A Regression Based Approach to Estimating Premorbid Neuropsychological Functioning in the Older Adult Population Using Four Tests of Executive Function

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Abstract

Introduction: Scores obtained on neuropsychological tests are frequently used to identify deficits or changes in cognitive functioning. It has been suggested that frontal-executive functions decline in older adulthood (West, 1996). Therefore, there is a strong clinical need to accurately determine the extent of this decline in the healthy older adult population. This would enable clinicians to determine with greater accuracy what constitutes an abnormal performance. Unfortunately, few neuropsychological measures of executive functioning have adequate test norms for older adults. Regression equations based on demographic variables offer an efficient and valuable way of making normative comparisons. Therefore, the main aim of the present study was to develop a reliable means of estimating premorbid executive functioning in the older adult population.

Objective: Build regression equations based upon a combination of demographic variables and an estimate of premorbid IQ (National Adult Reading Test) for four tests of executive function: the Trail Making Test (TMT), the Modified Six Elements Test (SET), and the Hayling and Brixton tests.

Method: One hundred and six neurologically stable community-dwelling older adults participated in the study. These volunteers completed all test measures. The data were analysed using descriptive statistics and correlation analysis. Hierarchical regression analysis was used to explore the relationship between potential predictor variables and test scores.

Results: As expected, age was a significant predictor of test score on all four tests of executive function. The proportion of variance explained by age varied. For instance, age alone accounted for 40.2% of the variance in performance on the TMT Part B, but only 8.1% of the variance on the SET. The addition of estimated IQ and other demographic variables to the regression analysis significantly improved prediction accuracy of test scores.

Conclusion: Advancing age was associated with poorer test performance on all outcome measures (all $ps<.01$). Poorer test performance was also associated with fewer years of education, lower educational achievements, lower socio-economic status, and lower estimated IQ. Incorporating such information, the set of equations produced provide clinicians with a practical means of estimating a client's executive function test performance. Clinicians can assess the abnormality of a client's executive function test performance by comparing the difference between their predicted and obtained test scores against a table of critical values. An example of how to apply these equations in clinical practice was presented. The findings presented here appear to provide further support for the hypothesis that normal aging is associated with a decline in frontal executive functioning.

Chapter 1: Introduction

A matter of considerable importance to clinical psychologists in their evaluation of a client's cognitive status relates to their interpretations of scores obtained on neuropsychological tests. Based on the observation that a decline in fronto-executive functioning abilities are amongst the most commonly reported psychological consequences of growing old (Dempster, 1992), there is a strong clinical need to accurately determine the extent of these executive deficits in the healthy older adult population in order to enable clinicians to more precisely classify what constitutes a normal performance and what is an unusual or abnormal performance. Unfortunately, very few tests of executive functioning have adequate test norms for older adults. Therefore, for the present study it was decided to focus on the neuropsychological assessment of executive functioning in the general older adult population with the specific aim of developing a reliable means of estimating premorbid executive functioning in this population.

Before expanding further upon the methodological justification for the approach adopted and the specific rationale for researching the area of cognitive functioning under investigation a brief introduction to neuropsychology that incorporates a general description of the aims of neuropsychological assessment is presented in order to orientate the reader to this often unfamiliar branch of psychological research and practice.

1.1 Neuropsychology: A Historical Perspective

> 'Men ought to know that from the human brain and from the brain only arise our pleasure, joys, laughter, and jests as well as our sorrows, pain grief, tears and lamentations.....by this, in a special manner, we acquire wisdom and knowledge, and know what are foul and what are fair..... And by the same organ we make inopportune mistakes, become absent-minded, or mad and delirious.....'
>
> Hippocrates (460BC – 377BC)

Man's desire to understand the relationship between his brain, his thoughts, emotions and behaviour has provoked a healthy debate and a spirit of enquiry that stretches back to ancient times. However, discoveries about the structure and function of the brain have been relatively slow in coming. Indeed, it was not really until the middle of the nineteenth century, following the observations of Paul Broca (1861) and Carl Wernicke (1874) on the localization of specific language disorders that significant developments in our understanding of brain-behaviour relationships began to be made.

Inspired by the findings of physicians such as Broca and Wernicke, the beginning of the twentieth century witnessed a burgeoning of interest in the study of brain-behaviour relationships and the impact of brain injury on individuals. However, it was the outbreak of World War 1 in 1914 and the numerous observations of brain-damaged soldiers that probably did most to fan the flames of interest in the behavioural and intellectual effects of brain damage - with the influential writings of Kurt Goldstein and his associates (Goldstein,

1939; Goldstein & Scheerer, 1941) providing classic descriptions of the cognitive symptoms associated with cerebral damage.

