the median response times for each. The η^2 was 0.01 with *t df* (249) = 2.2486, p 2-sided = 0.023232. This was also the case with the mean of median response time for correct responses on the 1-back test with rigid (M=456.55, SD=127.82) performing slower than the impulsive group (M=416.83, SD=103.05), *t df* (249) = 2.69438, p 2-sided = 0.007003. Here the η^2 was 0.02.

4.5.1.1.3 Motor praxis – MPRAXIS

The median response time on both the MPRAXIS trials was slower for rigid (M=830.8 and M=612.19, with SD=319.62 and SD=107.63; *t df* (250) = 2.41938, p = 0.016261, and *t df* (250) = 2.95134, p = 0.003465) than for impulsive (M=744.64 and M=575.44, with SD=235.61 and SD=88.1). The η^2 values here were 0.01 and 0.02 respectively. The MPRAXIS tests sensory-motor ability as well as intended to familiarise participants with the computer mouse which is required in all of the WebCNP tests. The test scores are derived from the median response times for correct responses on both trials as well as the number of correct responses for trial 2.

4.5.1.1.4 Penn conditional exclusion test (PCET)

Results on the Penn Conditional Exclusion test (PCET) which assesses abstraction in executive function related to the Wisconsin Card Sorting test (where the participant must identify which object out of four presented does not belong to the set), showed that the median response time for correct responses was slower for rigid (M=1994.36, SD=518.92) than for impulsive (M=1870.77, SD=466.27), *t df* (130) = 1.97811, p = 0.049019, and η^2 = 0.02. Scores are based on the number of correct and incorrect responses as well as the median response times which include both perseverative errors and correct responses.

4.5.1.1.5 Short Raven's Progressive Matrices (SRAVEN)

Finally, the shortRAVEN (a measure of abstraction and mental flexibility) scores revealed a significant difference in the median reaction time for correct responses with the rigid (M=18968.42, SD=8906.2) responding slower than impulsive group (M=15946.11, SD=7672.59), *t df* (130) = 2.85651, p = 0.004648, and with a η^2 of 0.02. The SRAVEN scores comprise the predicted RAVEN (60 question) number of correct responses as well as the median reaction times for the correct, incorrect, and combined responses.

4.5.1.2 Hyperthymic versus hypothymic

4.5.1.2.1 Abstraction and concept formation ("complex tasks") – AIM

It was observed that the hyperthymic cluster presented with more correct responses for items 21-30 (M=8.63, SD=1.22), items 41-50 (M=8.84, SD=0.9), and items 11-20 (M=8.24, SD=1.21) than the hypothymic cluster (M=8.1, SD=1.34, M=8.24, SD=1.21, and M=7.65, SD=1.36. In these instances, *t df* (166) = 2.64948, p = 0.008841; *t df* (166) = 3.58862, p 2-sided = 0.000292; and *t df* (166) = 2.95659, p = 0.003564, with η^2 values of 0.02, 0.04, and 0.02 respectively.

The hyperthymic cluster also performed faster than the hypothymic cluster on the median response time for correct responses to items 1-10 and 21-30, with M=2174.07, SD=655.29 compared to M=2455.72, SD=922.73; and M=2056.49, SD=588.69 compared to M=2314.25, SD=791.83; with *t df* (166) = -2.22824, p 2-sided = 0.000292 and *t df* (166) = -2.34422, p = 0.020251 respectively. The η^2 values here were 0.01 and 0.02.

A significant difference in response speed hyperthymic and hypothymic clusters was observed on the median response time for correct responses on items 31-40, with the hyperthymic cluster reaction times being faster than those for the hypothymic cluster. Here the differences in scores was M=1435.91, SD=399 compared to M=1595.48, SD=524.29; with *t df* (166) = -2.1758, p = 0.030984, with a η^2 value of 0.01.

The hyperthymic cluster also scored significantly higher on performance accuracy (which includes items 1-10, 21-30, and 41-50; and items 11-20, 31-40, and 51-60) than the hypothymic cluster. Here M=24.66, SD=3.12 compared to M=22.76, SD=3.3 with *t df* (165) = 3.7825, p = 0.000217; and M=24.86, SD=2.91 compared to M=23.71, SD=3.3, with *t df* (165) = 2.3668, p = 0.019102, with η^2 values of 0.04 and 0.02 respectively.

