

**An exploratory study of Novelty Seeking tendencies and students'  
performance on executive functioning tasks**

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# DEDICATION

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To my grandmother  
in appreciation for her constant support, love and guidance

# ACKNOWLEDGEMENTS

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This chapter has now come to an end and, upon reflection, this journey would not have been possible without the support and guidance of many people who have played a significant role in my life. I would first and foremost like to thank my supervisor, Prof. Nafisa Cassimjee, without whose unstinting support and guidance I would not have been able to explore the depths and wonders of the human mind. I would also like to express my sincere appreciation to Dr. Raegan Murphy for expert assistance in the statistical analysis.

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# ABSTRACT

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In light of collated research linking temperament traits and executive performance, the aim of this study is to explore, in a large non-clinical sample, the differences in executive performance profiles among participants with different intensities of the trait Novelty Seeking (NS). A further aim is to establish which facets of NS contribute to these differences. The NS temperament dimension and its subscales were operationalised as scores on the Temperament and Character Inventory (TCI), which is based on the psychobiological theory of personality. The University of Pennsylvania Computerised Neuropsychological Test Battery (PennCNP) of executive functioning (EF) and abstract reasoning was used to measure participants' neuropsychological EF.

The total sample of participants (n= 461) was divided into high NS (n= 216) and low NS (n= 245) groups to investigate any significant differences between them. Further analysis was then conducted in order to analyse the relationship between the NS scale, the four subscales (Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness), and performance in executive tasks.

The findings of this study indicated significant differences between groups with different intensities of NS, with the high NS group functioning notably better in performance and reaction time. Furthermore, this study showed that facets of NS, such as impulsiveness was a significant contributor to EF performance outcomes.

## **KEY TERMS**

Executive functioning; TCI; novelty seeking; subscales; impulsiveness; temperament; personality; psychobiological theory; neuropsychological performance; PennCNP.

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# ABBREVIATIONS

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Act:	Activity
ADHD:	Attention-deficit/hyperactivity disorder
Agg-Hos:	Aggression-Hostility
AIM:	Penn Abstraction, Inhibition and Working Memory Task
BAS:	Behavioural approach system
BDP:	Borderline personality disorder
BIS:	Behavioural inhibition system
CBD:	Compulsive buying disorder
CNB:	Computerised neurocognitive battery
CO:	Cooperativeness
COWAT:	Controlled Oral Word Association Test
D:	Disorderliness
E:	Extravagance
E:	Extraversion
EE:	Exploratory excitability
EF:	Executive functioning
FFFS:	Fight-flight-freeze system
GWPQ:	Gray–Wilson Personality Questionnaire
HA:	Harm avoidance
I:	Impulsiveness
ImpSS:	Impulsive sensation seeking
ImpUSS:	Impulsive Unsocialised Sensation Seeking
LNB:	Letter-N-Back
MAO:	Monoamine oxidase
MDD:	Major depressive disorder
MPRAXIS:	Motor praxis (PennCNP general sensory-motor ability and familiarisation trial)
mRT:	Median reaction time
N-Anx:	Neuroticism-Anxiety

NRF:	National Research Foundation
NS:	Novelty seeking
NS1:	Exploratory Excitability vs. Stoic Rigidity (novelty seeking subscale)
NS2:	Impulsiveness vs. Reflection (novelty seeking subscale)
NS3:	Extravagance vs. Reserve (novelty seeking subscale)
NS4:	Disorderliness vs. Regimentation (novelty seeking subscale)
P:	Persistence
PCET:	Penn Conditional Exclusion Test
PennCNP:	University of Pennsylvania Computerised Neuropsychological Test Battery
RD:	Reward dependence
r-RST:	Revised reinforcement sensitivity theory
RSH:	Rank sum high
RSL:	Rank sum low
RST:	Reinforcement sensitivity theory
SD:	Self-directedness
SN/VTA:	Substantia nigra/ventral tegmental area
SPSS:	Statistical Package for the Social Sciences
SPVRT:	Penn Short Logical Reasoning Test
SRAVEN:	Short Raven's Progressive Matrices
ST:	Self-transcendence
Stroop:	Stroop Colour and Word Test
SUD:	Substance use disorder
Sy:	Sociability
TCI:	Temperament and Character Inventory
TMT:	Trail Making Test
TOH:	Tower of Hanoi Test
TotNS:	Total (of) novelty seeking
UPPS:	Premeditation (lack of), urgency, sensation seeking, and perseverance (lack of) (Whiteside and Lyman Impulsive Behaviour Scale)
VNH:	Valid N high

VNL: Valid N low

WCST: Wisconsin Card Sorting Test

# CHAPTER 1

## INTRODUCTION

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### 1.1 OVERVIEW

Studies in the field of neuroscience have elucidated associations between certain types of neuropathology, changes in personality, and deficits in executive functioning (EF) (Campbell, Davalos, McCabe, & Troup, 2011). Indeed, a substantial amount of evidence has indicated a correlation between temperament and psychiatric disorders and, in particular, the relationship between temperament, neuropsychological performance, and psychopathology (Aigner et al., 2007; Boeker et al., 2006; Guillem, Pampoulova, Rinaldi, & Stip, 2008). Similarly, research has also set out to elucidate the neurophysiological aspects underlying and contributing towards temperament as well as neuropsychological performance (Henderson & Wachs, 2007; O’Gorman et al., 2006; Whittle, Allen, Lubman, & Yücel, 2006). Indeed, studies have found that not only does a correlation exist between personality traits and performance in neurocognitive measures (Baum et al., 2010; Bond, 2001; Cassimjee & Murphy, 2010; Keilp, Sackeim, & Mann, 2005), but also that certain personality traits can be associated with enhanced neuropsychological performance on these measures (Kagan, as cited in Verdejo-García, López-Torrecillas, Calandre, Delgado-Rodríguez, & Bechara. 2009).

It is consequently not surprising that, based on collated research, studies have stressed the importance of examining the connection between EF and individual differences in temperament and personality (Williams, Suchy, & Rau, 2009). By examining individual differences and personality traits, it is possible to elicit rich information regarding cognitive systems and thus further our understanding of the association between personality and EF (Campbell et al., 2011). Moreover, Campbell et al. (2011) have argued that by investigating individual differences in typical individuals as opposed to a clinical sample, knowledge of the relationship between temperament and EF may be promoted.

As this exploratory study sought to investigate the association between EF and individual differences in temperament, Cloninger's Temperament and Character Inventory (TCI) was utilised. The TCI is a psychobiological model of personality, describing personality in terms of the interaction between temperament and character (Cloninger, Svrakic, & Przybeck, 1993; Cloninger, Przybeck, Svrakic, & Wetzel, 1994). For the purpose of this exploratory study, only one of the four temperament clusters was employed, namely Novelty Seeking (NS). The NS temperament dimension consists of subscales, which were also operationalised. The theoretical motivation for focusing on this temperament trait will be outlined below.

## **1.2 RESEARCH PROBLEM**

Researchers have noted a theoretical substantiation for the association between EF and temperament in that these attributes share similarities in neuroanatomical sites and neurotransmitter functions (Cassimjee & Murphy, 2010). Further to this, studies that have investigated neuropsychological performance of temperament clusters, such as a study conducted by Bergvall, Nilsson, and Hansen (2003), have found an association between deficits in neuropsychological functioning and the development of certain personality traits. Indeed, certain temperament traits, in particular NS, have been associated with decreased neuropsychological performance (Black, Shaw, McCormick, Bayless, & Allen, 2012; Bond, 2001) and correlations between EF performance and temperament, in terms of NS, have indicated greater interference sensitivity and poorer manipulation (Guillem et al., 2008). Moreover, decreased performance on verbal memory tasks has been attributed to the temperament trait of NS (Bond, 2001). Despite these findings, there is still a need for research to investigate the neuropsychological performance profiles of extremes of the first-order traits.

In view of the above findings, the correlation between NS and EF was investigated, in particular the association between different intensities of NS and EF performance outcomes. To further contribute to the body of research on the association between NS and EF, this exploratory study included the following: firstly, categorization of NS participants into high and low groups in order to explore how the intensity of trait NS influences EF performance and, secondly, the inclusion of subscales to explore how facets of NS contribute to EF performance.

In order to categorise individuals with different intensities of NS, participants were divided into high and low NS groups in terms of the following formula:

- i) Low: total NS score  $\leq$  mean NS score
- ii) High: total NS score  $\geq$  mean NS score

In light of the differences between executive performance and intensities of trait NS profiles, further analysis was conducted to determine which of the NS subscales, namely Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness, were predictors of executive performance outcomes.

The instruments incorporated in this study comprise the TCI based on Cloninger's psychobiological model of personality, and the University of Pennsylvania Computerised Neuropsychological Test Battery (PennCNP) for measuring neuropsychological EF domains, such as working memory, abstraction, and attention. The TCI comprises a questionnaire that assesses normal and abnormal behaviour patterns based on seven dimensions that are grouped into four temperament scales and three character scales. For the purpose of this study, the temperament scale "NS" and its accompanying NS subscales were used. The PennCNP tests that were used to conduct this study consist of the following:

- the MPRAxis, general sensory-motor ability test;
- the Penn Abstraction, Inhibition, and Working Memory Task (AIM);
- the Letter-N-Back (LNB2);
- the Penn Conditional Exclusion Test (PCET);
- the Penn Short Logical Reasoning Test (SPVRT);
- Short Raven's Progressive Matrices (SRAVEN).

The current study also forms part of a larger research initiative that was funded by the National Research Foundation (NRF) and the University of Pretoria Development Fund. The data utilised in this study were collected over a two-year period and will be discussed in detail in the methodology section.

### 1.3 MOTIVATION

This exploratory study is premised on the demonstrable relationship that exists between EF and temperament. Prior research has indicated that these two constructs—which share underlying neurotransmitter and neuroanatomical systems—have been implicated in psychiatric disorders, neuropsychological performance, and psychopathology (Cassimjee & Murphy, 2010; Guillem et al., 2008; Henderson & Wachs, 2007). Although prior research has sought to delineate this relationship more clearly, studies of this nature are scant, and research that focuses on cognitively intact individuals (non-clinical samples) is also limited.

The aim of this exploratory study is thus to determine, in a large non-clinical sample, the differences in executive performance profiles among participants with different intensities of trait NS. Further objectives are to establish which facets of NS contribute to these differences, in the hope of contributing to the corpus of knowledge on the relationship between temperament and EF performance.

### 1.4 THESIS STRUCTURE

**Chapter 1** entails an introduction to the problems statement and a basic overview of the research study.

**Chapter 2** consists of a literature review that provides a detailed summary of research conducted in the fields of temperament and EF pertaining to psychobiology and neuropsychological performance.

**Chapter 3** includes a detailed description of the methodology utilised in this research, including the research design, procedure, and the assessment instruments employed.

**Chapter 4** contains the results obtained from the statistical analysis.

**Chapter 5** consists of a discussion of the findings of the study, integrated with prior research. This is then followed by the potential limitations of the study, as well as recommendations for future research.

# CHAPTER 2

## LITERATURE REVIEW

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### 2.1 OVERVIEW

The aim of the present study is to explore, in a large non-clinical sample, the differences in executive performance profiles among participants with different intensities of trait NS. Furthermore, the analysis of the NS subscales will be utilised to determine which facets of NS contribute to these differences. The NS temperament dimension and its subscales will be operationalised as scores on the Temperament and Character Inventory (TCI), which is based on the psychobiological theory of personality (Cloninger et al., 1993).

Based on prior research, a substantial amount of evidence has indicated a correlation between temperament and psychiatric disorders and, in particular, the relationship between temperament, neuropsychological performance and psychopathology (Aigner et al., 2007; Boeker et al., 2006; Guillem et al., 2008). Research has also set out to clarify the neurophysiological facets underlying and contributing towards temperament (Henderson & Wachs, 2007; O’Gorman et al., 2006; Whittle et al., 2006) as well as associated neuropsychological performance. Bergvall et al. (2003), for instance, have found an association between deficits in neuropsychological functioning and the development of certain personality traits. For example, decreased performance on verbal memory tasks has been attributed to temperament trait NS (Bond, 2001). In addition, correlations have been found between performance and temperament which, in terms of NS, indicates greater interference sensitivity and poorer manipulation (Guillem et al., 2008).

In particular, Cloninger’s temperament dimension NS has further been strongly associated with a number of psychopathologies, including major depressive disorder (MDD) and various anxiety disorders (Celikel et al., 2009; Matsudaira & Kitamura, 2006; Nery et al., 2009; Richter, Polak, & Eisemann, 2003).



Furthermore, NS has also been associated with underlying brain structure and functioning, and individuals with high NS show perfusion in the cuneus, cerebellum, and thalamus (O’Gorman et al., 2006). Neurotransmitter systems have also been implicated, with research suggesting a linkage between NS and the dopamine system (Carver & Miller, 2006; Gardini, Cloninger, & Venneri, 2009; Henderson & Wachs, 2007; Kantojärvi et al., 2008; Ravaja, Keltikangas-Järvinen, & Kettunen, 2006) and the serotonin system (Bjork et al., 2002; Congdon & Canli, 2008; Jakubczyk et al., 2012; Preuss et al., 2001).

A study conducted by Suchy (2009) has reported individual differences in EF among cognitively intact individuals. These differences in EF are attributed to several factors, such as genotypic variation, endophenotypes (e.g., performance on cognitive tasks) and phenotypic variations, such as temperament and personality (Williams et al., 2009). Research by Smith, Cloninger, Harms, and Csernansky (2008), and Williams et al., (2009), has postulated that temperament is one of the endophenotypes or phenotypic variations that influence neuropsychological outcomes, specifically EF. This theory of EF as a potential endophenotype is substantiated by research that espouses commonality in the neuroanatomical sites and neurotransmitter functions of executive function and temperament (Cassimjee & Murphy, 2010).

Although some research has been undertaken into the neuropsychological performance of temperament clusters (Meyer & Deckersbach, 2005), further research is required to discover the neuropsychological performance profiles of extremes of the first-order traits. Specifically in South Africa, very limited neuropsychological research has been conducted and there is an even greater dearth of investigations focusing on cognitively intact individuals (non-clinical samples). Moreover, studies exploring the profiles of executive performance as moderated by temperament traits are limited.

