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Temperament and character correlates of neuropsychological performance

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We investigate the association between temperament and character dimensions, on the one hand, and computerised neuropsychological test performance, on the other hand. Temperament and character dimensions were operationalised as scores on the subscales of the Temperament and Character Inventory (TCI), a 240-item measure that is based on the psychobiological theory of personality. Neuropsychological outcomes were measured on six computerised tests of executive functioning and abstract reasoning from the University of Pennsylvania Computerised Neuropsychological Test Battery (PennCNP). The executive and abstract reasoning tasks included a test of Motor Praxis (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 Task (SPVRT) and the Short Raven's Progressive Matrices (SRAVEN). Results from this exploratory study yielded significant associations between neuropsychological performance and temperament and character traits. The temperament traits of Harm Avoidance and Reward Dependence were positively correlated with reaction time on the AIM and the SPVRT. The character dimension of Self-Transcendence was significantly associated with performance accuracy on the AIM and the temperament dimension of Novelty Seeking was inversely related to performance accuracy on the LNB2. These results confirm the importance of addressing the temperament and character correlates of neuropsychological performance in both clinical and non-clinical studies.

Keywords: character; executive functioning; neuropsychology; personality; psychobiological theory; temperament

Research (Ardila, 2005; Byrd, Sanchez, & Manly, 2005; De Bruin, De Bruin, Dercksen, & Cilliers-Hartslief, 2005; Hsieh & Tori, 2007; Nell, 2007; Rosselli & Ardila, 2003; Shuttleworth-Edwards, Kemp, Rust, Muirhead, Hartman, & Radloff, 2004; Uzzell, 2007) has shown that neuropsychological test performance is influenced by an array of diverse variables such as socio-demographic (e.g. gender, age); socio-cultural (e.g. education, language); and ecological variables (e.g. verbal, non-verbal and performance content). Studies that focus on the relationship between personality and/or temperament and neuropsychological test performance are scant.

For the purposes of this investigation, personality is operationalised using Cloninger's psychobiological theory of personality (Cloninger, Svrakic, & Przybeck, 1993). This theory proposes a comprehensive personality model based on the interaction between temperament and character. It postulates four temperament and three character dimensions. Harm Avoidance (HA), Novelty Seeking (NS), Reward Dependence (RD) and Persistence (P) are the temperament dimensions, which regulate automatic emotional reactions and are considered reflections of individual differences in percept based habits and skills (neuro-biological dimension). The dimension of behavioural activation (NS) reflects the tendency toward exhilaration/impulsivity in response to novel stimuli or cues. A behavioural inhibition dimension (HA) is hypothesised to regulate inhibition or cessation of behaviours. Reward Dependence is defined as the tendency to maintain or pursue ongoing behaviours and the fourth temperament dimension, Persistence, functions asperseverance in behaviour despite frustration and fatigue (Cloninger & Gilligan, 1987; Cloninger, Przybeck, Svrakic, & Wetzel, 1994). People described as high in NS show an increased frequency of exploratory behaviour, impulsive decision making and active avoidance of frustration; people scoring high in HA are often pessimistic, worrying, easily fatigued and become tense and anxious in unfamiliar situations; and high scorers on RD are described as sentimental, socially attached and dependent on the approval of others (Cloninger & Svrakic, 1997).

The three character dimensions Self-Directedness (SD), Cooperativeness (C) and Self-Transcendence (ST) include both a cognitive perspective about self/non-self boundaries and an emotional perspective, and reflect individual differences in self concepts as related to the social dimension of experiences (Peirson & Heuchert, 2001). According to Cloninger *et al.* (1994), SD relates to the extent to which a person identifies the self as an autonomous individual and refers to their self-determination, self maturation and the ability to achieve aims in line with personal goals. A low SD individual is described as irresponsible, aimless, with unorganised behaviour, and as having poor impulse-control in general. Cooperativeness reflects the extent to which a person identifies as an integral part of society as a whole and refers to social maturity, individual empathy, agreeableness and cooperation. Uncooperative individuals are described as hostile, aggressive and opportunistic. Self-Transcendence, the third character dimension, refers to spiritual maturity, self-forgetfulness and transpersonal identification. Individuals low in ST show conventional and materialistically oriented behaviour with little or no concern for absolute ideas such as goodness and universal harmony. Character development implies changes in the propositional memory system whereas temperament variation implies individual differences in procedural memory.