Finally, the mean of the median response times for correct responses for items 1-10, 21-30, and 41-50; and items 11-20, 31-40, and 51-60 respectively was faster for the hyperthymic cluster than for the hypothymic cluster. M=2024.99, SD=485.28 compared to M=2295.05, SD=639.21, with *t df* (165) = -3.00876, p = 0.003035; and M=1430.62, SD=308.22 compared to M=1621.92, SD=526.43, with *t df* (165) = -2.76998, p = 0.006249, with η^2 values of 0.03 for both.

4.5.1.2.2 Letter-N-back attention and working memory ("simple tasks") – LNB2

A significant difference in error performance on the variable "LNB false positive responses for 0-back trials" was observed, with the hyperthymic cluster evidencing more errors than the hypothymic cluster. Here M=0.52, SD=0.68 compared to M=0.31, SD=.54, with *t df* (162) = 2.15474, p 2-sided = 0.03662 and a η^2 value of 0.02.

4.5.1.2.3 Penn conditional exclusion test (PCET)

On this task, the hyperthymic cluster (M=1955.56, SD=463.77) performed significantly faster than did the hypothymic cluster (M=2156.85, SD=729.4), *t df* (166) = -2.0749, p 2-sided = 0.031345, with a η^2 value of 0.03.

4.5.1.2.4 Short Penn's logical reasoning test (SPVRT)

The SPVRT assesses verbal intellectual ability, and the score is derived from the predicted PVRT number of correct responses, the percentage of correct responses, and the median reaction times for correct, incorrect, and combined responses. In this task, the hyperthymic cluster (M=15.77, SD=4.39) achieved significantly more correct responses than did the hypothymic cluster (M=13.88, SD=5.5), *t df* (165) – 2.4051, p 2-sided = 0.014649, with a η^2 value of 0.02.

4.6 CONCLUSION

The overall findings when comparing rigid-trait and impulsive-trait individuals' performance are relatively consistent with rigid-trait individuals reacting more slowly to both complex (executive functioning) and less complex tasks (attention and working memory) tasks. Interestingly, they attained fewer correct responses on complex tasks. Similarly, the results when comparing hyperthymic and hypothymic trait individuals' performance are also mostly consistent, with hyperthymic-trait individuals demonstrating faster response times on the various tasks than hypothymic trait individuals. In addition, the hyperthymic-trait individuals performed better on complex tasks (executive functioning) than did hypothymic-trait individuals. These results are discussed in more detail in the following chapter.

CHAPTER 5
DISCUSSION OF FINDINGS

5.1 OVERVIEW

The purpose of this study was to explore and compare the neuropsychological performance profiles of the temperament clusters rigid (high HA, low NS) versus impulsive (high NS, low HA); and hyperthymic (low HA, low NS) versus hypothymic (high HA, high NS). The previous chapter affirmed the existence of relationships between these temperament clusters and neuropsychological performance, which this chapter seeks to discuss in the context of current literature and within a psychobiological framework. Both the significant and non-significant results will be included for the purpose of theoretical discussion. The significant results will be substantiated by the statistical results to distinguish them from non-significant results. The chapter then concludes the study with a brief overview of limitations to the project, recommendations for future research, and a conclusion.

5.2 THE TEMPERAMENT CLUSTERS AND THEIR NEUROPSYCHOLOGICAL PERFORMANCE PROFILES

As indicated above, this study found compelling associations between temperament, and accuracy and speed on the Executive Functioning and Abstract Reasoning battery of PennCNP neuropsychological tests. This supports expectations underpinning the rationale for conducting this inquiry which is to investigate linkages between neuropsychological performance and personality, and is in accordance with findings in similar studies (Black, *et al*., 2009; Cassimjee & Murphy, 2010; Keilp, *et al*., 2005; McNamara, *et al*., 2008).