Over the intervening years, psychologists have become increasingly interested in this association, and this has led to the development of a specialised area within psychology that is specifically concerned with the scientific study of brain function and behavioural relationships. Commonly known as 'neuropsychology', this expanding area of research and practice integrates data from a number of sources, including neurology, neuroscience, cognitive psychology and cognitive science (Woodruff-Pak, 1997), in order to improve our understanding of the relationship between neuroanatomical structures and behaviour.

In clinical settings the practising neuropsychologist is intimately involved in the assessment and treatment of individuals with known or suspected brain damage. When confronted with such patients, the clinical neuropsychologist utilises a variety of assessment techniques in an attempt to accurately document the extent of a patient's difficulties. The neuropsychologist then applies their knowledge of the science of neuropsychology to formulate hypotheses about the possible cause(s) of cognitive or behavioural impairment. In the absence of corroborating evidence routinely provided by contemporary brain imaging techniques, this often involves making decisions about possible areas of brain damage or answering questions relating to differential diagnosis.

Furthermore, using their expert knowledge of neuropsychological models of functioning neuropsychologists can help ensure that the most appropriate rehabilitation strategies and/or

other interventions are introduced in order to enable the brain damaged individual to realise their rehabilitation potential and lead as independent a life as is practically possible.

1.2 Aims of Neuropsychological Assessment

As already alluded to, neuropsychological assessment is generally aimed at identifying, and documenting, the cognitive and behavioural sequelae of cerebral dysfunction (Report by The American Academy of Neurology, 1996). There are a number of reasons why this is an important and worthwhile endeavour. Firstly, the neuropsychological examination helps document which parts of the cognitive system are impaired and how severe these deficits are (Crawford, O'Carroll & Venneri, 1998). As well as this, the neuropsychological assessment also helps determine which components of the patient's cognitive system have been spared. Incorporating a battery of measures designed to evaluate a range of neuropsychological functions will help achieve this aim, and ensures that a detailed and comprehensive assessment of the patient's ability is undertaken. Using cognitive measures that have previously been found to be supported by particular brain regions can also allow predictions to be made about possible areas of brain damage (Beaumont, 1996).

Furthermore, the neuropsychological examination can help draw out the implications of any changes in mood or personality for a client's everyday functioning (Crawford et al, 1998). As well as this, Crawford and colleagues (1998) also point out that the neuropsychological assessment can help determine the extent to which such changes are likely due to the effects of neurological damage, or a psychological reaction to illness or the experience associated with sustaining an injury.

Consideration of the factors listed above obviously has important implications for a patient's rehabilitation, and undoubtedly contributes to what Beaumont (1996) has called 'the fundamental goal of assessment': improving the patient's condition and/or circumstances. More specifically, accurate quantification of an individual's cognitive strengths and weaknesses is particularly crucial when designing any formal rehabilitation strategies intended to enable a patient to realise their rehabilitation potential. Likewise, developing a cognitive and behavioural profile of the patient's strengths and deficits is especially helpful when considering what practical advice should be given to the patient and their family in order to help them cope with, or compensate for the difficulties that are evident (Lezak, Howieson & Loring, 2004).

1.2.1 Measurement of Deficits for Diagnostic Purpose

There are a number of situations where the practicing clinical neuropsychologist needs to measure possible changes in cognitive functioning. One rather common example presents itself when they are asked to determine whether cognitive decline has occurred in an individual with a suspected neurodegenerative disorder, such as Alzheimer's or Huntington's disease. Employed in this endeavour the neuropsychologist can use the information gleaned from the results of neuropsychological testing to form hypotheses about potential areas of brain damage (Woodruff-Pak, 1997). Should organic cerebral disease be suggested, the neuropsychologist's formulation can also provide valuable information on behavioural prognosis and the likely effects of the disease as it progresses (Beaumont, 1996).

In line with this, the importance of research into changes in cognitive function becomes particularly important when a clinician is involved in differentiating between cognitive complaints that may have a psychiatric rather than an organic basis (Lezak et al, 2004). In terms of attempting to identify the underlying nature of a client's cognitive difficulties, one of the most frequently posed referral questions encountered in clinical neuropsychology concerns the assessment of memory problems and, in particular, the differentiation between dementia and depression in older adults (Anastasi & Urbina, 1997). According to Lezak and colleagues (2004), the differential diagnosis of dementia versus depression is 'probably the knottiest problem of differential diagnosis'. This is because depression is a common disorder that can closely resemble the early stages of a dementing condition.