Temperament variability among individuals has been ascribed to neurophysiological variations in brain functioning (Henderson & Wachs, 2007; Whittle, Allen, Lubman, & Yücel, 2006). O'Gorman *et al.* (2006) found significant associations between temperament dimensions and perfusion in localised brain regions. The NS dimension was significantly associated with perfusion in the thalamus, cuneus and cerebellum, whereas HA was significantly associated with perfusion in the cerebellar vermis, cuneus, and medial frontal gyrus. Different neurotransmitters have been linked to specific temperament dimensions. For example, HA, NS, RD and P have been linked to the underlying serotononergic, dopaminergic, noradrenergic and cholinergic neurotransmitter systems (Carver & Miller, 2007; Cloninger, Svarkic, & Przybeck, 2006). This is evidenced in studies that report significant influences of temperament dimensions on antidepressant treatment outcomes (Tome, Cloninger, Watson, & Issac, 1997).

According to Bergvall, Nilsson and Hansen (2003) many executive functioning tasks and temperament and character dimensions may share common underlying neural bases. The prefrontal cortex and its associated neural projections are involved with planning, abstraction, attention and working memory tasks, which are usually grouped together under the rubric of executive functioning. Executive functioning refers to a complex system that includes behavioural, affective, motivational and cognitive components. It is a neuropsychological concept that relates specifically to higher order control and regulatory processes that function in synchrony to address the complexity of decision making inherent in goal directed and future oriented behaviours (Alvarez & Emory, 2006).

Studies on clinical samples with prefrontal impairment and executive functioning deficits found that these patients are also characterised by a personality profile of disinhihibition, impulsivity and lack of self-awareness and self-monitoring. Bivona *et al.* (2008) reported a significant correlation between metacognitive self-awareness and components of the executive system (flexibility, response inhibition, problem solving and set shifting). Self-awareness is related to processes described by Cloninger's character dimensions. In a clinical group with borderline personality disorder, Black *et al.* (2009) found that the patients had performance deficits in cognitive inhibition, working memory, perseveration and decision-making tasks and these where related to levels of NS, HA, SD and C. In a study on Parkinson's disease patients, McNamara, Durso and Harris (2008) proposed that changes in a sense of self are linked to prefrontal deficits and these are associated with changes in temperament and character. Associations between executive functioning tasks and the TCI yielded a significant inverse correlation between executive functioning and HA. They concluded that the HA subcomponent of the self in Parkinson's disease patients is changed and this is associated with frontal dysfunction.

Our purpose in this study is to explore the associations between temperament and character dimensions and performance on neuropsychological measures of executive functioning and abstract reasoning in a non-clinical sample. The motivation for linking two different psychological terms (personality and cognition) stems from: (a) literature which often espouses similar concepts to describe both temperament profiles and executive functioning strategies (Bergvall *et al*., 2003; Cheung, Mitsis, & Halperin, 2004; Hooper, Luciana, Wahlstrom, Conklin, & Yarger, 2008; Whitney, Jameson, & Hinson, 2004) and (b) psychobiological theory of personality as measured by the TCI.

METHOD

Research design

A non-experimental relational design was employed. The University of Pennsylvania Computerised Neuropsychological Test Battery was used for this study (PennCNP). The choice of a computerised battery facilitated group administration of tests (Gur *et al*., 2001). Working in collaboration with researchers at the Brain-Behavior Laboratory at the University of Pennsylvania, a web-interface was set up between the South African site and the USA site. The PennCNP comprises four computerised neuropsychological test batteries (Emotions, Memory, Executive Function and Abstract Reasoning and a full battery comprising all the tests from the three batteries). For the purposes of this study, the Executive Function and Abstract Reasoning test battery was administered.