In the present study, differences in neuropsychological performance were identified between the temperament clusters rigid and impulsive and hyperthymic and hypothymic. The findings show firstly that when comparing rigid-trait individuals and impulsive-trait individuals, the former tended to react more slowly to both complex (executive functioning) and less complex (attention and working memory) tasks. In addition, the rigid-trait individuals attained fewer correct responses on complex tasks. The results further showed that hyperthymic-trait individuals had faster response times on the tasks, and they performed better on complex tasks (executive functioning) than did hypothymic-trait individuals. These results are discussed in more detail below.

5.2.1 Rigid versus impulsive

Rigid-trait individuals are characterised by high HA scores and low NS scores. The implications of this are that these individuals would be more likely to be less impulsive and more "considered" in their decision-making process which could translate into slower response times for both complex and simple tasks. This was consistently observed as shown in the results section.

5.2.1.1 <u>Penn Abstraction, Inhibition and Working Memory (AIM) task</u>

The AIM assesses abstraction and concept formation both with and without working memory which includes response inhibition, response sequencing and resistance to interference, tapping into abstraction and planning abilities as well as self-regulation of goal directed behaviours (Cassimjee & Murphy, 2010; Henderson & Wachs, 2007). The AIM taps into abilities that are associated with prefrontal cortex activity, which has also been linked to high scores on HA (specifically dorsomedial prefrontal cortex). HA has been shown to implicate the serotinergic system which in turn is linked to delay and constraint and associated with lateral prefrontal cortex and parietal cortex activation (Bond, 2001; Britton, *et al.*, 2007; Christoff, Keramatian, Gordon, Smith & Mädler, 2009).

In this test, a difference in performance accuracy was observed with participants categorised as rigid (high HA, low NS) achieving fewer correct responses than participants classified as impulsive (low HA, high NS), on all items except items 1-10. Of statistical and practical[3] significance is that they evidenced slower response times for incorrect items 41-50 ($p \leq 0.04$ and $\eta^2 = 0.01$). Whilst the slower responses are in

[3] Refer to the discussion regarding the difference between practical and statistical significance on pages 40 and 47.

concordance with the rigid-trait individuals' lower impulsivity, their poorer performance accuracy seems contrary given that they appear to have less difficulty in tasks that require sustained attention, resistance to interference, and inhibition of responses than individuals scoring higher on NS (Guillem, *et al*., 2008). Reasons for this however may be due to increasing levels of anxiety as a result of the time pressure as well as the feedback of "correct/incorrect" after each response, as individuals who score high on HA tend to inhibit responses in an attempt to avoid punishment as well as non-reward (Cassimjee & Murphy, 2010; Cloninger, *et al*., 1994; Davis, *et al*., 2007). Furthermore, in comparison to impulsive individuals, those classified as rigid may have less spontaneous and reactive cognitive flexibility (more inwardly directed) and may fail to use negative feedback as a motivational boost to improve their performance.

5.2.1.2 Letter-N-Back (LNB2) task

The Letter-N-Back (LNB2) test measures attention and working memory, which have also been shown to involve dorsolateral prefrontal cortex circuitry (Deco & Rolls, 2003; Kane & Engle, 2002). In this test, rigid-trait individuals attained slightly more correct true positive responses as well as slightly fewer false positive responses overall than impulsive-trait individuals. This was conjectured given the attentional demands of retaining the important information and ignoring the irrelevant information presented by the task which is undermined by impulsivity. Similarly, as envisaged rigid-trait individuals had significantly higher median response times (slower) for all correct responses than impulsive-trait individuals (p 2-sided[4] ≤ 0.02 and $\eta^2 = 0.01$); as well as significantly slower median response times on the 1-back trial (p 2-sided ≤ 0.007 and $\eta^2 = 0.02$). Interestingly, rigid-trait individuals attained slightly fewer true positive responses on the 2-back trials which is a more demanding and complex stage of the LNB2. They also scored slightly more false positive responses on the 2-back trials. This could again be related to the rigid-trait individuals' proneness to anxiety which would increase deliberation and reduce impulsiveness and thus increase the time required to make a decision (Cassimjee &

[4] Refer to explanation of p 2-sided value on pages 40 and 48.

Murphy, 2010). Given that the LNB2 is a timed test, the pressure to respond could also undermine the rigid-trait individuals' performance accuracy.