In order to address this problem, Lezak and colleagues (2004) suggest that when the results of a neuropsychological examination leave the clinician in doubt about (differential) diagnosis, repeated examinations of an individual's neuropsychological status should reveal performance inconsistencies in those with functional disturbances. Re-examination spaced 6 to 12 months apart should reveal progressive deterioration in individual's with progressive neurological dysfunction. Therefore, we can see that by analysis of a patient's test scores, a clinician may rule out a particular diagnosis based upon the pattern of results obtained from occasion to occasion of testing. This obviously has important implications when considering treatment.

However, a significant deficit in a client's expected test performance in the absence of depressive features on the first occasion of testing can alert the clinician to a possible

neurodegenerative process prior to re-examination at some time in the future. This can have implications in terms of ensuring the timely introduction of interventions aimed at remediation of cognitive difficulties. Nonetheless, Lezak and colleagues (2004) point out that a diagnosis of probable Alzheimer's Dementia should really only be made after serial assessment in order to try and reduce the likelihood of diagnostic error occurring.

1.2.2 Measuring Deficits to Guide Intervention

As already noted, reliable quantification of change in an individual's level of cognitive functioning is crucial in helping the clinician develop an appropriate intervention or rehabilitation program for a client. According to Beaumont (1996), there are three principal methods through which clinical improvement in a client's situation might be achieved: (i) Medical intervention (ii) Psychological intervention, and (iii) General management of the disorder. Each of these intervention strategies merit further discussion in order to inform the reader how they might individually or collectively contribute to improving the client's functioning and quality of life.

1.2.2.1 Medical Intervention

Accurate diagnosis and quantification of neuropsychological deficits provides crucial information that health professionals utilise when making decisions about potential medical interventions. Whether the medical intervention under consideration involves the use of surgery, pharmacological treatment, or other physical management techniques, the neuropsychological assessment of a client produces an individualised profile that offers valuable insights into the possible aetiology of cognitive dysfunction. For instance,

specific deficits on specific cognitive measures can assist in the identification and localization of a possible tumour or lesion (Beaumont, 1996). Based on such information, informed decisions about the most appropriate treatment approach can then be made. Of course, the development of sophisticated brain-imaging techniques means the role of neuropsychology has somewhat declined in this area recently. However, it is important to remember that while brain scans may produce an image that establishes areas of brain abnormality, these same images do not document the cognitive, behavioural and emotional consequences of such abnormalities: the neuropsychological assessment details this (Lezak et al, 2004). Taking this into account, the neuropsychological assessment still informs a range of medical decisions, and they are especially relevant when it comes to monitoring the impact of interventions on functioning.

1.2.2.2 Psychological Intervention

An accurate description of the client's neuropsychological status is fundamental when it comes to devising therapeutic rehabilitation programs aimed at the amelioration of specific cognitive, behavioural and/or emotional difficulties associated with neurological dysfunction. The last twenty years or so have witnessed a considerable growth in the number of psychological interventions that are available. These include: specific rehabilitation techniques aimed at helping clients overcome specific cognitive deficits in, for example, attention (Sturm, Fimm, Cantagallo, Cremel, North et al, 2002) or memory (Wilson, Baddeley, Evans & Shiel, 1994); cognitive behavioural therapy aimed at targeting emotional difficulties associated with neurological change (Williams, 2003); and specific behavioural management techniques designed to modify behaviour, and help clients and

their families manage behavioural changes associated with neurological dysfunction (Alderman, 2001). This is by no means an exhaustive list of the range of psychological interventions available. For a more detailed description of the neuropsychological remediation techniques available, interested readers are referred to the excellent review edited by Wilson (2003).

1.2.2.3 General Management

In terms of the general management of clients with a neurological disorder, it is important to recognise the crucial role the multi-disciplinary team has in ensuring that appropriate support structures are put in place: not only in the hospital setting, but perhaps more critically, once the client is discharged from hospital. The forms of support necessary will vary from individual to individual and this is where the neuropsychological description of a client's functioning is essential. Bearing in mind factors such as aetiology and diagnosis, the clinician can use the results of the neuropsychological assessment to draw conclusions about likely prognosis and this too can influence management decisions (Beaumont, 1996). For instance, in the case of a suspected neurodegenerative disorder a client's condition may be expected to deteriorate as the disease progresses. Therefore, different forms of support may be required at different times. This might involve regular hospital review, on-going support in the form of routine nursing care, psychological support for the client and their family, practical support from social work, as well as input from other healthcare specialists.