Sample

Students registered for postgraduate courses in psychology were invited to participate. Of the total of 88 students, 63 who indicated no prior medical or psychiatric history were eligible for participation. 55 students had four years of tertiary education and eight students had five years of tertiary education. Ages ranged from 20 to 48 with a mean age of 23.68 (4.94). 58 participants were right handed, 3 were left handed and the remaining 2 ambidextrous. 44% of the sample indicated that English was their home language, 39% stated that Afrikaans was their home language and 17% spoke an African language at home. 61% indicated their primary school language medium as English and 39% were schooled in Afrikaans during their primary education. These values did not differ significantly from the medium of instruction in high school, with 64% being schooled in English and 36% in Afrikaans. The average number of years of mothers' education was 13.59 (2.60) and fathers' education was 14.33 (2.72).

Measuring instruments

A socio-demographic questionnaire was designed to capture basic data about respondents' gender, age, handedness, language of schooling, home language and parental education levels.

The PennCNP begins with a general sensory-motor and familiarisation trial (MPRAXIS) so as to allow participants to become comfortable with the computer-based testing procedure and demonstrate adeptness at using a computer and mouse. The battery of tests does not commence until the participant has successfully completed the MPRAXIS trial. This second part of the MPRAXIS is a test of sensory–motor skills. The Executive Functioning and Abstract Reasoning battery consists of the following tests: the Penn Abstraction, Inhibition and Working Memory Task (AIM); The Letter-N-Back (LNB2), the Penn Conditional Exclusion Task (PCET); the Penn Short Logical Reasoning Test (SPVRT) and Short Raven's Progressive Matrices (SRAVEN). The tests from the Executive Functioning and Abstract Reasoning Battery are administered in a set order (MPRAXIS, AIM, LNB2, PCET, SPVRT and SRAVEN). Below is a description of each task and the performance indicators selected for statistical analyses (http://penncnp.med.upenn.edu).

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

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

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

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

Short Penn Logical Reasoning Test: 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 8 questions. The participant must click with the computer mouse on one of the four choices that he/she thinks best fits the analogy presented. It is a forced-choice task (the question will remain on the computer screen until the participant chooses one of the four answers). No feedback is given in terms of correct or incorrect responses. Total number correct and reaction time for correct responses were selected as performance measures.

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

Temperament and Character Inventory (TCI): This is based on the psychobiological theory of Cloninger. It consists of 240 questions with a true-false answer format. Internal consistency coefficients range from .70 to .89 for the seven factors in a non-clinical sample (Cloninger *et al*., 1994). Only 57 of the original 63 participants completed the TCI. Due to the length of the computerised neuropsychological testing session, self-completion of the TCI outside the testing session itself was considered prudent. 8% attrition on the TCI completion was considered satisfactory.

Procedure

Ethical clearance for the study was obtained from the relevant departmental and faculty committees at the University of Pretoria. Pre-administration requirements were implemented and checked by the test administrators. Participants were seated at computer consoles in the Computer-Based Testing Laboratory (CBT) at the university. An introductory session was delivered to the participants informing them of the nature of the testing process, as well as providing information on the nature and complexity of some of the tasks. An assurance of anonymity and confidentiality of data was also given. Participants were informed that the attending research assistants monitoring the session would answer any queries. In addition to the three attending researchers, eight research assistants were trained in the administration of the battery. Each research assistant was responsible for the monitoring of eight participants. The research assistants had to electronically submit, upon completion of each task, the test status code (C-complete, I-incomplete) and the number (1-good data, 2-questionable data or 3-bad data) at the end of the testing session. The data collection for the pilot study was completed in one group testing session lasting approximately 120 minutes.

RESULTS

On the MPRAXIS trial, the participants scored perfect responses. This suggests that the full sample were accustomed to working with a computer mouse.

Descriptive statistics for the TCI dimensions are briefly discussed below and illustrated in Table 1. According to the TCI cut-off scores for a normal community-based sample, the South African pilot sample scored in the following categories for the three temperament typologies: HA - average, NS - high average and RD - average. Peirson and Heuchert (2001) utilised the TCI on a South African student sample (n = 472) and found the following mean scores on the seven dimensions: NS (20.70), HA (16.11), RD (15.52), P (4.58), SD (26.33), C (31.76) and ST (18.29). The mean scores compared favourably between the student samples.