Yang, Simmons, Scott, Matthews Tapert, Bischoff-Grethe *et al.* (2009) suggested that a personality more consistent with the attribution of errors to an internal source would be associated with greater activation of the subgenual anterior cingulate cortex, a neural structure that exerts inhibitory mechanisms on decision making and processing speed.

5.2.1.3 Motor Praxis (MPRAXIS) task

The MPRAXIS assesses sensory-motor ability. Here, rigid-trait individuals scored nominally fewer correct responses than did impulsive-trait individuals. However, their response speed was significantly slower than impulsive-trait individuals on trial 1 ($p \leq 0.01$ and $\eta^2 = 0.01$) and trial 2 ($p \leq 0.003$ and $\eta^2 = 0.02$).

5.2.1.4 Penn Conditional Exclusion Task (PCET)

The PCET measures abstraction and executive function similar to the Wisconsin Card Sorting Test (Kurtz, Ragland, Moberg & Gur, 2004; Kurtz, Wexler & Bell, 2004). As anticipated, rigid-trait individuals were consistently slower for correct responses (significant, $p \leq 0.04$ and $\eta^2 = 0.02$). Although not significant at the 5% level, a perusal of the results indicated that rigid-trait individuals also attained slightly more correct responses as well as fewer incorrect responses than did impulsive-trait individuals. Their general performance accuracy was also greater than impulsive-trait individuals in that they achieved a higher total number of trials and PCET categories, and made fewer perseverative errors. With regard to the rigid cluster, it appears that the profile of poorer performance and slower speed on complex tasks of abstraction (AIM and PCET) is pertinent to trials that require working memory. The dorsolateral PFC is the prominent substrate of working memory and its functioning is also implicated in BIS (Harm Avoidance) system and behavioural inhibition (Shackman, McMenamin, Maxwel, Greischar & Davidson, 2009).

5.2.1.5 The Short Penn's Logical Reasoning Test (SPVRT)

On the SPVRT, a measure of verbal intellectual ability, a difference in performance accuracy was observed with rigid-trait individuals attaining fewer correct responses than impulsive-trait individuals. This result is in accordance with findings by McNamara *et al*. (2008), which showed that individuals who scored higher on HA tended to perform more poorly on verbal fluency tests. Similarly, researchers have found that the left PFC is associated with *initiation of responses* and processing of information that is verbal and concrete and the left PFC is associated with BAS scores, which in turn are reflected in high NS scores (Amodio, *et al*., 2008).

Whilst research demonstrates that verbal fluency is positively correlated with level of education, it is believed that this would not have had a confounding influence on results given the relative homogeneity of this variable in the sample (Brickman, Paul, Cohen, Williams & MacGregor, *et al*., 2005).

5.2.1.6 Short Raven's Progressive Matrices (SRAVEN)

The SRAVEN is a measure of abstraction and mental flexibility. On this test, rigid-trait individuals had fewer correct responses than impulsive, as well as a significantly greater reaction time for correct responses ($p \leq 0.004$ and $\eta^2 = 0.02$). These results are not surprising given the rigid type's tendency to delayed decision-making as a result of anticipating failure and difficulties with adapting to change (Cassimjee & Murphy, 2010; Cloninger, *et al*., 1994).

5.2.2 Summary

Thus in summary, impulsive-trait individuals showed noticeably faster reaction times (processing speed) on the tasks that assessed attention, working memory, sensory-motor ability, concept formation, abstraction, and mental flexibility. They also exhibited a better performance on tasks assessing abstraction, concept formation, and mental flexibility (AIM and SRAVEN), as well as the more complex and demanding stage of the LNB2, namely the 2-back trials which relies on working memory.

With regards to practical significance or effect size, the findings show that the eta2 or η^2 values were relatively small, ranging between 0.01 and 0.02. Thus, whilst these results may seem low, it must be reiterated that the research is still in its early, exploratory stage and any evidence of association between temperament clusters and neuropsychological performance (even if very small) is in itself significant as a basis for prompting further investigation.