1.2.3 Measuring Deficits to Monitor Change

The neuropsychological assessment has a particularly valuable contribution to make when it comes to monitoring changes in performance over time (Crawford et al, 1998; Temkin, Heaton, Grant & Dikmen, 1999). For instance, repeated administration of neuropsychological tests is especially useful when involved in detecting deteriorating cognitive functioning owing to disease progression (Lezak et al, 2004; Temkin et al, 1999) or when assessing the influence a patient's rehabilitation program has had on their cognitive functioning. Positive changes in cognitive status could indicate improved functioning due to the effects of treatment following cerebral damage. On the other hand, a patient's post intervention performance may indicate a marked decline in cognitive functioning when compared to their baseline scores obtained prior to treatment. Should this be found, the clinician can assess the potential benefits and disadvantages of a particular intervention, and possibly consider an alternative course of treatment.

Bearing this in mind, we can see that measuring change is an issue of critical importance in neuropsychological research. More specifically, it is fundamental to developing and assessing the effectiveness of a particular intervention technique or rehabilitation program in helping counteract or alleviate the psychological problems that a patient is experiencing.

1.2.4 Measurement of Deficits for Medico-Legal Purposes

The clinical neuropsychologist's examination of an individual's psychological functioning can also provide valuable information that can be utilised in judicial proceedings. The information gathered from extensive neuropsychological assessment of clients is being used

increasingly more often in civil as well as criminal courtroom cases, in order to help establish and evaluate the veracity of particular legal arguments. According to Lezak and colleagues (2004), the findings of neuropsychological assessments are most frequently enlisted in cases of personal injury litigation where complainers often seek large sums of money in compensation for injuries sustained as a result of alleged negligence by the defendant.

However, Crawford and colleagues (1998) highlight many other medico-legal situations where the clinical neuropsychologist's expert knowledge is requested in order to aid the judicial process. For instance, one area of particular relevance to older adults relates to issues of guardianship, where the clinical neuropsychologist is required to compile a report evaluating whether or not a client is competent enough to live on their own or control their own financial affairs. Clearly, any report indicating a significant deterioration in functioning could have a profound impact when considering appointing a guardian. As well as this, Crawford and colleagues (1998) emphasise other areas of medico-legal interest, which include; assessing a client's 'fitness to plead in criminal cases' - which involves evaluating whether a client with suspected or known neuropsychological impairment can understand legal arguments against him or her and appreciate their significance; and evaluating 'pleas of diminished responsibility' – which involves assessing whether a pre-existing neuropsychological deficit contributed to a client's action, thus impairing their responsibility for that action.

Bearing the above situations in mind, it is clear that whether involved in assessing the effects of brain injury, accurately diagnosing the onset of degenerative disease, providing practical advice in planning a rehabilitation program, or whether implicated in medico-legal situations, the clinical neuropsychologist plays a valuable role in accurately quantifying changes in an individual's level of cognitive performance by identifying which components of a client's cognitive system are dysfunctional and how severe this dysfunction is.

1.3 The Process of Deficit Measurement

One rather common method of assessing a client's cognitive status is to compare their current test performance with the relevant test norms in order to see if their scores deviate significantly from that of the general population. However, given that considerable differences exist between individuals in terms of their cognitive skill, it has been suggested that this comparative method is of limited value (Crawford, McKinley & Parker, 1996). For instance, a particular test score below the test mean could reflect the typical level of performance for an individual of low previous ability, yet the same score could be indicative of severe cognitive decline in another individual of high previous ability (Baddeley, Emslie & Nimmo-Smith, 1993). Therefore, we can see that comparing a client's current test performance with existing normative data may not provide an accurate measure of change in neuropsychological functioning. Bearing the limitations of this conventional approach in mind, Crawford and colleagues (1998) critically point out that 'normative comparison standards are of limited utility in neuropsychological assessment' and should, wherever possible, be supplemented with an 'individualized comparison standard'.