Table 2 indicates the pilot sample means, standard deviations, range for the PennCNP tests and the means and standard deviations for the PennCNP normative data. Total number correct (accuracy) and reaction time for correct responses (speed) were selected as performance measures for the neuropsychological tests. The University of Pennsylvania normative data was used to calculate z-scores for PennCNP performance of the pilot sample. The normative data sample had an average age of 29.61 (11.13) and the average age of the South African sample is 23.68 (4.94). Normative data for the LNB2 task were not available for comparison.

Table 3 indicates the significant correlations between the seven TCI dimensions and PennCNP tasks. A brief summary of the correlations are outlined below.

Zero-order correlations indicated one significant association between performance on the LNB2-2Back and NS. A significant correlation between HA and reaction time on the AIM (with and without working memory) was found. Reward dependence was significantly correlated with participants' reaction time on the AIM (with and without working memory) as well as the response speed on a measure of logical reasoning (SPVRT). There were no significant correlations between P and neuropsychological tests. The character dimension of ST was significantly associated with the working memory and non-working memory components of the AIM.

Due to sample size limitations and the lack of variability in terms of education, gender and age, the demographic variable of parental education level (mothers and fathers) was used as a covariate in a partial correlation analyses to determine if the associations between the neuropsychological performance indicators and temperament and character dimensions would still be significant. For the purposes of this analysis, only the associations between accuracy of performance (not reaction time correlations) were included.

After controlling for parental education levels the association between ST and performance on the AIM remained significant. The association between NS and LNB2-2Back appears to be mediated by parental education as once this is controlled for the association is no longer significant. Similarly, a non significant association was found for RD and C and the total number of correct responses on the verbal logical reasoning test, however, when parental education is controlled for these associations reach statistical significance. Clearly, this measure of socio-cultural mediation accounts for an important source of variance. Table 4 evidences both the zero-order and partial order correlations between the TCI dimensions and the executive variables.

Table 1. Descriptive statistics for the seven TCI dimensions

TCI dimensions	Range	Minimum	Maximum	Mean	*SD*	Variance	Skewness	Kurtosis	Range	Minimum
Novelty seeking	34	4	38	20.07	6.469	41.843	.149	.325	.175	.639
Harm Avoidance	30	1	31	13.22	7.213	52.026	.079	.322	–.775	.634
Reward Dependence	18	5	23	15.78	3.998	15.987	–.446	.325	–.111	.639
Persistence total	6	2	8	5.87	1.656	2.743	–.424	.322	–.865	.634
Self directedness	29	13	42	32.11	7.573	57.346	–.389	.325	–.937	.639
Cooperativeness	19	23	42	35.50	5.249	27.549	–.734	.330	–.512	.650
Self transcendence	26	5	31	19.31	6.534	42.699	–.286	.322	–.537	.634

Table 2. PennCNP descriptive performance data

Neuropsychological measures	Mean, SA study	*SD*	Mean Penn normative data	Standard devPenn normative data
AIM sum of correct responses (no working memory)	23.09	3.46	24.40	3.17
AIM sum of correct responses items (working memory)	23.87	3.17	23.40	4.17
AIM reaction time (no working memory)	2 130.99	619.82	2 072.65	718.89
AIM reaction time (working memory)	1 498.57	426.44	1 456.46	488.23
LNB2 true positive responses	42.95	5.25	-	-
LNBC2 reaction time for all true positive responses	432.84	99.7	-	-
PCET Number of correct responses	38.24	8.68	41.43	11.62
PCET reaction time for correct responses	2 116.78	697.05	2 728.36	1 214.43
PCET number of perseverative errors	17.4	9.19	23.18	16.71
SPVRT total number of correct responses	17.53	4.89	21.68	4.33
SPVRT reaction time for correct responses	8 757.62	2 826.4	8 381.2	3 006.21
SRAVEN number of correct responses	44	9.31	47.47	8.57
SRAVEN reaction time for correct responses	18 657.22	12 112.14	8 477	2 448