## **2.2 CRITICAL ASPECTS OF EXECUTIVE FUNCTIONING**

### **2.2.1 Executive Functioning in brief**

Most of our daily activities are carried out in an automatic and routine compartment, although there are situations in which conventional, acquired responsive behaviours and cognition are inadequate (Collette, Hogge, Salmon, & Van der Linden, 2006).

It is in these situations, where the task precludes an automatic or routine response, that the once dormant executive functions become active to address the precipitating factors (Stuss, 1992, Stuss, 2011). Executive functions are essential for everyday functioning. Indeed, our ability to adapt to new or complex situations, to monitor and control thought and action, to solve novel problems, implement strategies, inhibit inappropriate behaviours, modify behaviour in light of new information, and follow through with plans, all reside in higher-order cognitive processes and behavioural competencies that are collectively known as executive functions (Chan, Shum, Touloupoulou, & Chen, 2008; Cummings & Miller, 2007; Miyake et al., 2000). These higher-order cognitive processes are highly effortful and will thus remain inactive for most of our waking hours. Yet, although they may be “new” complex process and behaviours when activated for the first time, they can eventually become automatic with repetition and be transferred to a lower level, and the executive functions will once more become dormant (Stuss, 2011).

According to Chan et al. (2008), executive functions can be viewed in two separate categories depending on their functions. On the one hand, there are “cold” functions, which refer to cognitive processes that are not necessarily emotional in nature, but rather mechanistic and logical (Grafman & Litvan, 1999). On the other hand, the “hot” processes tend to have an emotional component and may refer to individuals’ decision-making experience and personal, internalised interpretation of their experience of situations, such as rewards and punishment (Bechara, Damasio, Tranel, & Damasio, 1997; Grafman & Litvan, 1999).

Since executive functions play such an important role in daily functioning, any impairment that might hamper these executive processes for optimal functioning may have devastating effects on an individual’s performance (Goel, Grafman, Tajik, Gana, & Danto, 1997; Grafman & Litvan, 1999). Indeed, EF is predominantly found to be associated with a part of the brain known as the prefrontal cortex, which is not only responsible for cognitive processes but is also associated with personality (Chow, 2000).

### **2.2.2 Components of Executive Functioning**

A number of studies, both empirical and contemporary, have examined executive functions in terms of conceptions about fractionation and unitariness. These earlier studies have focused on the interdependence of executive functions through single-case and group study analysis of both brain-damaged patients and healthy candidates (Duncan et al., 1997; Godefroy, Cabaret, Petit-Chenal, Pruvo, & Rousseaux, 1999; Lowe & Rabbitt, 1997; Robbins et al., 1998; Shallice & Burgess, 1991).

The results obtained from these studies have suggested that the central executive network of the brain is not purely unitary in its functioning, but is rather fractioned and operates in a relatively independent way. More specifically, Baddeley (1996) has proposed that executive functions are divided into four distinct types: the capacity to allocate resources during the simultaneous execution of two tasks (dual task coordination), the capacity to switch retrieval strategies (shifting), the capacity to attend selectively to one stimulus and inhibit the disrupting effect of others (inhibition), and the capacity to hold and manipulate information stored in long-term memory (updating).

A study conducted by Miyake et al. (2000) has examined to what extent these functions—shifting, inhibition, and updating (dual task coordination)—are segregated, as well as their role in executive tasks, to systematise them in a theoretically and clinically more useful construct. Their study indicated that although executive functions can be characterised as separable, there is an underlying commonality among them. These researchers furthermore postulated that the reasons for the commonality among these executive functions are rooted in inhibitory control and working memory. Later studies and further advances in neuroimaging have confirmed the results obtained by Miyake et al. (2000) by corroborating the supposition that EF can be categorised as both a fractioned and unitary construct (Collette et al., 2006; Fournier-Vicente, Larigauderie, & Gaonac'h, 2008).

### **2.2.3 Measuring Executive Functioning**

Increasing interest in EF has led to the development of a variety of neuropsychological tests. Assessment instruments such as the Wisconsin Card Sorting Test, the Controlled Oral Word Association Test, the Tower of Hanoi Test, the Trail Making Test, and the Stroop Colour and

Word Test, were designed to provide clinicians and researchers with objective means for studying and measuring EF (Campbell et al., 2011; Chaytor, Schmitter-Edgecombe, & Burr, 2006; Lezak, Howieson, & Loring, 2004; Suchy, 2009). Although these tests are widely used, they appear to have many inherent problems. Past research has indicated that there is uncertainty regarding what these executive tests actually measure, which in turn compromises the usefulness of the results obtained (Chan et al., 2008; Fournier-Vicente et al., 2008; Miyake et al., 2000).

In order to address some of the limitations of executive tests, such as those mentioned above, the computerised Penn Conditional Exclusion Test (PCET) was developed (Kurtz, Ragland, Moberg, & Gur, 2004a). They noted that there are several advantages in utilising computerised cognitive assessments such as the PCET. Firstly, there are alternative forms that may be used, which limit confounding effects; secondly, testing time is much shorter than that of other EF tests; and thirdly, they offer the advantage of automated scoring, which also reduces test-retest variability. Similarly, a study conducted by Gur et al. (2001) set out to address the effectiveness of a cognitive computerised assessment, specifically regarding its standardisation and initial construct validity. The researchers developed a set of computerised neurobehavioural measures, which are collectively referred to as the computerised neurocognitive battery (CNB). The CNB assesses nine different neurocognitive domains, which include the abstraction and mental flexibility assessed by the PCET (Kurtz et al., 2004a) and working memory assessed by the Letter N-Back test (LNB) (Ragland et al., 2002). Their findings revealed moderate to high indices of reliability, construct validity, and more preliminary criterion validity on these neurocognitive measures, which underscored the importance and value of utilising computerised neurocognitive assessments.

#### **2.2.4 Executive Functioning and neural substrates**

EF is referred to as higher-order cognitive functions, and it is these higher-order functions that essentially provide humankind with the ability to overcome animal-like tendencies (Suchy, 2009). Indeed, the area of the brain mostly commonly associated with EF is the prefrontal cortex (Lezak et al., 2004; Suchy 2009), which is the most recently evolved part of the human brain, and which has aptly been referred to as “the organ of civilization” (Goldberg, 2001, p. 2).

Research conducted by Wager and Smith (2003) has indicated that different executive processes are associated with specific cerebral areas. For example, cognitive processes such as manipulation of information, updating of working memory, and selective attention activate the right inferior cortex, superior frontal cortex and the medial prefrontal cortex respectively. Although research has revealed specific links between EF and the frontal cortex, a number of other brain regions have also been associated with executive processes.

Previous studies, such as those carried out by Andrès and Van der Linden (2000), have shown that patients with non-frontal lesions can exhibit similar executive deficits as those of frontal patients. Furthermore, patients have frequently been discovered to exhibit deficits in EF after sustaining diffuse rather than focalised injuries (Andrès & Van der Linden, 2000; Vilkki, Virtanen, Surma-Aho, & Servo, 1996). It has consequently been suggested that EF is not solely localised within the frontal lobes, but is rather based on a neural network involving both the anterior and posterior cerebral areas, including the anterior cingulate gyrus, the basal ganglia and diencephalic structures, the cerebellum, deep white matter tracts, sections of the parietal lobes, the limbic system, and the brainstem (Collette et al., 2006; Williams et al., 2009).

Specific neurotransmitter systems have also been implicated in executive function, in particular certain aspects of the dopamine and serotonin systems. Additionally, Fossella, Sommer, Swanson, Pfaff, and Posner (2002) found an underlying association between the dopamine D4 receptor and monoamine oxidase A genes and executive attention. Monoamine neurotransmitters are of great importance, as these are at the basis of fundamental personality traits (Zuckerman, 1995). A study by McNamara, Durso, and Harris (2008), which examined alterations in personality in Parkinson's disease, noted that changes in personality and the perception of self are associated with changes in EF. This is significant in that Parkinson's disease is associated with alterations in the dopamine neurotransmitter system. Research has shown that Serotonin (5-HT) has also been implicated in EF (Robbins & Arnsten, 2009; Robinson, Dalley, Theobald, Glennon, & Pezze, 2008). Specifically, a study by Enge, Fleischhauer, Lesch, Reif, and Strobel (2011) has found 5-HTTLPR and MAOA-uVNTR to play a significant role in the executive control of inhibitory processes during response selection, which is essential for working memory processes.

## 2.3 PSYCHOBIOLOGICAL THEORIES OF PERSONALITY

The terms personality and temperament are often used interchangeably, as there are some empirical and conceptual linkages between them (Hagekull & Bohlin, 1998; Strelau, 1987). However, there are some noteworthy distinctions, in that temperament does not include complex processes central to the expression of personality, such as attributions, self concept, or consciousness self-presentation. Instead, the focus centres on individual differences in reactivity and self-regulation (Henderson & Wachs, 2007). Personality, in turn, can be defined as an innate force that integrates individuals' behaviour and allows them to adjust to the environment, or initiates their feedback response to the actions and reactions of other individuals (Eysenck, 1967).

Interest in personality and temperament can be traced back to classical antiquity (Goldsmith et al., 1987; Rothbart as cited in Komsis et al., 2006; Strelau, 1987), and the linkage between these constructs is currently the focus of multidisciplinary research in the fields of neuroscience and psychology (Henderson & Wachs, 2007). Temperament is seen as a genetically endowed biological construct that can be defined as the initial state from which personality develops as a result of interaction with experience (Rothbart, Ahadi, & Evans, 2000). Since it influences, and is influenced by experience, it can be considered the source of individual differences in emotional, motor, and attentional reactivity (Rothbart, 2007). According to Henderson and Wachs (2007), temperament tends to be relatively stable, although it does have the propensity to change as a function of age, personality, and social and cultural experiences. A study completed by Van Schuerbeek, Baeken, De Raedt, De Mey, & Luyckaert (2010) has indicated that individual variations in brain morphology can be related to different temperament dimensions, and that brain maturation is influenced by both genetics and the environmentally determined component of personality. There is also evidence that points to neurotransmitter activity, specifically the serotonin and dopamine systems, which may account for individual differences in temperament.

A number of personality models exist that seek to describe the relationship between neurobiology, genetics, and personality (Ha, Kim, Abbey, & Kim, 2007). Within this context, various theorists have explored the neurobiological underpinnings of temperament, given its heritable and relatively stable nature (Mardaga & Hansenne, 2007).

A number of models based on these theories have been formulated, with Eysenck (1967) developing a model of personality based upon three universal traits, namely Introversion/Extraversion, Neuroticism/Emotional Instability, and (added later) Psychoticism. Additionally, Zuckerman introduced a model of personality that incorporated five personality traits, namely Sociability, Neuroticism-Anxiety, Impulsive Unsocialised Sensation Seeking, Aggression-Hostility and Activity (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993).

Cloninger et al. (1993), in turn, differentiated personality into temperament and character, and devised a seven-factor model of personality encompassing four temperament dimensions (Harm Avoidance, Novelty Seeking, Reward Dependence, and Persistence), and three character dimensions (Self-directedness, Cooperativeness, and Self-transcendence). In the ensuing discussion, the above models will be discussed in order to contextualise the neurobiological underpinnings of personality.

### **2.3.1 Eysenck's theory of personality**

As mentioned in the previous paragraph, Eysenck (1967, 1997) developed a psychobiological model of personality based on a factor analysis consisting of Extraversion, Neuroticism, and Psychoticism. Extroversion can be described as a propensity towards being social and outgoing, whereas Neuroticism refers to anxious and under-confident tendencies. Psychoticism, which was incorporated in this model only much later, refers to a propensity towards solidarity, aggression, impulsiveness, and risk-taking. In tandem with this three-factor model, Eysenck developed numerous personality questionnaires to measure the aforementioned factors in terms of a continuum. The Extroversion scale represents social extraversion. A high score on this scale could imply sociability and outgoingness, whereas a high score on the Neuroticism scale, which represents emotional instability, reflects a proneness to anxiety, moodiness, and possible depression. Finally, the Psychoticism scale corresponds to cruelty and sensation seeking, and a high score on this scale could describe a propensity towards solitary, cruel, and inhumane behaviour.

Eysenck attributed two board brain systems as being central to his psychobiological model of personality. Firstly, it is believed that introverts are typically more aroused than extroverts, which is in part due to the reticulocortical circuit which controls arousal from incoming stimuli.



Secondly, the reticulolymbic system, which is related to Neuroticism, is thought to become aroused with emotion-inducing stimuli. The biological basis for Psychoticism is, however, not as clear and has as yet to be fully identified (Jackson, 2001).

### **2.3.2 Zuckerman's theory of personality**

Zuckerman, who was a former student of Eysenck, developed a five-factor psychobiological model of personality. Although Eysenck's Extroversion and Psychoticism factors do relate respectively to sensation seeking and impulsive traits, Zuckerman, Kuhlman, and Camac (1988) noted that most factor analysis measures were unable to provide an adequate representation of sensation seeking and impulsive measures. Eysenck's Neuroticism factor, for example, is unable to explain the negative affect of hostility or anger adequately. Moreover, the proposed location of hostile affect in Psychoticism might be inappropriate in that it does not quite correlate with aggressive behaviours.

Zuckerman's psychobiological model consists of five factors, namely Sociability (Sy), Neuroticism-Anxiety (N-Anx), Impulsive Unsocialised Sensation Seeking (impUSS), Aggression-Hostility (Agg-Hos) and Activity (Act) (Zuckerman et al., 1993). Sociability refers to one's propensity to engage socially with others, the number of close acquaintances one has, and the frequency of one's social interactions as opposed to being socially withdrawn. Neuroticism-Anxiety refers to emotional upset, tension, worry, fearfulness, obsessive indecision, lack of self-confidence, and sensitivity to criticism. The Impulsive Unsocialised Sensation Seeking items refer to lack in planning and a tendency to act impulsively without considering the consequences. It should also be noted that these items are associated more with content, as opposed to activities, and are better described as experience seeking or the willingness to take risks for the sake of excitement or novel experience (Zuckerman et al., 1993).