5.2.3 Hyperthymic versus hypothymic

Hypothymic-trait individuals are characterised with high scores on both HA and NS, whilst hyperthymic-trait individuals have low scores on HA and NS. As such, it would be expected that the hypothymic cluster would have slower reaction times when presented with the stimuli given their approach-avoidance tendencies and balancing their need for security and novelty (Cloninger, *et al.*, 1994). Lustman, Frank and McGill (1991) describe individuals scoring high on HA and NS as explosive personality types who show a tendency to score low on measures of persistence and attachment. In terms of performance accuracy and reaction times for the hyperthymic cluster, the low HA and low NS would indicate that these individuals may tend to be resistant to negative emotions and prone to overconfidence regardless of the situation. This may translate into a more heterogenous performance profile on executive functioning tests involving neurocognitive skills such as set formation, set maintenance and set-shifting.

5.2.3.1 <u>Penn Abstraction, Inhibition and Working Memory (AIM) task</u>

On the AIM, hyperthymic-trait individuals' performance accuracy was significantly better on tasks with and without working memory. These include items 21-30 ($p \le 0.008$ and $\eta^2 = 0.02$), items 41-50 (p 2-sided ≤ 0.00 and $\eta^2 = 0.04$), and items 11-20 ($p \le 0.003$ and $\eta^2 = 0.02$). They also exhibited significantly faster reaction time for correct responses on tasks with and without working memory than the hypothymic-trait individuals. These include items 1-10 (p 2-sided ≤ 0.00 and $\eta^2 = 0.01$), items 21-30 ($p \leq 0.02$ and $\eta^2 = 0.02$), and items 31-40 ($p \leq 0.03$ and $\eta^2 = 0.01$). Hyperthymic-trait individuals scored significantly higher on the total number of correct responses on tasks with and without working memory ($p \leq 0.00$ and $\eta^2 = 0.04$; and $p \leq 0.01$ and $\eta^2 = 0.02$). Finally, the mean of the median response times for correct responses on tasks with and without working memory was significantly faster for the hyperthymic cluster than for the hypothymic cluster ($p \leq 0.003$ and $\eta^2 = 0.03$; and $p \leq 0.006$ and $\eta^2 = 0.03$).

Thus it can be suggested that hypothymic individuals, who are prone to manifestations of neurotic behaviour such as second thoughts and checking initial impulses, performed more poorly than hyperthymic individuals in terms of speed and accuracy (Svrakic, Przybeck & Cloninger, 1992). Affirming the findings of this study, Keilp *et al.* (2005) showed that when information-processing demands (which require conflict resolution strategies) and response complexity (which incorporate set shifting processes) are increased and require timed responses, individuals characterized by impulsivity and behavioral dyscontrol (hypothymic) perform slower on complex tasks.

5.2.3.2 Letter-N-Back (LNB2) task

On the LNB2 task, the hyperthymic cluster had fewer true positive responses on 0-back, 1-back, and 2-back trials. The hyperthymic cluster had significantly ($p \leq 0.03$ and $\eta^2 = 0.02$) more false positive responses on 0-back trials. Interestingly, a difference between hypothymic and hyperthymic individuals' median response times for all correct responses was observed, with hyperthymic individuals being slower.

In contrast to their performance on the more complex AIM, the overconfident (hyperthymic) participants were slower on this simpler task and more prone to errors. Yang *et al.* (2009) observed using fMRI that the subgenual anterior cingulate cortex was more active during easy trials and greater activation of the subgenual anterior cingulate cortex (sgACC) was observed as the level of inhibitory difficulty decreased (reflected in the LNB2). They found that activation of the sgACC was positively correlated to higher scores on HA as well as higher levels of depression or sadness.

It can therefore be suggested that hypothymic individuals (high HA, high NS) may attribute errors or failures during the easy trials to themselves, given that accurate and fast responses are perceived as attainable by the individual. Hence, these errors may have been implicitly processed by the individual as more emotionally negative and evocative, influencing arousal and attention. Contrary to this, whilst the overconfident, resolute and less adaptable hyperthymic individuals (low HA, low NS) would also have perceived accurate and fast responses as attainable, they may have (in contrast to the hypothymic individuals) attributed errors made during the easy tasks to external factors and therefore possibly been less likely to "adapt" their responses on simpler tasks. Further, these errors may have been explicitly processed, reducing the emotionally negative and evocative salience potential. It appears that greater sgACC activity has a greater inhibitory effect on hyperthymic individuals than on hypothymic individuals on the simpler task, and a lower inhibitory effect on hyperthymic individuals on the more complex task.