Response times are indicated in milliseconds

Table 3. Significant correlations between TCI variables and executive measures

	Temperament			Character
Neuropsychological measures	Novelty Seeking	Harm avoidance	Reward Dependence	Self Transcendance
AIM sum of correct responses (no working memory)	-	-	-	0.317
AIM sum of correct responses items (working memory)	-	-	-	0.324
AIM reaction time (no working memory)	-	0.323	0.2819	-
AIM reaction time (working memory)	-	0.287	0.2747	-
LNB2-2Back true positive responses	–2.92	-	-	-
SPVRT reaction time for correct responses	-	-	0.3255	-

* $p < 0.05$; $n \geq 54 \leq 56$

DISCUSSION

The present study found significant associations between temperament and character dimensions and accuracy and speed of performance on PennCNP tests of Executive Functioning and Abstract Reasoning. This supports studies which report correlations between personality and neuropsychological outcomes in various clinical and community samples (e.g. Henderson & Wachs, 2007; Keilp, Sackeim, & Mann, 2005; Robinson & Tamir, 2005; Robinson & Wilkowski, 2006).

Studies by Bergvall *et al.* (2003) and Boeker, Klieser, Lehman, Jaenke, Bogerts and Northoff (2006), found that the character dimensions of the TCI were significantly associated with neuropsychological performance while the temperament dimensions showed no significant association with accuracy of performance on the neuropsychological tests. Boeker *et al.* (2006) found that the character dimensions of Self Transcendence (ST) and Self Directedness (SD) were significantly associated with working memory tasks in healthy participants and were significantly associated with executive functioning tasks in schizophrenics. In the current study, results indicate that the higher the ST the better the performance on the AIM (with and without working memory). Higher ST scores may reflect a tolerance for ambiguity and in non-clinical individuals there may be a strong reliance on working memory and internal monitoring and manipulation of feedback in the presence of time pressure on this task. It appears that participants with higher internal monitoring perform better on this task. The other executive tasks that require internal manipulation of incoming information do not provide feedback after each trial and are forced choice tasks.

Bergvall *et al.* (2003) found a significant association between character dimensions and performance on a set-shifting task and explained this on the basis that character dimensions on the TCI build on complex cognitive processes including insight learning and that character dimensions and certain executive functions may share underlying neural substrates. Individual differences or patterns of “neurological individuality” in brain circuitry (a function of genetics and experience) may be expressed as an interrelation between aspects of personality and advanced cognitive abilities (Henderson & Wachs, 2007, p. 401). Eisenberg (2002), considered a two-fold characterisation of restraint/inhibition, where reactive inhibition (temperament) is under the control of the subcortical areas and effortful inhibition (character) under the control of the executive cortical area. This links with the contention that temperament traits depend on procedural memory and habits and character traits depend on propositional memory and greater effortful processing (Cloninger *et al.*, 1993).

Effortful control, when conceptualised as anaspect of personality, alludes to strategies that regulate behaviour through voluntary inhibition, response modulation and self monitoring. When conceptualised as executive functioning the strategies allude to response inhibition, resistance to interference

Table 4. Significant zero-order and partial order correlations between the TCI dimensions and the executive variables

	Zero-order correlations							Partial correlations [a]						
	P	**NS**	**HA**	**RD**	**SD**	**CO**	**ST**	**P**	**NS**	**HA**	**RD**	**SD**	**CO**	**ST**
AIM sum of correct responses (no working memory)	.153	.192	–.175	.062	.089	.024	.317*	.171	.247	–.214	.129	.171	.125	.377*
AIM sum of correct responses items (working memory)	.087	.177	–.244	.042	.097	.047	.324*	.138	.260	–.351*	.145	.234	.160	.409*
LNB2 true positive responses	–.133	–.257	.251	.171	–.096	.088	.022	.139	–.222	.107	–.233	.145	–.046	–.193
LNB2-0Back true positives responses	–.152	–.195	.204	.261	–.142	.093	.112	.280	–.016	–.122	.267	.008	–.055	.225
LNB2-1Back true positive responses	–.131	–.215	.246	.168	–.149	.054	.060	.206	–.155	.179	–.298	.021	–.194	–.135
LNB2-2Back true positive responses	–.107	–.292*	.248	.100	–.013	.103	–.061	.075	–.218	.080	–.206	.171	.016	–.210
LNB2-2Back reaction time for 2Back true positive responses	.078	–.022	.188	.197	–.097	–.049	.144	.047	–.026	.208	.245	–.119	–.009	.130
PCET Number of correct responses	–.002	–.055	.160	.039	–.002	.054	.007	–.011	–.061	.119	.154	.154	.162	.016
PCET total number of trials	.154	.042	–.019	.128	.124	.012	.060	.221	.063	–.072	.124	.213	–.026	.090
PCET total number categories achieved	–.156	–.107	.058	–.050	–.072	.063	–.066	–.152	–.158	.054	.037	.012	.180	–.067
PCET number of perseverative errors	.180	–.004	–.095	.095	.138	.006	–.032	.221	–.011	–.128	.038	.150	–.057	–.048
SPVRT total number of correct responses	–.121	–.102	.166	–.265	–.155	–.109	–.187	–.165	–.053	.158	–.377*	–.205	–.333*	–.308*
SRAVEN number of correct responses	–.033	–.082	.022	.055	.097	.053	–.134	–.002	–.158	.094	–.110	.115	–.046	–.199