The preponderant number of items on Aggression-Hostility involves verbal expression, whereas the remainder of them include rude, vengeful, or antisocial behaviour. It has been found that people who score high on this scale are easily angered and lack patience with others (Zuckerman et al., 1993). On the Activity scale, half of the items refer to a propensity for challenging and hard work, along with an active and high-energy lifestyle, while the other half of them refer to an inability to relax and to being idle.



### 2.3.3 Gray's theory of personality

Gray proposed a neuropsychological theory of personality known as the reinforcement sensitivity theory (RST) (Pickering, Diaz, & Gray, 1995), which served as an alternative to Eysenck's model of personality. The RST model is based on the interaction of three emotional systems that underlie motivated behaviour: The behavioural approach system (BAS), the behavioural inhibition system (BIS), and the fight-flight-freeze systems (FFFS) (Corr, 2002; Gray & McNaughton, 2000; Jackson, 2003; Mardaga & Hansenne, 2007). Carver and White (1994) designed a model to measure BAS and BIS sensitivity. Later, the Gray–Wilson Personality Questionnaire (GWPQ) was designed to serve as a measure for Gray's RST model, which was followed by Jackson, who designed the “Jackson-5 scales” to measure Gray's revised reinforcement sensitivity theory (r-RST) (Jackson, 2002; Jackson, 2009; Wilson, Gray, & Barrett, 1990).

According to Gray's theory, the BAS is sensitive to signals of reward (Approach) and punishment (Active Avoidance), whereas the BIS system is sensitive to signals of punishment (Passive Avoidance) and non-reward (Extinction) and, finally, the FFFS is sensitive to the need for rapid escape from sources of punishment (Flight) and defensive aggression (Fight) (Corr, 2001). The BAS is associated with the experience of positive feelings (hope, elation, and happiness), and is sensitive to signals of reward in that this system is a causal factor in an individual's behaviour to move towards a goal. The BIS system, however, is associated with the experience of negative feelings (anxiety, frustration, and sadness), and is sensitive to signals of punishment and novelty in that this system is the causal factor that will inhibit behaviour towards a goal. There is however, some indication that BIS is more responsible for the detection and resolution of goal-conflict between the tendency towards risk (BAS) and the avoidance of risk (FFFS), as opposed to solely inhibiting behaviour (Corr, 2010; Corr & Perkins, 2006).

With regard to an individual's personality traits, the BAS has been associated with impulsivity and the BIS with anxiety, as both traits are found to have a biological basis in BAS and BIS respectively (Aubi, Yousefi, & Alimoradi, 2011; Carver & White, 1994; Gray, 1982; Jackson, 2003).

Gray's BAS/BIS model has also been associated with numerous underlying neurophysiological substrates. The BAS, for instance, has been associated with the dopaminergic neurotransmitter system, and the BIS with the monoamine neurotransmitter along with the noradrenergic and serotonergic networks (Gray & McNaughton, 2000). Furthermore, the BAS can be associated with striatal dopamine projections in the prefrontal cortex, more specifically the lateral and orbital regions, while the BIS has been more closely linked to the brainstem, specifically the amygdala and the septohippocampal system and the anterior cingulate cortex (Corr & Perkins, 2006; Gray & McNaughton, 2000; Yanagisawa et al., 2011). Furthermore, a study by Harmon-Jones (2003) indicated a positive correlation between approach-related motivation with left-sided frontal asymmetry, and between avoidance-related motivation and right-sided frontal asymmetry.

Many studies have been conducted to explore the correlations between psychobiological models of personality. Although Gray's BAS and BIS theory was developed as an alternative to Eysenck's model of personality, there are some underlying relations between them. Initially Gray (1987) proposed that BIS could be positively associated with Neuroticism and negatively with Extraversion (E), while BAS can positively associated with both Extraversion and Neuroticism. Studies have confirmed this association and have indicated that a correlation exists between Eysenck's and Gray's theories, although this correlation is not as seemingly clear-cut as initially proposed (Corr, 2001; Corr & McNaughton, 2008; Heym, Ferguson & Lawrence, 2008; Hughes, Moore, Morris, & Corr, 2012; Torrubia, Ávila, Moltó & Caseras, 2001).

## **2.4 CLONINGER'S PSYCHOBIOLOGICAL MODEL OF PERSONALITY**

Robert Cloninger sought a general model that applied to both normal and abnormal personality, similar to the model postulated by Eysenck. He proposed a psychobiological model describing personality in terms of the interaction between temperament and character (Cloninger et al., 1993; Cloninger et al., 1994). This model distinguishes between four temperament dimensions: Harm Avoidance (HA), Novelty Seeking (NS), Reward Dependence (RD), and Persistence (P). Further, it also describes three character dimensions: Self-Directedness (SD), Cooperativeness (CO), and Self-Transcendence (ST).

HA can be described as one's tendency to either inhibit behaviour or to avoid punishment, NS to initiate impulsive behaviour towards novel stimuli, RD to engage or maintain behaviours that generate a reward, and P to maintain an ongoing behaviour despite an absence of reward. SD describes one's view of the self as an autonomous individual, CO as an integral part of society, and ST as a part of a broader universe, including the tendency towards spiritualism (Cloninger et al., 1993).

The temperament traits are found to be genetically determined, heritable, and relatively stable during lifetime, and have been defined in terms of individual differences in associative learning in response to novelty, danger or punishment, and reward (Cloninger et al., 1993). The character traits that evolve during one's entire lifespan are a result of learning, maturation, and socio-cultural factors. Cloninger's theory then postulates that temperament involves individual differences in procedural memory (unconscious), whereas character development involves changes in the propositional memory system (conscious) (Cloninger et al., 1993).

There is evidence of correlations between specific traits across the dominant psychobiological models of personality. A study conducted by Zuckerman and Cloninger (1996) set out to examine the correlation between their and Eysenck's respective models of personality. Their findings revealed a high correlation between Cloninger's NS scale and Zuckerman's Impulsive Sensation Seeking scale (ImpSS), and to a somewhat lesser extent with Eysenck's extraversion (E). Furthermore, both NS and impulsive sensation seeking were supportively inversely correlated to the enzyme monoamine oxidase, which implies a common biological basis.

A study by Mardaga and Hansenne (2007) aimed to establish whether there was a correlation between the dimensions of Gray's BAS and BIS, and Cloninger's NS and HA. Their study revealed that HA and RD were positively associated with the BIS, whereas NS and P were positively associated with the BAS when external variables, such as age and gender, were controlled.

For the purpose of this study, Cloninger's psychobiological model personality will be elucidated with emphasis on the NS temperament trait.

## 2.5 NOVELTY SEEKING

Cloninger's NS is a multifaceted temperament trait that is responsible for the activation or initiation of behaviours. NS behaviour refers to behaviours that include frequent exploratory activity in response to novelty, impulsive decision-making, and extravagance in approach to cues of rewards. It tends, additionally, to be accompanied by shortness of temper and active avoidance of frustration (Cloninger et al., 1993). NS is closely associated with impulsivity, since the TCI is considered to be a general measure of impulsivity (Álvarez-Moya et al., 2011; Cloninger et al., 1993). As with NS, impulsivity itself is referred to as a complex and multifaceted construct (Jakubczyk et al., 2012; Whiteside & Lynam, 2001) that has been incorporated into most, if not all, the biological theories of personality (e.g., Eysenck's biosocial model of behaviour, and Gray's RST).

As impulsivity has been incorporated in these models (or rather facets of it), there are some underlying commonalities between them. For instance, according to Mardaga and Hansenne (2007), NS can theoretically be related to Gray's BAS, and according to Wallace, Newman, and Bachorowski (1991), very high levels of BAS have been linked to impulsivity disorders. Work done by Congdon and Canli (2008) has highlighted the ambiguity among theorists regarding the construct of impulsivity and its "proper" placement within personality theories. Indeed, in some personality models, impulsivity is considered a main factor, whereas in others it is viewed as only a subfactor or a combination of factors, such as Cloninger's NS (Evenden, 1999).

As impulsivity is considered a multidimensional construct, research has aimed at elucidating which of the impulsive personality traits are in fact responsible for behaviour. Studies have indicated that the inability to inhibit a motor response (behaviour inhibition) appears to be a key aspect of impulsivity. There is, moreover, a consensus in recent literature that impulsivity consists of, at least, the ability to disinhibit behaviour and/or to engage in impulsive decision-making (Aron, 2007; Eagle & Robbins, 2003; Franken & Muris, 2006). Indeed, decision-making impairment is a common trait amongst impulsive individuals, as they tend to display an "insensitivity to variations in reward" (Álvarez-Moya et al., 2011. p. 166) in decision-making tasks (Franken, Van Strien, Nijs, & Muris, 2008; Mobbs, Crépin, Thiéry, Golay, & Van der Linden, 2010; Moeller et al., 2005). Research by Whiteside and Lynam (2001) has further attempted to indicate, through factor analysis, the different constructs of impulsivity.

Their research has postulated four separate components of impulsivity, namely urgency, lack of perseverance, lack of premeditation, and sensation seeking. These four components have helped to establish the basis of their scale of impulsivity referred to as the UPPS Impulsive Behaviour Scale.

In the TCI, Cloninger's NS consists of multiple aspects or lower-order traits of impulsivity. He developed four separate components that correlate to some aspects of Whiteside and Lynam's UPPS scale. For instance, NS1 (Exploratory Excitability vs. Stoic Rigidity) correlates with *sensation seeking*, as both are defined as a tendency for sensation seeking. Persons exhibiting this trait find exploring unfamiliar places enjoyable and seek thrills and excitement, and have an innate need towards novel stimuli (Cloninger et al., 1994; Whiteside & Lynam, 2001).

While some functional adaptive aspects of impulsivity have been noted in the literature (Dickman, 1990; Vigil-Colet & Morales-Vives, 2005), impulsivity is generally regarded as a dysfunctional trait, associated with actions that may be criminal, physically harmful to the self (suicide), personality disorders, substance abuse, tobacco use/alcohol dependence, as well as symptoms of depression and attention-deficit/hyperactivity disorder (ADHD) (Congdon & Canli, 2008; DeWit, 2008; Flory et al., 2006; Miller, Joseph & Tudway, 2004; Scheres et al., 2006; Verdejo-García, Lawrence, & Clark, 2008). According to the study of Verdejo-García et al. (2008), high levels of impulsivity may predispose individuals to recreational drug use, as impulsive behaviour exists prior to the onset of both recreational drug use and gambling.

Yet, these researchers further postulate that impulsivity is not *necessarily* a predictor of substance use disorder (SUD) or gambling disorder, but rather a "shared risk factor" in many clinical disorders and manifestations. This correlates with earlier work by Howard and Walker (as cited in Dawe & Loxton, 2004) which indicated that Cloninger's NS personality trait can be seen as a predictor of recreational drug use, as well as other risky behaviour. Furthermore, Cloninger views his temperament traits such as NS as moderately heritable and stable throughout life (Cloninger et al., 1994).

Objective measures of impulsivity have been established by incorporating both cognitive and behavioural models of impulsivity. These measures focus on performance in terms of accuracy and reaction time (Verdejo-García et al., 2008). Neuropsychological tests that have been used to measure impulsivity include the Go/No-Go Test, the Stop Signal Test and the Stroop Test. These tests measure response inhibition, which is one's ability to respond to or suppress an automatic prepotent response (Logan, Schachar, & Tannock, 1997).

### **2.5.1 Neural correlates of Novelty Seeking**

A facet of impulsivity is its lack of inhibiting a prepotent response (Congdon & Canli, 2008), and studies have indicated a correlation between the right-frontal striatal pathway and behavioural inhibition. The maturation of certain brain structures has also been related to inclining young persons towards impulsive behaviour. Ernst, Pine, and Hardin's (2006) triadic model of motivated action has elaborated on this by stating that certain brain areas are more developed in adolescents. Yet, it is not only a question of more rapid development in certain brain structures exerting an effect: It needs to be taken into account that areas such as the prefrontal cortex (regulatory system) and the amygdala (avoidance system) are underdeveloped at this stage as compared with the maturation of the ventral striatum (reward system). The difference in the rates of development between these structures appears to have an influence on risk-taking behaviour.

Studies that have focused on structural features within the cortex have found individual differences in grey matter volumes, in that elevated impulsivity is closely associated with reduced volumes (Moeller et al., 2005). Van Schuerbeek et al. (2010) have attempted to correlate different temperament and character traits with local grey matter and white matter volumes.

Their study has revealed that NS correlates positively with grey matter volumes in the posterior cingulate cortex and left prefrontal cortex, and negatively with grey matter volumes in the left vermis. This supports a possible relationship between individual variations in brain structure and NS in frontal and cingulate regions known to be involved in generating impulsive behaviour (Van Schuerbeek et al., 2010). These findings corroborate those of Amodio, Master, Yee, and Taylor (2008), which have found a significant association between BAS and the prefrontal cortex. Approach- or appetitive-related motivation has been hypothesised to be governed by BAS, which facilitates behaviour that brings the individual closer to rewards (Gray, 1991).

Harmon-Jones (2003) has noted that approach-related motivation and emotions have been linked to greater left-sided frontal asymmetry, while avoidance-related motivation and emotion have been linked with greater right-sided asymmetry. Furthermore, significant associations have been found between some dimensions of temperament and perfusion in localised areas of the brain (O’Gorman et al., 2006), in particular with NS being associated with perfusion in the cuneus, cerebellum, and thalamus. Neurotransmitter systems have also been implicated, with studies suggesting that NS is linked to the dopamine system (Carver & Miller, 2006; Gardini et al., 2009; Henderson & Wachs, 2007; Kantojärvi et al., 2008; Ravaja et al., 2006). Research has indicated that dopamine is closely associated with behavioural inhibition, specifically the dopamine D4 receptor, as this receptor has been identified in areas known to be involved in behavioural inhibition (Congdon & Canli, 2008). Other dopamine polymorphisms such as the 7 repeat of DRD4 have also been found to be associated with NS (Ebstein et al., 1996).