This difference could be a function of greater activation of prefrontal cortex (PFC) convexities based on findings by Sylvester, Wager, Lacey, Hernandez, Nichols, Smith *et al*. (2003), which provides evidence for the "seperability of cognitive processes underlying executive control" (p. 357), which are performed by the different neural areas located in the PFC. For example, complex tasks require the executive function skills of set formation, set maintenance and set-shifting, which correspond to the executive function processes of initiation, conflict resolution/response selection, selective attention, self-monitoring, attentional vigilance, inhibition, discrepancy detection, cognitive flexibility, and working memory (Cassimjee & Murphy, 2010; Guillem, *et* al., 2008; Lezak, *et al*., 2004; Morasch & Bell, 2010; Whitney*, et al*., 2004). Neural substrates of these processes include the dorsolateral PFC, ventromedial PFC, and the orbitofrontal cortex. Tasks that require attention and working memory without conflict resolution depend mainly on the dorsolateral PFC for the executive function skill of planning and reasoning (that is, generating goals-set formation) and the executive functioning processes of focusing attention and working memory.

Another explanation for these differences relates to the functioning of the right insular cortex (Suhara, Yasuno, Sudo, Yamamoto, Inoue, Okubo, *et al*., 2001). The right anterior insular regulates the interaction between the salience of the selective attention created to achieve a task, namely the dorsal attention system, and the salience of arousal created to keep focused upon the relevant part of the environment, namely the ventral attention system (Fox, Corbetta, Snyder, Vincent & Raichle, 2006). This regulation of salience might be particularly important during challenging tasks where attentional resources might dissipate or fatigue and so cause careless mistakes. However, too much arousal can lead to increased anxiety which then presents a risk for deterioration in performance.

Whilst there has been conflicting evidence as to whether anxiety alone has a negative impact on neuropsychological performance, it has been shown that when anxiety is combined with depression, performance on attention and memory tasks are impaired (Kizilbash, Vanderploeg & Curtiss, 2002; Waldstein, Ryan, Jennings, Muldoon & Manuck, 1997). Thus, the association between implicit processing, proneness to depression and anxiety could explain the poor performance of hypothymic individuals on the AIM. Corroborating this hypothesis on a clinical level, Black *et al*. (2009) found that individuals diagnosed with borderline personality disorder (characterized by high NS and HA - hypothymic) performed poorly in the areas assessing decision-making, working memory, and cognitive inhibition.

5.2.3.3 Motor Praxis (MPRAXIS) task

Differences in performance speed were observed, with the hyperthymic cluster exhibiting a faster median reaction time for both MPRAXIS trials than the hypothymic cluster. The number of correct responses on trial two was the same for both clusters.

5.2.3.4 Penn Conditional Exclusion Task (PCET)

On the PCET, the hyperthymic cluster attained a greater number of correct responses than the hypothymic cluster as well as a significantly faster median response time for all correct responses (p 2-sided ≤ 0.03 and $\eta^2 = 0.03$). Hypothymic-trait individuals achieved a lower number of PCET categories again suggesting faster reaction times but poorer performance accuracy. They also made more perseverative errors. Studies on subjects with borderline personality disorder (BPD) show that these individuals reflect more frequent impairment on the Wisconsin Card Sorting Test (WCST) than normal controls (Black, *et al.*, 2009). The WCST measures executive function including problem-solving strategies in response to external feedback. It can therefore be inferred from this that BPD, characterized by high scores on both HA and NS is related to hypothymic (high HA and high NS), and the PCET is the computer equivalent of the WCST. Thus it follows that the hypothymic cluster (associated with BPD) performed poorly on the PCET when compared to the hyperthymic cluster.

5.2.3.5 The Short Penn's Logical Reasoning Test (SPVRT)

On the SPVRT, hyperthymic-trait individuals achieved significantly more correct responses than the hypothymic cluster (p 2-sided ≤ 0.01 and $\eta^2 = 0.02$). However, they also had a slower median reaction time for both correct and incorrect PVRT trials than hypothymic individuals.