* $p < 0.05$; $n \geq 51 \leq 55$; *a* Controlling for Parental Education

and response sequencing (planning, abstraction and self-regulation of goal directed behaviours), which are aspects of cognition that are measured by the AIM (Henderson & Wachs, 2007). According to Sugarman (2002), the concept of executive functioning has been usurped by reductionistic thought and is often defined as an exclusively cognitive process stripped of any underlying social or emotional valence. He argues that what we define as executive functioning may be intertwined with aspects of recursive and self-reflexive conscious awareness.

A significant negative association was found between the LNB2-2Back and Novelty Seeking (NS), which indicates that participants high in novelty seeking display less accurate performance on this task. In a study of 58 healthy volunteers, Keilp *et al.* (2005) found that individuals with high impulsivity reflected poorer performance scores on the Continuous Performance Test (a measure of sustained attention). In the current study a significant correlation was found between NS and the more complex and demanding stage of the LNB2 task. According to Whitney *et al.* (2004), when information processing demands and response complexity are increased, participants with higher impulsivity may lack the attentional resources to retain critical information and inhibit irrelevant information. The activation of reactive control, which is a system that monitors, modulates and regulates reactive aspects of temperament, is inhibited in individuals high in novelty seeking (Henderson & Wachs, 2007).

Mardaga and Hansenne (2007) found that the Behavioural Inhibition System was best predicted by the temperament dimensions Harm Avoidance (HA) and Reward Dependence (RD). Harm Avoidance is the tendency to inhibit responses and avoid punishment and non-reward. Participants with a high RD tendency would be sensitive to both reward and punishment in social settings and would inhibit responses that negate approval and invite criticism. The results of this study indicate that for tasks that require a timed response (AIM — both for the component with and without working memory) reaction time correlated positively with HA and RD in the presence of feedback on each response. Participants who scored high on HA and RD had slower reaction times. According to Robinson, Wilkowski and Meier (2006), choice reaction time performance reflects individual differences in self-regulation and appraisal. According to Barkley (1997), behavioural inhibition comprises three interconnected processes that are fundamental to executive functioning: (a) inhibition of prepotent responses, (b) inhibiting an ongoing response, creating a delay, and (c) maintaining the delay period in the presence of any disruption. These processes provide the basis for a delay in the decision to respond, thereby providing the underlying control of motor responses (Cheung *et al.*, 2004).

Carver and Miller (2006) indicate that studies using the TCI and tests of serotonin receptor sensitivity yielded a positive association between HA and serotonin levels (high HA — high serotonin level — low receptor sensitivity). They contend further that studies indicate that high serotonin levels relate to executive functioning factors such as concentration and deliberation. According to Cloninger *et al.* (1994), the HA scale also reflects an aspect of anxiety proneness and persons scoring high on this trait tend to over anticipate failure, rarely take risk and have difficulty adapting to changes. In a South African study, Lochner *et al.* (2007) found that patients diagnosed with social anxiety disorder scored significantly higher on HA when compared to normal controls, implying that both HA and facets of anxiety symptoms may derive from underlying neurotransmitter functioning. Higher HA is associated with more deliberate inhibited behavioural responses and anxiety proneness. This would influence the reaction time on timed tasks that tap into frontal brain areas and serotonergic systems. Aspects of anxiety proneness would be high, deliberation would be enhanced and impulsiveness would be inhibited, thus more time would be taken to respond to the stimulus on tasks like the AIM.