Current research has reflected associations between DRD4 and NS (Laucht, Becker, Blomeyer, & Schmidt, 2007), a personality trait correlated with EF performance (Cassimjee & Murphy, 2010). Furthermore, DRD4 has been associated with increased recreational drug use, and recent evidence has indicated that this association may be mediated via increased NS scores (Laucht et al., 2007). A study by Reeves et al. (2012) has focused on the relationship between dopamine D2/3 receptor availability in the ventral (limbic) striatum and individual components of trait impulsivity. They have found a significant association between limbic striatal D2/3 dopamine receptor function and facets of impulsivity. Krebs, Schott, and Düzel (2009) have also conducted a study on the substantia nigra/ventral tegmental area (SN/VTA) and personality traits. They have, however, hypothesised that the SN/VTA responses to NS and reward dependence respectively may reveal that although there are commonalities between them, they are in fact two distinct entities. Indeed, their study has revealed that NS and reward dependence can be distinguished from each other because of different mesolimbic responses.

Studies that have focused on the heritability of impulsivity, such as the Jakubczyk et al. (2012) study on impulsivity in alcohol-dependent patients, suggest that impulsivity may be a potential endophenotype. An endophenotype can be referred to as an intermediate variable that lies between genetics and neurological processes on the one hand, and the clinical behaviour of a disorder on the other (Schumann, 2007).



Indeed, a study of Verdejo-García et al. (2008) on impulsivity as a vulnerability marker for SUD has proposed that the constructs of impulsivity meet the suggested criteria (Gottesman & Gould, 2003) for an endophenotype.

### **2.5.2 Novelty Seeking subscales**

As NS is considered a multifaceted temperament trait, Cloninger's TCI includes four subscales for measuring it: Exploratory Excitability vs. Stoic Rigidity (NS1), Impulsiveness vs. Reflection (NS2), Extravagance vs. Reserve (NS3), and Disorderliness vs. Regimentation (NS4) (Cloninger et al., 1994).

Individuals who score high on NS1 can be described as sensation seeking since they find exploring unfamiliar places and situations enjoyable, and seek thrills, excitement, and adventure since they have an innate need for novel stimuli. These individuals are easily prone to boredom and intolerant of routine. Low scorers on NS1 have little or no need for novel stimulation. These individuals tend to prefer familiar places and people, and are not easily prone to boredom. They can be described as conventional (Cloninger et al., 1994).

High scorers on NS2 tend to make rash decisions, have poor impulse control and are easily distracted as they have difficulty staying focused for extended periods of time. These individuals tend to be histrionic, impressionable, and temperamental. Persons with low scores, however, tend to reflect a more rational decision-making approach. They would seldom make impulsive decisions or act on hunches. They are not easily distracted (Cloninger et al., 1994).

High scores on NS3 are characteristic of extravagant, flamboyant, and unrestrained individuals. They are prone to push the boundaries of both their resources and capacities. By contrast, low scores are reflective of persons who are restrained, controlled, and often frugal (Cloninger et al., 1994).

Lastly, individuals who score high on NS4 prefer to participate in activities that are not governed by rigorous rules and regulations, as they dislike fixed routine and rules. They are more inclined to be quick tempered and are prone to express their anger or dissatisfaction. In contrast, persons who score low on NS4 tend to be well organised and systematic, and they would rather participate in rule-governed activities.



These individuals are not likely to display their anger or dissatisfaction and can delay gratification when frustrated for extended periods of time (Cloninger et al., 1994). Scoring on any particular subscale may well differ considerably from scores on the other subscales (either very high or very low). Whatever the outcome, the data obtained from subscales are of great value as they provide a more detailed, information-rich image of the temperament trait being measured.

In clinical cohorts, subscale analyses have yielded informative results on the trait NS. For example, Flegr et al. (2003) have examined the impact, if any, of *Toxoplasma* infection on personality profiles (TCI), with the study including both positive and negative individuals. *Toxoplasma gondii*, a parasitic protozoan, infects about 30% to 60% of people worldwide. Infected individuals tend to score more negatively in neuropsychological tests such as the psychomotor performance tests and have personality profiles different from those of *Toxoplasma*-negative individuals.

It has been postulated that the presence of parasitic cysts causes an increase in the concentration of dopamine. Flegr et al.'s (2003) study has indicated that *Toxoplasma*-positive subjects have lower scores for NS generally, and specifically for three of its four subscales, namely NS2 (Impulsiveness), NS3 (Extravagance) and NS4 (Disorderliness), as compared with scores for *Toxoplasma*-negative subjects.

The lower values for three out of four NS subscales suggest that the *Toxoplasma*-positive subjects are on average more reflective, tend to require more detailed information when forming an opinion, and are not easily distracted. Hence, in clinical populations characterised by specific neuropsychological profiles, NS subscales have been shown to have the capacity for differentiating between clinical and control cohorts.

NS subscale scores have been associated with differences in withdrawal symptoms linked to abstinence health behaviours. For instance, Leventhal et al. (2007) have found that smokers who have scored high in NS, and specifically NS2 and NS3, are significantly more prone to withdrawal symptoms than smokers with lower NS scores. Williams and Thayer (2009) have suggested that abstinence behaviours and adherence to health protocols are dependent on effortful control, which is a facet of EF.

Hence, they emphasise that studies explicating the relationship between temperament traits and EF will contribute to a more thoroughgoing understanding of the triad comprising Temperament/Executive Functioning/Health.

### **2.5.3 Executive Functioning, personality, and temperament**

Studies have elucidated associations between certain types of neuropathology, changes in personality, and deficits in EF (Campbell et al., 2011). Indeed, according to Álvarez-Moya et al. (2011), impairments in EF and decision-making processes can be reflected in impairments in an individual's self-regulatory behaviour. In addition, inadequate development of personality traits could be associated with deficits in neuropsychological functioning (Bergvall et al., 2003). Black et al. (2009), for example, have investigated the relationship between borderline personality disorder and executive function performance. This relationship can be expressed as consisting of high scores on both NS and HA, reported poor performance in assessment measures of decision-making, working memory, cognitive inhibition, and perseverance. A study conducted by Cassimjee and Murphy (2010) has also found a correlation between NS and neuropsychological performance in that NS has proved to be significantly inversely associated with performance on the Letter-N-Back test (LNB2-2Back), which assesses attention and working memory.

Furthermore, Black et al., (2012) have investigated the relationship between neuropsychological performances of individuals with compulsive buying disorder. This disorder is characterised by the exhibition of traits such as “excessive or poorly controlled preoccupations, urges, or behaviours regarding shopping and spending that lead to subjective distress or impaired quality of life” (Black et al., 2012, p. 1). In their study, these authors have revealed that individuals with compulsive buying disorder had significantly higher levels of trait impulsivity, ADHD and high levels of NS.

Pursuing research along similar lines, Kagan (as cited in Verdejo-García et al., 2009) has found a correlation between personality traits and performance on neurocognitive measures, more specifically that certain personality traits can be associated with enhanced performance on these measures. According to Williams et al. (2009), it is important to examine the connection between EF and individual differences in temperament and personality.

Campbell et al. (2011) stress that by examining individual differences and personality traits, one might elicit rich information on cognitive systems and possibly further our understanding of the association between personality and executive functions. Moreover, they argue that investigating individual differences in a normal as opposed to a clinical sample may further our knowledge of the relationship between personality and EF.

## **2.6 SUMMARY**

As noted above, research has indicated an association between neuroanatomical and neurochemical sites of EF and temperament. With regard to neurochemical sites, Campbell et al. (2011) have noted that extraversion and EF are both thought to share an association with dopamine. In particular, extraversion has been linked with dopamine reward and EF with dopamine amelioration (Depue & Collins, 1999; Luciana, Depue, Arbisi, & Leon, 1992). Furthermore, serotonin systems have also been implicated in both EF (Bjork et al., 2002; Jakubczyk et al., 2012; Preuss et al., 2001) and NS (Enge et al., 2011; Robbins & Arnsten, 2009; Robinson et al., 2008).

EF and NS also share certain neuroanatomical sites within the brain. For example, not only EF has been linked specifically with the frontal cortex (Lezak et al., 2004; Suchy 2009), but also NS—in particular the frontal and cingulate regions as they are involved in the generation of impulsive behaviour (Van Schuerbeek et al., 2010).

Research has also reported associations between neuropsychological functioning and temperament (Baum et al., 2010; Bergvall et al., 2003; Boeker et al., 2006; Henderson & Wachs, 2007), and has indicated that certain personality traits could potentially contribute to enhanced neuropsychological performance on specific EF tests (Kagan as cited in Verdejo-García et al., 2009).

Conversely, however, certain temperament traits, in particular NS, have also been found to decrease neuropsychological performance on specific EF tests (Black et al., 2012; Bond, 2001). Thus, the following research questions are posed:

- i) Do participants with high NS proclivities show stronger or weaker performance and faster or slower reaction times on EF tasks than participants with low NS proclivities?

- ii) Does performance accuracy and reaction times for participants with high and low NS tendencies vary according to the specificity and complexity of the EF tasks?

# CHAPTER 3

## METHODOLOGY

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### 3.1 OVERVIEW

This research study was quantitative in nature and employed an exploratory non-experimental, comparative design to investigate the relationship between different intensities of NS and EF performance outcomes. Participants for the study were identified in terms of differences between executive performance and intensities of trait NS profiles, and NS subscale analysis was utilised to determine which facets of NS contributed to these differences. The details of the sampling, testing instruments, procedure, data analysis, and ethical concerns of the study will be discussed below.

### 3.2 SAMPLE

The data were 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 1,124 registered students invited to participate in the study agreed to do so. For the purpose of this study, processing of the data yielded a realised sample of 461 after participants with incomplete neuropsychological test and TCI data, as well as those with a medical and psychiatric history, had been omitted from the final data analyses.

### 3.3 TESTING INSTRUMENTS

The administration of the computerised neuropsychological test battery was approved and implemented for the original study in collaboration with the Brain Behaviour Centre of the University of Pennsylvania. The choice of a computerised battery served to facilitate group administration of the tests (Gur et al., 2001). With the technical support of researchers at the Pennsylvania Brain-Behaviour Laboratory, a Web interface was set up between the South African site and the US site.

The University of Pennsylvania Computerised Neuropsychological Test Battery (PennCNP) comprises four computerised neuropsychological test domains (Emotions, Memory, Executive Function, and Abstract Reasoning, as well as a full battery comprising all the tests from the three batteries). A sociodemographic questionnaire was administered to each participant at the commencement of the battery, which yielded data on age, gender, home and schooling language, parental education level, handedness, and past and current medical and psychiatric history.

### **3.3.1 The Temperament and Character Inventory (TCI)**

The TCI derived from Cloninger's psychobiological personality model was administered. It is a 238-item, forced-choice, true-false, standardised, self-administered questionnaire. Internal consistency coefficients range from 0.70 to 0.89 for the seven factors in a non-clinical sample (Cloninger et al., 1994). The TCI has been used both internationally and in different groups in South Africa (Du Preez, Cassimjee, Ghazinour, Lauritz, & Richter, 2009; Lochner, Simeon, Niehaus, & Stein, 2002; Peirson & Heuchert, 2001).

For the purpose of this study, only scores on the temperament trait NS were utilised. According to the TCI, the trait NS consists of four subscales:

- Exploratory Excitability vs. Stoic Rigidity (NS1);
- Impulsiveness vs. Reflection (NS2);
- Extravagance vs. Reserve (NS3);
- Disorderliness vs. Regimentation (NS4) (Cloninger et al., 1994).

### **3.3.2 Executive Functioning and Abstract Reasoning battery**

The PennCNP begins with a general sensory-motor and familiarisation trial (MPRAXIS) 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 begin until the participant has successfully completed the MPRAXIS trial.

The PennCNP thus comprises one sensory-motor test, followed by five tests of abstract reasoning and EF:

- MPRAXIS;
- 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);
- Short Raven's Progressive Matrices (SRAVEN).

The tests from the Executive Functioning and Abstract Reasoning Battery are administered in a set order, namely the one appearing above. A description of each task and the performance indicators selected for statistical analyses will follow here.

### ***3.3.2.1 Motor Praxis***

The MPRAXIS, a measure of sensory-motor ability, 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 unlikely that they will be able to complete any other PennCNP task.

During the test session proper, the participant needs to move the computer mouse cursor over a green box and click on it once. The ever-shrinking box, which disappears and reappears in a different location on the test-screen after each successful mouse-click, is presented 20 times in a non-randomised manner. This will continue until all 20 sizes/locations of the box have been presented. If the participant fails to click on the box within 5 seconds, it moves automatically in the reduced size to the next location on the screen. The total of correct responses on the test trial and reaction time for correct responses were selected as performance measures.

### ***3.3.2.2 Penn Abstraction, Inhibition and Working Memory Task***

The AIM assesses abstraction and concept formation with and without working memory. It is divided into two separate question types that the participant practises before starting the task. During the first question type, the participant sees two pairs of stimuli at the top of the screen (adjusted to the left and to the right) and one single stimulus at the mid-bottom. The participant's task is to decide with which pair the stimulus at the bottom best belongs. The participant then mouse-clicks 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 proceeds automatically to the next question after the feedback has been presented. In the second question type, the bottom stimulus flashes for less than a second and only then the two pairs of stimuli appear at the top.

This type of trial also measures working memory, namely 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, with 30 based on the first trial type and 30 based on the second (working memory) type. The criteria for best fit must take colour and shape of all stimulus figures into consideration. Total number correct and reaction time for correct responses were selected as performance measures.

### ***3.3.2.3 Letter-N-Back***

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 (e.g., in the series "T", "R", "R" the participant should press the spacebar on or immediately after the appearance of the second "R").



For 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 (e.g., 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 practises 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. The 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.

#### ***3.3.2.4 Penn Conditional Exclusion Task***

The PCET is a measure of abstraction in executive function related to the Wisconsin Card Sorting Test (Kurtz et al., 2004a; Kurtz, Wexler, & Bell, 2004b). It is a computerised variant form of the “Odd Man Out” model in which 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 mouse-clicking 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.