5.2.3.6 Short Raven's Progressive Matrices (SRAVEN)

There were no significant differences between the groups in terms of performance accuracy and speed. The non-significant results show that the hyperthymic cluster achieved more correct responses on the SRAVEN as well as faster median reaction for correct responses. They also had a slower reaction time for incorrect responses.

5.2.4 Summary

In summary, hyperthymic-trait individuals displayed faster reaction times for the tasks assessing abstraction, concept formation (AIM, PCET, and SRAVEN), and sensory-motor ability (MPRAXIS). They also performed better on the SPVRT which assessed verbal intellectual ability, as well as on the abstract and concept formation tasks both with and without working memory (AIM, PCET, and SRAVEN). They did however, produce more errors on the LNB2 (attention) test.

5.3 LIMITATIONS OF THE RESEARCH PROJECT

The foremost limitation of this study is that the computerised PennCNP battery of tests used is relatively narrow, measuring specific aspects of executive function and abstract reasoning. Given the complexity of the relationships between brain function and temperament, a wider selection of neuropsychological tests assessing different aspects of neurological (and executive) performance would enhance current understanding. In addition, the results analysed were obtained from a single test situation, where individual performance could have been mediated by external, contextual factors not accounted for.

A further limitation is posed by the relative homogeneity of the sample used. Whilst the sample size is quite large, the socio-demographic composition is largely uniform, specifically in terms of age and level of education attained. Whilst participants with any history of psychiatric or medical illness were excluded, the study did not take into account the mediating effect of overall cognitive ability. Similarly, as per the TCI, the contribution of character traits (including when combined with temperament) was not factored which therefore motivates for further research using both character trait clusters as well as combinations of character and temperament trait clusters.

In addition, the study does not account for the mediating influence of psychosocial and contextual factors (which can be difficult to isolate, define, and assess empirically) on the cognitive behavioural outcomes of temperament and the related neuroanatomical functioning as evidenced by performance on neuropsychological tests. Sugarman (2002) reminds us that executive functioning is not limited to "tangible" elements such as measurable cognitive processes but incorporates many other dimensions such as social and emotional influences, which "may be intertwined with aspects of recursive and self-reflexive conscious awareness (Cassimjee & Murphy, 2010).

Finally, the measuring instruments used have not been normed for a South African sample, and therefore caution should be exercised in the interpretation of the results.

5.4 RECOMMENDATIONS FOR FUTURE RESEARCH

Whilst the focus of this research was limited to exploring the neuropsychological performance profiles of second order clusters comprised of the temperament traits harm avoidance (HA) and novelty seeking (NS), the findings reveal significant associations which provide motivation for further investigations. Therefore, it is recommended that future larger scale studies be conducted that:

- Explore the relationships between temperament clusters which include the additional temperament traits of reward dependence (RD) and persistence (P) as per the TCI; as well as clusters comprised of the character traits self-directedness (SD), cooperativeness (CO), and self-transcendence (ST).

- Use both clinical and non-clinical samples incorporating more heterogeneous socio-demographics given the influence of psychosocial factors on neuropsychological test performance.

- Use a wider selection of tests that tap into different areas of executive ability and performance.

5.5 CONCLUSION

This study has provided evidence of notable differences in neuropsychological performance profiles between the impulsive and rigid clusters and the hypothymic and hyperthymic clusters as measured and defined by the TCI, and neuropsychological performance on the PennCNP battery of neuropsychological tests for executive functioning and abstract reasoning.

The observed influence that temperament has on neuropsychological performance is based on the initial premise upon which this research rests, which is that temperament and executive functioning share common underlying neuroanatomical sites and processes. However, the degree to which personality influences neuropsychological performance will benefit from further research as per the recommendations above.

Therefore, the difference in neuropsychological performance profiles according to temperament configurations raises the following questions:

- Do these differences reflect specific convexities of the PFC?

- Do neuropsychological performance profiles and temperament clusters constitute independent or linked vulnerability features for psychopathology onset?

- Research has shown that, for example, participants with BPD (hypothymic) & APD (impulsive) symptoms, characterized by impulsivity and behavioral dyscontrol, showed distinct neurocognitive profiles. Hence, future research needs to investigate between group differences as well.

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