The positive association between RD and reaction time on the SPVRT suggests that individuals with higher scores on RD tend to have slower reaction times on the task of verbal analogical reasoning. Individuals high in RD are considered to have low basal rates of noradrenaline in the projections between the locus cereulus and the prefrontal cortex and low cortical arousal levels (Cloninger *et al.*, 1994). In a study of dopamine and noradrenaline dysfunction in attention-deficit/hyperactivity disorder Frank, Santamaria, O'Reilly and Willcutt (2007) found that reaction time variability was consistent with cortical noradrenergic dysfunction. A correlation between frontal lobe function and noradrenaline was evidenced in a study showing a negative association between neuropsychological performance on the Stroop-Interference test and verbal fluency test and noradrenaline levels (Oades, Röpcke, Henning, & Klimke, 2005). In a study on methylphenidate-Ritalin (a noradrenaline and dopamine reuptake inhibitor) Kim, Ko, Na, Park and Kim (2006) found that after a single dose, patients with traumatic brain injury had improved reaction times on measures of verbal working memory. Modafinil, a noradrenaline agonist, improves cognitive performance on tasks such as logical reasoning (Minzenberg & Carter, 2008). The link between verbal relational reasoning tasks and activity in the prefrontal cortex has been demonstrated by functional magnetic resonance imaging studies (Wendelken, Nakhabenko, Donohue, Carter, & Bunge, 2008). Expanding on this reasoning one would assume that RD would also be associated with performance or reaction time on a task of visual logical reasoning such as the SRAVEN. However, according to Goel (2007),visuospatial and verbal/linguistic logical reasoning processes imply a fractionated underlying brain system that dynamically responds to specific tasks and environmental cues.

When controlling for parental education, performance on the AIM and ST are still significantly associated, but the correlation between NS and LNB2-2Back fails to reach significance. HA, RD and Conscientiousness (C) show significant correlations with the AIM and SPVRT. It appears that contextual and psychosocial factors may mediate the relationship between temperament via the associated central nervous system functions and cognitive-behavioural outcomes. Parents with better education may provide a more stimulating environment, more sophisticated verbal interaction, enhanced contextual factors conducive to educational performance and thereby influence the nature and quality of components of executive development (Braga, 2007; Hoff, 2003). Ardila, Roselli, Matute and Guajardo (2005) found that parental education has a stronger influence on executive functioning tests with a high verbal loading than on tests that are regarded as non-verbal. Interestingly, the test with the highest verbal loading (SPVRT) evidenced more significant relationships with TCI dimensions when parental education levels were controlled. This may suggest that parental education levels may account for an important source of variance in the relationship between verbal executive functioning tests and personality. Although this research tackles substantive issues within the area of temperament and character correlates of neuropsychological performance, the generalisability of the results to clinical populations is limited due to the restricted range of the sample in terms of both number and level of functioning. Large-scale studies using clinical sub-populations will further serve this domain of enquiry.

CONCLUSION

This study shows that temperament and character, as measured by the TCI, may influence performance on neuropsychological tests. This derives from the hypothesis that neurotransmitter functions and neuro-anatomical sites underlie expressions of temperament and character and similar processes may underlie expression of executive abilities. Conclusions from the present study are limited by the relatively small sample size. The extent to which personality (in a psychobiological sense) is related to neuropsychological test outcomes will require further exploration in a more representative sample. Furthermore, the computerised executive battery comprised a small select group of tests that measure specific aspects of executive functioning and abstract reasoning. A wider selection of tests tapping into different executive abilities may help in further understanding the relationships between specific temperament and character dimensions and executive functioning both in clinical and non-clinical groups. There is substantial evidence that neuropsychological test performance is mediated by psychosocial factors and studies on larger samples with more diverse socio-demographics (age, gender, education and language) may further enhance understanding of the relationship between temperament, character and neuropsychological performance.

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