### ***3.3.2.5 Penn Short Logical Reasoning Task***

The SPVRT is a measure of verbal intellectual ability. It is a short version of the Penn Verbal Reasoning Test (Gur et al., 2001; Gur, 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 eight questions. Presented with four choices in each question, the participant must mouse-click the one 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. The total number correct responses and the reaction time for them were selected as performance measures.

### ***3.3.2.6 Short Raven's Progressive Matrices***

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 mouse-click the pattern that best fits the visual analogy of non-representational designs displayed on the page. The SRAVEN has a total of nine questions drawn from the regular RAVEN, which has 60 questions. Of the nine questions, Questions 1 and 2 have six responses to choose from and Questions 3–9 have eight choices. This 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 stimulus cards from the paper-and-pencil RAVEN task (Gur et al., 2001). The total number of and reaction time for correct responses were selected as performance measures. Performance indicators for the computerised tasks were median reaction time (mRT) and performance accuracy.

### 3.4 PROCEDURE

The data that were obtained for this study was gathered from 630 participants following the administration of the PennCNP. A Web interface between the computer laboratory at the University of Pretoria and the Brain-Behaviour 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. Ethical approval for the study was obtained from the relevant authorities. Furthermore, volunteer participants were given information regarding the study, assured of confidentiality, and requested to sign informed-consent forms.

A maximum of 25 participants attended each group session, which was facilitated by three attending researchers and eight research assistants who had all been trained in the administration of the battery. The research assistants were each tasked with monitoring four 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 constituting the battery.

### 3.5 DATA ANALYSIS

As mentioned previously, the aim of this study was to investigate the differences between groups with high and low trait NS in their performance on EF tasks. In order to derive the above groups, participants were divided into high and low NS groups based on the following formula:

Low: Total NS score  $\leq$  mean NS score

High: Total NS score  $\geq$  mean NS score

Descriptive statistics were used to indicate the sample performance on the NS subscales of the TCI, as well as the tests of Executive Functioning and Abstract Reasoning battery. Because of the skewed data distribution, and unequal variance between the two groups, the Mann–Whitney statistical procedure was utilised to determine differences between the high and low NS groups in their executive performance.

The Mann–Whitney statistical test (or U test) is designed to incorporate data from two separate samples to determine the difference between groups when the data violate one or more of the assumptions underlying inferential statistics (Houser, 1998). The Mann–Whitney test is believed to be an effective substitute for t-tests when variances are unequal (Ruxton, 2006).

Unlike many other statistical results, there are no strict rules for reporting the outcome of a Mann–Whitney U test. APA guidelines suggest, however, that the report include a summary of the data (including information such as the sample sizes and the sum of the ranks) and the obtained statistic and p value. When the two samples are large (approximately  $n > 20$ ), the null hypothesis is true, and the distribution of the Mann–Whitney U statistic tends to approximate a normal shape. In this case, the Mann–Whitney hypothesis can be evaluated using a z-score statistic and the unit normal distribution (Gravetter & Wallnau, 2009).

Further analyses utilising stepwise regression were incorporated to determine which subscales of NS were predictors of executive performance outcomes. In studies where a large number of independent variables are used, stepwise regression serves as a tool to establish the most suitable combination of independent variables that best suits the dependent variable (Campbell, 2001).

Stepwise regression is based on the premise that effective determination of the best combination of subset models requires a process of consecutively adding and deleting the variable or variables that have the greatest effect on the residual sum of squares. Furthermore, variables may be either forward, backward, or a combination of both (Rawlings, 1998). Logistical regression was also utilized in order to establish the accuracy of NS in classifying participants into groups regarding performance outcomes. Logistical regression is used in order to predict discrete outcomes from a group of variables that may be either continuous, dichotomous or both. Logistical regression is the preferred method in instances where the independent variables are categorical or a combination of categorical and continuous variables (Agresti, 1996).

### **3.6 ETHICAL CONSIDERATIONS**

The original study (Grant Number: TTK2006042400049) provided the data that were utilised for this project and 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. Furthermore, 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 analyses fall within the parameters approved by the Ethics Committee at the initiation of the study. Ethical approval for this study was granted by the Ethics Committee of the Faculty of Humanities at the University of Pretoria.

### **3.7 CONCLUSION**

As stated above, this study sought to investigate the differences between groups with high and low NS traits and their performance on computerised EF tests. Further analyses were conducted on the NS subscales of Exploratory Excitability vs. Stoic Rigidity (NS1), Impulsiveness vs. Reflection (NS2), Extravagance vs. Reserve (NS3), and Disorderliness vs. Regimentation (NS4), as well as on EF outcomes, to determine which facets of NS (subscales) contributed to these differences.

# CHAPTER 4

## RESULTS

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This chapter outlines the sample characteristics, analyses of group differences between high and low NS on EF tasks, and reports on the relationship between NS, NS subscales, and EF. The statistical techniques utilised in this study include the Mann–Whitney U test, Pearson bivariate correlations, stepwise regression, and logistic regression.

### 4.1 BIOGRAPHICAL INFORMATION

The biographical information of the sample is described below.

#### 4.1.1 Age

The majority of the participants fell within the age group of 18–22 years ( $M = 19.82$ ,  $SD = 3.11$ ). The youngest participant was 17, and the oldest participant was 49 years.

#### 4.1.2 Home language

The majority of participants had Afrikaans ( $n = 199$ ) as home language, and the remainder were mother-tongue speakers of English ( $n = 119$ ), Setswana ( $n = 20$ ), Zulu ( $n = 19$ ), and Sepedi ( $n = 18$ ).

#### 4.1.3 Gender

The gender distribution of the sample was biased towards females, the female/male ratio being 84:16%.

#### 4.1.4 Level of Education

The average years of education were  $M = 13.24$ ,  $SD = 0.60$ .

## 4.2 TCI NOVELTY SEEKING

The findings indicate that the mean score for the NS scale was  $M = 20.28$ ,  $SD = 6.15$ . In comparison with Cloninger's typology (Cloninger et al., 1994), this sample can be characterised as moderate in NS.

Since this study was aimed at investigating the relationship between EF and different levels of NS, the total sample of 461 participants was divided into high NS and low NS groups. Mean scores were utilised to differentiate between high and low groups owing to the skew nature of the data. In terms of categorisation, the following procedure was used for grouping participants into high and low groups:

- i) High NS: Total NS score  $\geq$  mean NS score
- ii) Low NS: Total NS score  $\leq$  mean NS score

## 4.3 NOVELTY SEEKING AND EXECUTIVE FUNCTIONING

The following PennCNP tests were utilised to measure EF: The MPRAXIS served to measure general sensory-motor abilities and to establish familiarisation with the testing equipment. The AIM was used to measure abstraction and concept formation with and without working memory. The Letter-N-Back (LNB2) measured attention and working memory, the Penn Conditional Exclusion Task (PCET) evaluated abstraction in executive function, the Penn Short Logical Reasoning Test (SPVRT) rated verbal intellectual ability, and the Short Raven's Progressive Matrices (SRAVEN) assessed abstraction and mental flexibility.

Table 1 shows the descriptive statistics for the high and low NS groups, and performance on the EF tasks.

Table 1  
*Descriptive statistics for low and high NS groups*

Variable	Low NS Group			High NS Group			
	Valid N	Mean	Std.Dev.	Valid N	Mean	Std.Dev.	
Sensory-Motor Abilities – MPAXIS							
Correct responses	[trial 2]	245	20	0.06	216	20	0
Reaction time	[trial 2]	245	617.26	120.88	216	586.93	99.33
Abstraction and Concept Formation – AIM							
Correct responses	[block 1]	245	6.68	1.83	216	6.88	1.88
Reaction time	[block 1]	245	2388.46	891.08	216	2214.03	771.51
Correct responses	[block 3]	245	8.23	1.39	216	8.56	1.3
Reaction time	[block 3]	245	2249.11	753.1	216	2108.57	667.94
Correct responses	[block 5]	245	8.41	1.3	216	8.71	1.12
Reaction time	[block 5]	245	1956.79	655.1	216	1930.92	624.56
Total responses correct		245	23.26	3.63	215	24.32	3.29
Total reaction time		245	2196.39	620.48	215	2090.16	565.21
Abstraction and Concept Formation (Working Memory) – AIM							
Correct responses	[block 2]	245	7.68	1.36	216	8.06	1.27
Reaction time	[block 2]	245	1580.84	603.68	216	1507.87	452.49
Correct responses	[block 4]	245	8.38	1.45	216	8.5	1.38
Reaction time	[block 4]	245	1560.97	535.35	216	1452.46	443.05
Correct responses	[block 6]	245	7.85	1.48	216	8.16	1.5
Reaction time	[block 6]	245	1486.1	499.96	216	1446.91	473.32
Total responses correct		245	23.83	3.41	215	24.79	3.21
Total reaction time		245	1535.69	457.22	215	1475.35	385.08



Variable	Low NS Group			High NS Group		
	Valid N	Mean	Std.Dev.	Valid N	Mean	Std.Dev.
Reaction time incorrect [block 1]	228	2345.32	864.8	205	2327.63	1027.65
Reaction time incorrect [block 3]	201	2766.89	1322.21	163	2537.02	1108.85
Reaction time incorrect [block 5]	194	2794.23	1334.62	165	2517.69	1020.04

Attention and Working Memory – LNB2

True positive responses	238	43	3.12	214	42.81	3.03
False positive responses	238	0.89	1.2	214	0.93	1.04
Total reaction time	238	433.57	107.74	214	421.55	89.11
True positive responses [0-back]	238	14.86	0.9	214	14.85	0.87
False positive responses [0-back]	238	0.31	0.52	214	0.43	0.67
Total reaction time [0-back]	238	411.03	87.21	214	404.37	71.71
True positive responses [1-back]	238	14.64	1.08	214	14.55	1.15
False positive responses [1-back]	238	0.26	0.48	214	0.23	0.5
Total reaction time [1-back]	238	447.03	128.53	214	429.85	117.6
True positive responses [2-back]	238	13.5	1.73	214	13.41	1.86
False positive responses [2-back]	238	0.32	0.81	214	0.25	0.57
Total reaction time [2-back]	237	479.65	140.45	214	466.64	124.27

Abstraction in Executive Function – PCET

Correct responses	244	37.99	8.21	215	38.3	7.62
Reaction time	244	2077.61	633.7	215	1924	503.49
Incorrect responses	244	27.17	14.94	215	28.14	15.38
Reaction time (incorrect resp.)	244	2919.01	906.19	215	2805.58	970.3
Total number of trials	244	65.16	18.52	215	66.44	18.63
Categories achieved	244	2.65	0.61	215	2.63	0.6

Variable	Low NS Group			High NS Group		
	Valid N	Mean	Std.Dev.	Valid N	Mean	Std.Dev.
Preservative errors	244	14.61	8.74	215	15.37	8.8
Verbal Analogical Reasoning – SPVRT						
Correct responses	244	14.49	5.29	214	15.49	4.86
Reaction time	241	8258.42	2905.27	210	8308.32	3050.8
Reaction time (incorrect resp.)	241	9305.18	3850.1	212	9671	4367.79
Abstraction and Mental Flexibility – SRAVEN						
Correct responses	244	41.52	11.01	213	43.05	9.23
Reaction time	237	18641.97	9417.53	211	16164.15	7447.77
Reaction time (incorrect resp.)	240	23365.3	13500.95	209	24580.83	16363.46

*Note:* resp. = response

#### 4.4 SIGNIFICANT DIFFERENCES BETWEEN HIGH AND LOW NOVELTY SEEKING AND EXECUTIVE FUNCTIONING

There were no significant differences between the groups regarding age and gender. Owing to unequal variance across both groups of NS, a Mann–Whitney U test was conducted to investigate any significant differences between the high and low NS groups. Table 2 highlights the significant differences found between the two groups on a number of EF tasks.

Table 2

*Mann–Whitney results for significant differences between high and low NS groups on EF*

Variable	RSL	RSH	U	Z	p-value	VNL	VNH
Sensory-Motor Abilities – MPRAXIS							
Reaction time [trial 2]	60983.50	45507.50	22071.50	3.074159	0.002	245	216

Variable	RSL	RSH	U	Z	p-value	VNL	VNH
Abstraction and Concept Formation – AIM							
Reaction time [block 1]	59764.00	46727.00	23291.00	2.219798	0.026	245	216
Correct responses [block 3]	52888.50	53602.50	22753.50	-2.59636	0.009	245	216
Correct responses [block 5]	5282500	53666.00	22690.00	-2.64085	0.008	245	216
Total responses correct	51940.00	54090.00	21805.00	-3.18587	0.001	245	215
Total reaction time	59260.00	46770.00	23550.00	1.959182	0.050	245	215
Abstraction and Concept Formation (Working Memory) – AIM							
Correct responses [block 2]	52398.50	54092.50	22263.50	-2.93965	0.003	245	216
Reaction time [block 2]	59636.00	46855.00	23419.00	2.130123	0.033	245	216
Reaction time [block 4]	59662.50	46828.50	23392.50	2.148689	0.031	245	216
Correct responses [block 6]	53062.50	53428.50	22927.50	-2.47446	0.013	245	216
Total responses correct	52037.50	53992.50	21902.50	-3.11733	0.001	245	215
Abstraction in Executive Function – PCET							
Total responses correct	52960.00	52151.00	23070.00	-2.14931	0.031	244	214
Abstraction and Mental Flexibility – SRAVEN							
Reaction time	57349.50	43226.50	20860.50	3.028409	0.002	237	211

*Note:* RSL = rank sum low; RSH = rank sum high; VNL = valid N low; VNH = valid N high

A Mann–Whitney U test was conducted to evaluate the difference in EF performance between high and low NS groups. No significant differences were found on either attention and working memory (LNB2) or verbal analogical reasoning (SVPRT).

On overall performance accuracy, the results indicated that on the abstraction and concept formation task the high NS group had performed significantly better than the low NS group ( $z = -3.18, p < .001$ ), and on the abstraction and concept formation (with working memory) the high NS group performed significantly better than the low NS group ( $z = -3.12, p < .001$ ). However, on the abstraction in Executive Function task, the low NS group performed significantly better than the high NS group ( $z = -2.14, p < .05$ ).

The results further indicated that on overall reaction time the high NS group were significantly faster than the low NS group on the sensory-motor abilities task ( $z = 3.07, p < .01$ ), the abstraction and concept formation task ( $z = 1.95, p < .05$ ), and the abstraction and mental flexibility task ( $z = 3.02, p < .01$ ).

#### **4.5 NOVELTY SEEKING SUBSCALES AND EXECUTIVE FUNCTIONING**

The NS scale is further subdivided into four subscales, namely Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness. A Pearson bivariate correlation was used to analyse the relationship between the NS scale and the four subscales on the one hand, and performance on executive tasks on the other. Table 3 highlights significant correlations between various executive performance outcomes and total NS scores, as well as NS subscale scores.

Table 3  
*Significant Pearson bivariate correlations for Total NS, all four subscales and executive performance outcomes*

Executive outcomes		Total NS	EE	I	E	D
Sensory-Motor Abilities – MPRAXIS						
Reaction time	[trial 2]			-0.12*	-0.12*	
Abstraction and Concept Formation – AIM						
Correct responses	[block 3]			0.11*		
Correct responses	[block 5]	0.10*		0.12*		
Reaction time	[block 1]			-0.18*		
Reaction time incorrect	[block 5]	-0.25*			-0.11*	-0.11*
Total responses correct		0.15**		0.15**		0.10*
Total reaction time				-0.12*		
Abstraction and Concept Formation (Working Memory) – AIM						
Reaction time	[block 2]			-0.15**		
Reaction time	[block 2]		0.10*			
Reaction time	[block 4]			-0.11*		
Correct responses	[block 2]	0.013*		0.12*	0.10*	
Correct responses	[block 4]					0.12*
Correct responses	[block 6]			0.10*		
Total responses correct		0.15**	0.12*	0.13*		0.11*
Attention and Working Memory – LNB2						
False positive responses	[0-back]	-0.11*			-0.11*	
False positive responses	[2-back]	-0.10*			-0.10*	

Executive outcomes	Total NS	EE	I	E	D
Abstraction in Executive Function – PCET					
Reaction time (incorrect responses)			-0.10*		
Abstraction & Mental Flexibility – SRAVENS					
Reaction time	-0.12*	-0.11*	-0.14**		

*Note:* EE = exploratory excitability; I = impulsiveness; E = extravagance; D = disorderliness

\*  $p < .05$ . \*\*  $p < .01$ .

#### 4.5.1 Performance accuracy

Results indicated the following on

- *abstraction and concept formation task:* Better performance by participants with higher overall NS traits ( $r = 0.15$ ,  $p < .01$ ), Impulsiveness ( $r = 0.15$ ,  $p < .01$ ), and Disorderliness ( $r = 0.10$ ,  $p < .05$ );
- *abstraction and concept formation (with working memory):* Better performance by participants with higher NS traits ( $r = 0.15$ ,  $p < .01$ ), Exploratory Excitability ( $r = 0.12$ ,  $p < .05$ ), Impulsiveness ( $r = 0.13$ ,  $p < .05$ ), and Disorderliness ( $r = 0.11$ ,  $p < .05$ );
- *attention and working memory task:* Participants who were prone to incorrect response choices, were likely to have lower scores on NS traits ( $r = -0.10$ ,  $p < .05$ ) and the Extravagance subscale ( $r = -0.10$ ,  $p < .05$ ).

#### 4.5.2 Reaction time

Results indicated the following on

- *sensory-motor task:* Faster reaction times by participants with higher Extravagance scores ( $r = -0.12$ ,  $p < .05$ ) and Impulsiveness tendencies ( $r = -0.12$ ,  $p < .05$ );
- *abstraction and concept formation task:* Faster responses by participants with higher scores on the Impulsiveness subscale ( $r = -0.12$ ,  $p < .05$ );

- *abstraction in executive functioning task*: Faster reaction times by participants with higher Impulsiveness ( $r = -0.10$ ,  $p < .05$ );
- *abstraction and mental flexibility task*: Faster reaction times by participants with higher NS traits ( $r = -0.12$ ,  $p < .05$ ), Exploratory Excitability ( $r = -0.11$ ,  $p < .05$ ), and Impulsiveness ( $r = -0.14$ ,  $p < .05$ ).

Impulsiveness encompasses a larger number of significant correlations in comparison with the other subscales. Furthermore, the majority of reaction time and performance outcomes for participants with higher Impulsiveness tendencies indicated that these individuals were most likely to evidence faster reaction times and better performance on EF tasks that tap into a broad spectrum of executive abilities.

## 4.6 REGRESSION ANALYSIS

As is evident, a number of performance outcomes were significant across three or more scales and, based on this data, further data exploration in the form of a stepwise multiple regression was carried out. Additional analyses were done to determine which NS subscale predicted performance outcomes. Preliminary analyses of the outcome and predictor variables evidenced no colinearity—as can be seen in the tolerance results—and this indicated that the variables were independent.

The regression analysis was conducted in three steps:

*Step 1.* Total NS and all four NS subscales were entered into the model in a stepwise manner.

The output evidenced Total NS as significantly predicting all outcomes except for correct responses in terms of Raven's response time, which were predicted by Impulsiveness.

*Step 2.* Subsequently, only the four subscales were entered in the model in a stepwise manner.

Impulsiveness predicted four of the five outcomes, with Extravagance predicting one outcome. However, despite the statistically significant findings of these results, all residuals in all the models were exceptionally high and hence the prediction model disclosed a considerable measure of unaccounted-for variance. Adjusted  $R^2$ 's were distinctly small for each outcome, explaining only between 0.9% and 12% of the variance. Substantively, this means that the model predictions are not practically robust.

*Step 3.* Finally, Total NS and all four NS subscales were entered in five blocks using the “enter” method in SPSS (Statistical Package for the Social Sciences). The correlations between Total NS, the four NS subscales, and executive outcomes served as guidance for the variable to be entered in the model and at what stage.

Multiple R was higher and residuals were lower when Total NS, followed by each of the four subscales, was entered into the regression, as compared with the lower multiple R values and higher residuals when the orders were entered differently. Tables 4 and 5 highlight the findings of the predictions for the following performance outcomes:

- i) Abstraction and Concept Formation:
  - Correct responses [block 2]
  - Reaction time incorrect [block 5]
  - Total responses correct
- ii) Abstraction and Concept Formation (Working Memory)
  - Total responses correct
- iii) Abstraction and Mental Flexibility
  - Reaction time

Table 4  
*Stepwise regression for predictors of significant executive outcomes for Total NS and NS subscales*

Dependent Outcome	Predictor	Multiple R	Adjusted $R^2$	F value	P value
Abstraction and Concept Formation – AIM					
Correct responses [block 2]	TotNS	0.123	0.013	6.382	0.12
Reaction time incorrect [block 5]	TotNS	0.125	0.12	5.024	0.26
Total responses correct	TotNS	0.154	0.021	10.068	0.002



Dependent Outcome	Predictor	Multiple R	Adjusted $R^2$	$F$ value	$P$ value
Abstraction and Concept Formation (Working Memory) – AIM					
Total responses correct	TotNS	0.151	0.021	9.757	0.002
Abstraction and Mental Flexibility – SRAVENS					
Reaction time	Impulsiveness	0.14	0.017	8.11	0.005

Table 5  
*Stepwise regression for predictors of significant executive outcomes for NS subscales*

Dependent outcome	Predictor	Multiple R	Adjusted $R^2$	$F$ value	$P$ value
Abstraction and Concept Formation – AIM					
Correct responses [block 2]	Impulsiveness	0.119	0.012	5.986	0.015
Reaction time incorrect [block 5]	Extravagance	0.11	0.009	3.93	0.048
Total responses correct	Impulsiveness	0.151	0.02	9.71	0.002
Abstraction and Concept Formation (Working Memory) – AIM					
Total responses correct	Impulsiveness	0.124	0.013	6.52	0.011
	+ exploratory excitability	0.162	0.022	5.625	0.004
Abstraction and Mental Flexibility – SRAVENS					
Reaction time	Impulsiveness	0.14	0.017	8.11	0.005

The criteria used for determining the best model are the size of multiple R and the amount of variance accounted for by the prediction, which is inversely related to the residual variance. As was evident for the former regression runs, the amount of unaccounted-for residual variance is large, even though the prediction models listed in Table 6 are statistically significant. The percentage of variance that is explained by the various NS subscales is substantively very small, varying between 1.2% and 2.3%.

In addition, it should be noted that of the NS subscales, Disorderliness was not found to be predictive of executive performance outcomes. Table 6 highlights the best predictor model for each executive performance outcome.

Table 6  
*Prediction models for executive performance outcomes*

Dependent outcome	Predictor	Multiple R	Adjusted $R^2$	$F$ value
	Abstraction and Concept Formation			
Correct responses [block 2]	TotNS + exploratory excitability	0.123	0.013	11.615 733.33
Reaction time incorrect [block 5]	TotNS	0.125	0.012	7381112 4.748
Total responses correct	TotNS + exploratory excitability + impulsiveness + extrava- gance	0.154	0.021	126.527 4596.384

Dependent outcome	Predictor	Multiple R	Adjusted $R^2$	$F$ value
Abstraction and Concept Formation (Working Memory)				
Total responses correct	TotNS + exploratory excitability + impulsiveness + extrava- gance	0.151	0.021	124.851 4194.384
Abstraction and Mental Flexibility				
Reaction time	TotNS + exploratory excitability + impulsiveness + extrava- gance	0.181	0.023	1.039 3.02210

#### 4.7 ACCURACY OF NOVELTY SEEKING IN CLASSIFYING PERFORMANCE

In order to determine how accurate the trait NS is in classifying participants into groups regarding performance outcomes, two analyses were conducted:

- i) a discriminant analysis entailing the use of three dependent outcomes;
- ii) a logistic regression involving the use of dichotomous groups.

The latter procedure is a more suitable instrument in terms of having more flexible assumptions regarding the nature of the data. It was considered how accurate NS is in classifying performance on executive tasks. The variables of interest are those as identified in the above regressions. Scores on all the EF variables were analysed descriptively and, based on the mean score as well as standard deviation, dummy coded groups were created to include below-average, average, and above-average groups.

This analysis was conducted in three steps:

*Step 1.* Participants were categorised into groups based on the standard deviation. One standard deviation below and above the mean was used for categories “below average”, “average”, and “above average”.

*Step 2.* Here the standard deviation was revised to one-half its size and the same category codings were used. This step was necessitated because of discrepant group sizes in the created categories even though the analyses used prior probabilities associated with sample size in each group.

*Step 3.* Finally, the participants were divided into two groups based on the mean. Those scoring at or below the mean were placed in one group “below average” and those scoring above the mean in the second group labelled “above average”.

The results of the first analysis culminated in fewer groups being classifiable, although for groups in which the classification was robust—namely for abstraction and concept formation “total responses correct”, and abstraction and concept formation (with working memory) “total responses correct”—original classifications ranged from 66%–70% accurate classifications.

Step 2 improved the fit of the data, but percentage correct classification ranges were decreased, varying between 38.2% and 47.5% for abstraction and concept formation (with working memory)—respectively for correct responses on block 2, abstraction and concept formation for the total responses correct, abstraction and concept formation (with working memory) on total responses correct, and abstraction and mental flexibility on reaction time. Step three resulted in the best overall classification fit for all variables for two groups and ranged between 68.4% and 70.6% correct classification.

The findings in Table 7 reflect the conclusion that the data fit was more robust with the logistic regression analyses. This table summarises only the best-fit models, as all variables (Total NS, Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness) were included sequentially in the analyses for each executive performance outcome.

Table 7  
*Goodness of model fit for three performance outcomes*

Variable	& Model Fit	Predictor	Significance	Nagelkerke R	Hosmer and Lemeshow
Abstraction and Concept Formation					
Reaction time incorrect [block 5]	69.7	TotNS, Exploratory, Excitability, Impulsiveness, Extravagance + Disorderliness	0.02	0.351	$X^2$ 8.93 DF 8 Sig 0.348
Correct responses [blocks 1, 3 ,5]	70.6	TotNS, Exploratory, Excitability, Impulsiveness, + Extravagance	0.044	0.241	$X^2$ 10.96 DF 8 Sig 0.203
Abstraction and Mental Flexibility					
Reaction time	68.4	TotNS, Exploratory, Excitability, Impulsiveness, Extravagance + Disorderliness	0.033	0.28	$X^2$ 6.08 DF 8 Sig 0.638

For three performance outcome variables, a test of the model (with Total NS and other NS subscales used as predictor variables) compared with a constant-only or null model was statistically significant for these three variables.

For abstraction and concept formation for incorrect responses on block 5,  $X^2(70) = 96.33$ ,  $p = .020$ . The strength of the association between NS subscales and performance outcome was relatively weak with Nagelkerke's  $R^2 = .351$ .

For abstraction and concept formation for total responses correct and 5,  $X^2(62) = 82.19$ ,  $p = .044$ , the strength of the association between NS subscales and performance outcome was relatively weak with Nagelkerke's  $R^2 = .241$ .

For abstraction and mental flexibility: reaction time for correct results,  $X^2(71) = 94.39$ ,  $p = .033$ . The strength of the association between NS subscales and performance outcome was relatively weak with Nagelkerke's  $R^2 = .28$ .

Three of the five performance outcomes yielded model fits in terms of classifications of participants to correct groupings as identified by NS.

For abstraction and concept formation for reaction time on incorrect results on block 5, 69.7% of the variance in the classification was accounted for by all subscale results in NS. This was significant and explained 35% of the variance.

For abstraction and concept formation for total responses correct, 70.6% of the variance in the classification was accounted for by TotNS, Exploratory Excitability, Impulsiveness, and Extravagance. This was significant and explained 24% of the variance.

For abstraction and mental flexibility for reaction time, 68.4% of the variance in the classification was accounted for by all the NS subscales. This was significant and explained 28% of the variance.

The Hosmer–Lemeshow test results are also shown, as these are another indicator of the goodness-of-fit for quantitative predictor variables, as is the case here. All chi-squares are low and significant levels are about .05, indicating a good fit.

Nevertheless, all Nagelkerke  $R$  values are low, ranging from 24%–35% of variance accounted for by the classification of NS, but as this statistic is a pseudo  $R$ , caution should be used when interpreting the result.

Table 8 summarises the improvement in fit for each outcome variable. From a statistical point of view, the degree of accurate classification is moderately successful, but the results should be interpreted with caution as the substantive relation between the executive performance outcomes and NS scales is relatively weak. Moreover, categorising the performance outcomes into categorical variables is not optimal as these categories are in a sense contrived and artificial.

Table 8  
*Improvement in model fit with Total NS and NS subscales included as classifiers*

Executive function	% improvement in fit	% correct classified when only TotNS is entered into the model	% correct classified when all NS scales are entered into the model
Abstraction and Concept Formation			
Reaction time [block 5]	3.4	66.3	69.7
Reaction time [blocks 1, 3, 5]	5.4	64.6	70
Abstraction and Mental Flexibility			
Reaction time	3.7	64.7	68.4

## 4.8 CONCLUSION

The above statistical analyses indicated that there are significant differences between high and low NS groups in EF performance, with the high NS group performing notably better and faster than the low NS group. The analyses also indicated a relationship between EF performance and the facets of NS such as Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness. Interestingly, of all the four facets of NS, Impulsiveness tendencies are significantly correlated with performance and reaction time on EF tasks.

In addition, prediction models have shown that NS and its facets of Impulsiveness, Exploratory Excitability, and Extravagance predict specific executive performance outcomes, and the goodness of fit is enhanced when, in addition to overall NS scores, the facets of NS are included in the statistical model. The following chapter elaborates on the significance of these findings in view of the existing neuropsychological knowledge.



# CHAPTER 5

## DISCUSSION

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The purpose of this study was to explore, in a large non-clinical sample, the differences in executive performance profiles among participants with different intensity of trait NS, and, additionally, to establish which facets of NS contribute to these differences. This chapter seeks to discuss the findings presented in the previous chapter in view of existing neuropsychological literature, and will elaborate on significant results for the purpose of the theoretical discussion. This chapter will then conclude with a brief overview of the limitations of this project, recommendations for future investigations, and a conclusion.

### 5.1 MAIN FINDINGS

The findings of this exploratory study indicated significant associations between NS and specific EF performance indicators. As noted above, significant differences were found between groups of different intensities of NS, with the high NS group performing notably better on neuropsychological measures of accuracy and speed, in comparison with the group with low NS tendencies. Moreover, the analysis indicated a relationship between facets of NS that may account for these differences. Of all the facets of NS, such as Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness, it was Impulsiveness tendencies that were most significantly associated with performance and reaction time on specific EF tasks.

In the present study, prediction models have further illustrated that NS and its facets of Impulsiveness, Exploratory Excitability, and Extravagance can anticipate specific executive performance outcomes. The goodness of fit was enhanced when, in addition to overall NS scores, the facets of NS were included in the statistical model. These findings will be elaborated upon in the sections below.

### **5.1.1 Significant differences between groups of different intensities of Novelty Seeking and Executive Functioning performance**

Individuals who score high on the TCI's multifaceted temperament trait NS can be described as thrill-seeking and drawn to excitement and adventure. It is this trait that is responsible for some individuals' proneness to push boundaries and to seek out exciting new challenges and rewards, as they have an innate need for and inclination towards novel stimuli. These individuals are also prone to impulsive decision-making, poor impulse control, being easily distracted, and being temperamental (Cloninger et al., 1994). In a test setting, this trait seems to be responsible for decreased performance on verbal memory (Bond, 2001), as well as on attention and working memory tasks (Cassimjee & Murphy, 2010). Greater interference sensitivity and deficits in manipulation have also been reported (Guillem et al., 2008).

#### ***5.1.1.1 Performance accuracy***

The present study revealed that participants with high NS tendencies performed significantly better than participants with low NS tendencies on the AIM ( $z = -3.18, p < .001$ ) and AIM (with working memory) ( $z = -3.12, p < .001$ ) task. The AIM is designed to measure abstraction and concept formation (with and without working memory), and these EF skills as measured by the AIM are related to frontal lobe functioning (Glahn, Cannon, Gur, Ragland, & Gur, 2000; Goodman, Knoll, Isakov, & Silver, 2005). In addition, this test also incorporates response inhibition, resistance interference, and response sequencing (Cassimjee & Murphy, 2010; Henderson & Wachs, 2007).

During this task, the participants were provided with immediate feedback after each response ("correct/incorrect"); which could have stimulated their innate need for an immediate reward, which in turn may have activated the BAS (NS) system (Gray & McNaughton; 2000). The BAS is associated not only with activation of the prefrontal cortex (Amodio et al., 2008), but also with sensitivity to signals of reward in that this system is a causal factor in an individual's behaviour to move towards a goal.

The BAS is reportedly linked to striatal dopamine projections in the prefrontal cortex, more specifically the lateral and orbital regions (Corr & Perkins, 2006; Gray & McNaughton, as cited in Mardaga & Hansenne, 2007; Yanagisawa et al., 2011), which are associated with EF. The high NS group may have a stronger need towards a reward, thus positively contributing to their performance. Alternatively, the increase in performance by the high NS group, specifically in the “with working memory” trial, may be attributed to a stronger response to novel stimuli independent of an actual or perceived reward. Interestingly, Collette et al. (2006) have noted that there is a strong association between activity on the superior cortex in cases where working memory must be continuously updated and sustained.

Krebs et al. (2009) have reported that novelty can be assigned as a fundamental learning tool that may attract one’s attention, modify goal-directed behaviour, and promote stimulus encoding into long-term memory. Furthermore, they have found NS to be linked to the SN/VTA, which in turn releases dopamine that modulate “synaptic plasticity in the medial temporal lobes and prefrontal lobes” (p.103), which in essence provides a link between novelty and its support-related function in long-term memory. It can be postulated that the way in which the high NS group perceived the test stimulus may have assisted the participants in keeping the stimulus in mind long enough to respond correctly. Thus this group’s strong need for reward and/or response towards the stimulus may have helped minimise stereotypical executive traits such as difficulty in sustained attention and resistance interference (Guillem et al., 2008), and enhanced their performance.

The findings from this study revealed that the high NS group’s performance on PCET was significantly poorer than that of the low NS group (-2.14,  $p < .05$ ), with the low NS group performing better on this task. The PCET is a measure that focuses on abstract reasoning and executive function, similar to the WCST (Kurtz et al., 2004a; Kurtz et al., 2004b). The WCST has been correlated with bilateral increases in cerebral activity in the dorsolateral, inferior parietal and occipital regions, as well as temporal areas, and to a lesser extent in the frontopolar, orbital, and medial areas (Collette et al., 2006; Shallice, 1982). It is therefore possible to argue that the PCET taps into similar cognitive areas.

Studies have reported a relationship between Impulsiveness and poorer performance on complex, speeded tasks (Dougherty et al., 2003; Keilp et al., 2005). Indeed, Keilp et al. (2005) have found that higher levels of impulsivity are positively correlated to “poorer, slower and more liberal responding” (p. 196) in a test setting. Furthermore, Verdejo-García et al. (2008) have focused on measures of impulsivity, in particular impulsive behaviour in the context of decision-making, which is referred to as “cognitive impulsivity”. An important component of cognitive impulsivity is “reflective impulsivity”, which refers to one’s ability to obtain and evaluate information before making a complex decision (Kagan as cited in Verdejo-García et al., 2009). Consequently, should the participants have had inadequate opportunity for reflection at the pre-decision stage (as would be the case for participants with high NS), the accuracy of their performance may be reduced (Evenden, 1999). This aligns with Cloninger’s description of individuals with lower NS as being more reflective, reserved, orderly, and systematic (Cloninger et al., 1994).

Interesting research by Álvarez-Moya et al. (2011) has focused on two types of impulsivity, namely “rash impulsiveness” and “sensitivity to reward”. Rash impulsiveness may be relevant in this context as it refers to “the inability to inhibit behaviour, carelessness, lack of sufficient reflection, planning as well as making rash decisions and actions” (Baumeister & Vohs, 2004). It would thus seem that the PCET task was particularly more complex and influenced the performance of the high NS group more, as the literature above indicates that a relationship exists not only between the complexity and speed of a task, but also the level of impulsivity measured in the individual. In addition, Brown (1999) views the central feature of ADHD (categorised as clinical impulsivity (Casey et al., 1997)) as the inability to activate and manage EF at the right time, especially for those tasks that are considered less interesting. Impulsive individuals have reported impairments in decision-making in general, and in the case of this study it may be due to the complexity of the task—combined with the high level of NS and the inability to carefully reflect before making a decision—that may have hampered the high NS group’s performance.

### *5.1.1.2 Reaction time*

The high NS group obtained a better response time than the low NS group on the MPRAXIS task ( $z = 3.07, p < 0.01$ ). The MPRAXIS is a test that assesses sensory-motor ability.

During the second trial, the task was timed and the difficulty level increased. The high NS group may have been faster on this test owing to their high levels of impulsivity. Studies have indicated that the inability to inhibit a motor response (behaviour inhibition) is a key aspect of impulsivity (Aron, 2007; Eagle & Robbins, 2003; Franken & Muris, 2006). Moreover, impulsive individuals have a predisposition to have rapid and unplanned reactions towards both internal and external stimuli. Indeed, it is reported that it is a characteristic of individuals with a high measure of the trait impulsivity to have difficulty waiting for a more appropriate time to act, which has been related to an “overestimated perception of time” (Bachorowski & Newman, 1985; Correa et al., 2010; Wittmann & Paulus, 2008). One can thus further postulate that as the participants were not provided with the time limit (5 sec), they may have misperceived the deadline as occurring earlier and thus reacted faster.

The findings further revealed that on the AIM task the high NS group were significantly faster than the low NS group ( $z = 1.95, p < .05$ ). As mentioned above, the AIM is a measure of abstraction and concept formation, with or without working memory. Impulsive individuals tend to have swift and unplanned reactions towards stimuli and are less likely to exhibit caution when performing a task, as stated above. This is in contrast with EF, which includes the ability to inhibit a proponent response—thus enabling a person to monitor and control a thought and action. Cognitive areas that have been implicated in inhibiting processes with perceptual and motor paradigms include the cingulate, prefrontal, parietal, and temporal regions (Bench et al., 1993; Chee, Sriram, Siong Soon, & Ming Lee, 2000; Collette et al., 2006). This being noted, there is as yet insufficient understanding of how these regions are associated with inhibitory processes (Collette et al., 2006). It is thus possible that in the current study, NS traits such as the inability to inhibit a response and associated rapid reactions towards novel stimuli were more pronounced in the high NS group, which enabled them to respond faster.

On the SRAVEN, the high NS group once again obtained faster reaction times than the low NS group ( $z = 3.02$ ,  $p < .01$ ). The SRAVEN is a measure of abstraction and mental flexibility. As mentioned above, there is a complex relationship between the task complexity and speed on the one hand, and impulsivity on the other. More specifically, literature has indicated that impulsive individuals—in spite of faster reaction times—are in fact slower and have poorer performance in terms of successful outcomes on complex and speeded tasks (Dougherty et al., 2003; Keilp et al., 2005). Although the SRAVEN is a test that increases in difficulty, it does not require the participants to act as fast as possible; it rather uses a forced-choice method in that the question will remain on the screen until the participant selects an item. In the current study, the lack of pressure to complete the task within a set time frame may have contributed to the faster responses in the high NS group, even though the complexity increased.

Interestingly, a study conducted by Shaw, Grayson, and Lewis (2005) has investigated the inhibitory performance exhibited by children in commercially available games. They have found that participants with ADHD demonstrated a significant reduction in “impulsive responding and an increase in on-task activity” (p.166), and have consequently argued that there could be contexts in which inhibitory performance might be enhanced. Indeed, their postulate suggests that there appears to be a correlation between framing the task in a gaming context, and a reduction in impulsivity, which positively affected the performance of the children with ADHD.

It may thus be plausible that given the context of the assessment and the use of computerised tests, the participants may have formed an association between the task and elements of a computer game (such as in the other assessments mentioned above), which consequently may have contributed to enhanced performance in the high NS group, as higher impulsivity levels are closely associated with ADHD.

### ***5.1.1.3 Summary***

As reflected in the discussion above, it is apparent that the differences in trait NS contribute to differences in neuropsychological performance. Thus, in brief, the high NS group performed notably better on tasks that assessed abstraction and concept formation, with or without working memory (AIM). Conversely, the low NS group evidenced better performance in tasks that measured abstract reasoning and executive function (PCET).

With regard to reaction time, the high NS group were notably faster on tasks that assessed abstraction and concept formation, sensory-motor abilities, and abstraction and mental flexibility (MPRAXIS, AIM, and SRAVEN). The results consequently indicate that differences in intensity of trait NS contribute to differences in executive performance outcomes, and that high NS overall contributes to notably better performance and reaction times in neuropsychological tasks. However, performance differences may be dependent on the artefacts of the tests (complexity, forced choice, etc.) and the specific EF skills measured.

### **5.1.2 Facets of Novelty Seeking and their contribution to differences in Executive Functioning performance**

Cloninger et al. (1994) describe NS as a multifaceted temperament trait that can be subdivided into four subscales for measuring NS: Exploratory Excitability, Impulsiveness, Extravagance, and Disorderliness. These subscales serve as descriptors of individuals with high and low NS scores and may evidently contribute to differences in EF performance.

#### ***5.1.2.1 Performance accuracy***

The findings of this study revealed that for the AIM task better performance was found in participants with higher overall NS traits ( $r = 0.15$ ,  $p < .01$ ), and higher NS subscale scores of Impulsiveness ( $r = 0.15$ ,  $p < .01$ ) and Disorderliness ( $r = 0.10$ ,  $p < .05$ ). Impulsiveness refers to individuals who are easily excited and are prone to act on instinct and hunches, and who tend to have a short attention span (Cloninger et al., 1994). However, the trait Disorderliness implies that individuals are easily angered, especially in cases where they do not achieve what they want, and they further dislike fixed routines and rules. Disorderliness has been closely associated with avoidance behaviour in tasks that are perceived as frustrating or boring (Cloninger et al., 1994). It is thus interesting that, in the current study, these combinations of factors contributed to better performance on the AIM task.

Álvarez-Moya et al. (2011) have argued for a strong association between Disorderliness and Impulsiveness, giving rise to the construct “rash impulsiveness”, which, as mentioned above, is responsible for rapid decision-making, carelessness, and failure to inhibit behaviour. In the current study, given the increase in performance on this test, it would appear that the participants were particularly engaged in this task and motivated to obtain the correct responses in order to achieve the desired outcome. As mentioned above, the innate need for an immediate reward activates the BAS (NS) system, which is associated with an individual’s behaviour to move towards a particular goal (Gray & McNaughton, 2000; Mardaga & Hansenne, 2007), which seems likely in this case.

It can thus be postulated that the participants did not find the task too complex or tedious, and this may have contributed to their being more engaged in the task and thus achieving better performance. Alternatively, it could be assumed that the participants showed a lack of interest in this task and wanted to complete it as fast as possible. For this reason, their better performance was attributable to their hunches being correct, thus enhancing their results purely by chance.

On the AIM task (with working memory), the study revealed better performance by participants with higher NS traits ( $r = 0.15$ ,  $p < .01$ ), Exploratory Excitability ( $r = 0.12$ ,  $p < .05$ ), Impulsiveness ( $r = 0.13$ ,  $p < .05$ ), and Disorderliness ( $r = 0.11$ ,  $p < .05$ ). Exploratory Excitability closely reflects sensation-seeking, and is defined as being excited and open to new experiences, as well as being drawn to activities that the individual finds pleasurable. This trait has been associated not only with polymorphisms in the dopamine D4 receptor (DRD4), but also with decreased “somatic D2-like auto-inhibition of dopaminergic neurons” (Álvarez-Moya et al., 2011, p.108; Krebs et al., 2009; Marinelli, Rudick, Hu, & White; 2006). As mentioned previously, if the participants in the present study found the task exciting and novel enough, it is possible that that the task would have attracted and held their attention to the point where stimulus encoding into longer-term memory was able to take place (Krebs et al., 2009), thus contributing to better performance.

The LNB2 task is a test that measures attention and working memory. The findings of this study indicated that participants who were prone to incorrect response choices were likely to have lower scores on NS traits ( $r = -0.10$ ,  $p < .05$ ) and the Extravagance subscale ( $r = -0.10$ ,  $p < .05$ ).



According to Baddeley (2000), working memory serves as an “episodic buffer, where multimodal information is continuously integrated” (p. 258) and has been linked to activity in the dorsolateral prefrontal cortex (Braver et al., 1997; Gur et al., 2010; Kane & Engle, 2000). The lower scores on the Extravagance subscale have been associated with controlled and restrained behaviour, and a slow reaction to novelty (Cloninger et al., 1994). The findings of this test are of particular interest as they are contrary to the results reflected in current literature. Although studies have found significant inverse associations between performance on the Letter-N-Back test (LNB2-2Back) and NS (Cassimjee & Murphy, 2010), most literature sources argue that higher, and not lower, scores on Impulsiveness would account for poorer performance on these tasks (Dougherty et al., 2003; Evenden, 1999).

For example, Logan et al. (1997) found that the speed at which impulsive individuals were able to inhibit a response was slower when compared with that of non-impulsive individuals on complex tasks, such as the Go/No-Go task. This is noteworthy in view of the fact that lower scores on trait NS and subscale Extravagance in the present study were indicative of poorer performance. What also needs to be taken into account is that different behavioural manifestations arise from multidimensional interactions between different temperament and character traits. It is possible that the performance in this task was strongly influenced by other temperament and character dimensions. Additionally, the findings on the LNB2 task indicated a correlation between the incorrect responses, in particular the “false positive” (2-back) responses and the lower scores on traits NS and Extravagance. False positives imply that the participants pressed the spacebar but were not following one of the ruling principles. This may imply a ‘trade-off’ tendency to respond faster at the expense of accuracy.

It would therefore appear that the participants had difficulty in inhibiting their behaviour and not reflecting carefully before responding. An alternative explanation is that participants were experiencing fatigue and possibly performance anxiety. These two factors can influence performance as fatigue can cause a decrease in required sustained attention, and anxiety has been related to a decrease in performance in testing environments (Eysenck, Derakshan, Santos, & Calvo, 2007). Moreover, participants with lower NS traits are likely to have higher Harm Avoidance tendencies, which may in part account for their error-prone responses on the LNB-2 task.

### *5.1.2.2 Reaction time*

Results indicate that in the MPRAXIS task, faster reaction times were shown by participants with higher Extravagance scores ( $r = -0.12$ ,  $p < .05$ ) and Impulsiveness tendencies ( $r = -0.12$ ,  $p < .05$ ). High scores on Extravagance can be related to flamboyant and unrestrained behaviour, and these individuals are known to push their boundaries in terms of resources and capacities. Álvarez-Moya et al. (2011) has reported that extravagance can be related to increased sensitivity to reward, which in turn can be linked to poor planning. In view of this, the MPRAXIS task does not provide feedback per se, but it is rather a question of the stimulus material being decreased in size. It is thus unlikely that the sensitivity to reward was a contributing factor. Nonetheless, one can infer that given the participants' high impulsiveness (rapid responding, poor inhibition) and Extravagance, these traits contributed positively to their faster response times, especially if they were pushing the limitations of their own capacities.

On the AIM, faster responses were shown by participants with higher scores on the Impulsiveness subscale ( $r = -0.12$ ,  $p < .05$ ). As previously stated, Impulsiveness relates to individuals who are easily excited and who have shorter attention spans. The faster response time can be attributed to Impulsiveness reflecting the inability to stay focused long enough to make an informed decision, since a key aspect of impulsivity is the ability to inhibit a motor response (behaviour inhibition) and/or engage in impulsive decision-making (Aron, 2007; Eagle & Robbins, 2003; Franken & Muris, 2006).

The lack of inhibiting a prepotent response (Congdon & Canli, 2008) has been associated with the right-frontal striatal pathway and behavioural inhibition. Moreover, differences in grey matter volumes have been correlated with impulsivity in that higher impulsivity was closely associated with reduced grey matter volumes in the left prefrontal cortex and posterior cingulate cortex (Gardini et al., 2009; Moeller et al., 2005; Van Schuerbeek et al., 2010). In turn, the prefrontal cortex and the posterior cingulate cortex form part of the neural network that is responsible for response inhibition and making impulsive decisions (Crews & Boettiger, 2009; Kim & Lee, 2011; Van Schuerbeek et al., 2010).

One can thus postulate that in the present study the faster reaction times may have been due to lack of inhibition leading to rapid responding. Furthermore, as this task was not particularly complex, slower and poorer responding typically associated with complex tasks (Evenden, 1999) is not likely to have been an influencing factor.

Faster reaction times were evidenced by participants with higher Impulsiveness ( $r = -0.10$ ,  $p < .05$ ), on EF tasks measuring abstraction abilities (PCET). The participants displayed faster reaction times for incorrect responses. This is in accordance with literature and the research findings above indicating that Impulsive individuals tend to respond faster but that accuracy, as a consequence, might then be impaired especially on tasks with increased complexity (Dougherty et al., 2003; Pailing, Segalowitz, Dywan, & Davies, 2002).

Finally, results on the participants mental flexibility skills (SRAVENS) indicated faster reaction times by participants with higher NS traits ( $r = -0.12$ ,  $p < .05$ ), Exploratory Excitability ( $r = -0.11$ ,  $p < .05$ ), and Impulsiveness ( $r = -0.14$ ,  $p < .05$ ). These findings are of interest, as higher Impulsiveness has been associated with poorer and slower responding on complex tasks. It is possible, however, that the participants of the current study did not find the task too complex (as evidenced by their better performance), yet found it sufficiently challenging and stimulating, as may be shown by the interaction between NS tendency and the Exploratory Excitability facet. This combined with Impulsiveness being characterised by rapid responding and relying on instinct and hunches rather than careful reflection, may have contributed to participants' faster reaction times.

### ***5.1.2.3 Prediction models***

The findings discussed above are in part corroborated by prediction models which indicated that NS and NS subscales can predict executive performance outcomes, specifically relating to tasks of abstraction, concept formation, and mental flexibility (AIM and SRAVEN) in terms of performance and reactions times.

The present study revealed that on the AIM and AIM (with working memory) task higher NS traits and NS subscales of Exploratory Excitability, Impulsiveness and Extravagance were able to predict executive performance outcomes in terms of performance. Whilst, higher NS traits and NS subscales of Exploratory Excitability, Impulsiveness and Extravagance were able to predict executive performance outcomes in terms of reaction times on the SRAVEN task. Interestingly, of the NS facets, Disorderliness was not found to be predictive of executive performance outcomes. These findings are corroborated by the goodness-of-fit model which further indicated that on abstraction, concept formation, and mental flexibility (AIM and SRAVEN) task improvement was enhanced when total NS and facets of NS were included as classifiers.

As previously stated, temperament and EF share common neuroanatomical sites and processes that can influence neuropsychological performance. More specifically, NS and its facets have been shown to be associated with similar neurotransmitter systems and neuroanatomical sites that have been implicated in EF. It is thus possible to argue that NS, and facets of NS, can serve as predictors of performance as they tap into similar cognitive areas associated with performance. At that, they may collectively be better able to predict performance as they have a more robust influence on a greater number of neuroanatomical sites and neurotransmitter systems associated with performance, or target more of them. While there is a need for clarifying the reasons that Disorderliness was not found to be predictive of executive performance, it is possible that Disorderliness may not exert an influence on cognitive areas that are strongly associated with the skills measured in the specific EF tasks utilised in this study.

#### ***5.1.2.4 Summary***

In brief, a relationship exists between NS trait tendencies and facets of NS and the differences in neuropsychological performance on EF tasks. Specifically, NS traits and facets of NS that include Excitability, Impulsiveness, Extravagance, and Disorderliness have, in this study, been found to contribute to differences in both performance and reaction times. Differences in performance were found on measures that assess abstraction, concept formation, attention, and working memory (AIM and LNB2). Differences in reaction time were evident on measures that assessed sensory-motor abilities, abstraction, concept formation, mental flexibility, and abstraction in EF (MPRAXIS, AIM, SRAVEN, and PCET).

It also emerged that of all the facets, Impulsiveness tendencies were most significantly associated with both performance and reaction time on EF tasks. Moreover, prediction models have indicated that NS and its facets may serve as predictors of specific executive performance outcomes, and that the goodness of fit was enhanced when the facets of NS were included in the statistical model in addition to overall NS scores.

## **5.2 LIMITATIONS**

An important limitation of this exploratory study has been the use of the computerised PennCNP battery of tests, in that these tests themselves are relatively narrow in scope, measuring specific aspects of EF and abstract reasoning. One can deduce, given the complexity of relationships between brain function and temperament, that a wider selection of neuropsychological tests assessing different aspects of neuropsychological (and executive) performance would enhance current understanding. Furthermore, the analysis of the results was obtained from a single test situation in which individual performance could potentially have been mediated by external and contextual factors that were not accounted for.

It is important to reflect also on the relative homogeneity of the sample used. Although the sample size utilised for this study is quite large, the sociodemographic composition is preponderantly uniform, specifically in terms of age and level of education attained. A further limitation from a statistical point of view is that although the degree of accurate classification was moderately successful, it should be interpreted with caution since the substantive relation between the executive performance outcomes and NS scales was relatively weak. Moreover, classifying the performance outcomes into categorical variables was not optimal as those categories were in a sense contrived and artificial in nature. Finally, the measuring instruments utilised in this study had not been normed for a South African sample, and therefore caution should be exercised in the interpretation of the results.

### 5.3 RECOMMENDATIONS FOR FUTURE RESEARCH

The findings of this exploratory research study have indicated significant differences with regard to executive performance profiles among participants with different intensities of trait NS. Furthermore, this study has revealed certain facets of NS that could potentially contribute to these differences. Although the findings were to an extent limited, they did reveal significant associations that call for further exploration. It is thus suggested that future research be conducted that:

- explores differences between executive performance profiles and additional temperament traits of Harm Avoidance, Reward Dependence, and Persistence to establish the dynamic interaction of these traits with NS and its effect on EF performance;
- utilises both clinical and non-clinical samples that would include a more heterogeneous sociodemographic profile, as there is the possibility that psychosocial factors may influence the neuropsychological test performance;
- incorporates a broader selection of neuropsychological tests so that different areas of executive ability and performance may be explored.

### 5.4 CONCLUSION

In conclusion, the aim of this exploratory study was to investigate the differences in executive performance profiles among participants with different intensities of trait NS, and to establish which facets of NS contributed to these differences. The study provided evidence of notable differences among participants with different intensities of the TCI trait NS and neuropsychological performance, as measured by the PennCNP battery.

Significant differences were found between the two groups with different intensity of NS, with the high NS group performing notably better on performance and reaction time. Moreover, the study evidenced a relationship between NS trait tendencies and facets of NS that contributed to these differences. Impulsiveness tendencies were most significantly associated with performance and reaction time on EF tasks. This study contributes to the overall literature on temperament and EF in two ways. Firstly, the results corroborate that NS is a multifaceted construct and that the intensity of trait tendencies has a differential influence on EF performance.

This aspect is also dependent on the EF skills measured and the artefacts of the EF tests. Secondly, the multifaceted nature of NS is furthermore evident in results showing different subscales with varied significant associations with EF skills. In sum, the relationship between NS and EF is not a simplistic linear association, and further research is needed to unravel the complex and varied associations between temperament traits and EF.

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