Of course, when quantifying change the clinician would ideally prefer to obtain an individualised comparison standard from psychological test results acquired during the period preceding the point at which neurological impairment was suspected (Lezak et al, 2004). In such cases, a significant discrepancy between an individual's previous level of intellectual functioning and current test performance could be indicative of acquired neurological impairment. However, such information is rarely available to clinicians (Strauss, Sherman & Spreen, 2006). Fortunately, a number of methods have been developed in order to address the deficit measurement problem. Three of the most investigated procedures used to estimate an individual's previous or premorbid level of functioning are described briefly below.

1.4 Using a Current Ability Measure to Estimate Premorbid Ability

One approach to dealing with interpretative problems when quantifying impairment in the individual case is to use a present ability measure which is thought to be resistant to the effect of cerebral dysfunction (so called 'hold' tests) and incorporate it into simple regression equations[1] in an attempt to estimate a client's premorbid level of performance on other tests (Crawford, 1992). In order to assist in this process, specific tests that have been found to correlate highly with general intelligence have been designed for use as predictor variables.

In relation to this, one's knowledge of word pronunciation is perhaps the most useful method currently employed in contemporary neuropsychological research and practice to

[1] The methodological basis for the regression approach is discussed in the 'Method' section of this document

provide an estimate of an individual's likely level of ability. The most significant development in this area came with Hazel Nelson's publication of the National Adult Reading Test (NART) in 1982. Derived from Nelson and O'Connell's (1978) New Adult Reading Test, through its design, the NART capitalises on Nelson and McKenna's (1975) finding that one's capacity to read and pronounce a word with which they are familiar is relatively insensitive to general intellectual deterioration.

Basically, the NART is a short oral reading test, which consists of 50 single-words that a client has to read and pronounce in order for the administrator to score the accuracy of their pronunciation. The majority of words are short in length and all are irregular: that is, they do not obey the common rules of pronunciation (e.g. ache). In terms of their frequency of use in everyday language, the words used range from familiar to rare. Using words that are short minimises the demands placed on the client's current cognitive capacity (Nelson & O'Connell, 1978), while the irregularity of each word should prevent 'intelligent guess work' from producing the correct pronunciation (Crawford & Parker, 1989): this significantly contributes to the tests primary aim of tapping previous knowledge rather than current knowledge (Crawford et al, 1998).

In terms of its psychometric properties, the NART has been found to correlate highly with intelligence, display impressive reliability and be relatively insensitive to a variety of neurological disorders. A detailed discussion of the NART's psychometrics is presented in the 'Method' section of this document.

1.5 Using Demographic Variables to Estimate Premorbid Ability

Another approach to accurately quantifying impairment in the individual case is to gather information from studies on relevant neuropsychological instruments administered to particular populations and investigate whether demographic characteristics (such as age, years of education and occupational classification) influence performance on the tests (Crawford et al, 1996). Should this be the case, the clinician can then use these variables to predict the level a client should be performing at by incorporating them into simple regression equations. Crucially, this method of estimating premorbid ability has the major advantage of being unaffected by recent brain injury or disease and, therefore, completely independent of a patient's present level of cognitive functioning (Crawford et al, 1998; O'Carroll, 1995).

In relation to this, a consistent body of evidence has emerged demonstrating that an individual's demographic characteristics significantly influence their performance on neuropsychological tests. Indeed, many studies (Hester, Kinsella, Ong & McGregor, 2005; Temkin et al, 1999; and Tombaugh, 2004 to cite but a few) have found that factors such as age, years of education, and social class significantly affect performance on neuropsychological tests. Based on such findings, numerous researchers (Crawford & Allan, 1997; Heaton, Ryan, Grant & Matthews, 1996; Temkin et al, 1999; and Wilson, Rosenbaum, Brown, Rourke, Whitman & Grisell, 1978), have been able to use this information to develop demographically based regression equations to accurately estimate a client's expected level of test performance based on these variables.

For instance, using Wechsler's (1955) original standardisation sample Wilson and colleagues (1978), developed regression equations to predict premorbid intelligence. Incorporating information on an individual's education, occupation, age, sex and race, they found that the resulting equations accounted for 54%, 53% and 42% of the variance in WAIS[1] Full Scale, Verbal and Performance IQ, respectively. In line with this, Crawford and Allan (1997) have since built demographically based regression equations for use with the WAIS-R and found that age, years of education and social class accounted for 53% of the variance in WAIS-R FSIQ and VIQ, while 32% of the variance in PIQ was explained.

Therefore, based on the idea that age and other demographic variables may affect neuropsychological test performance, it would be beneficial to examine the relationship of these variables to level of performance on the test of interest. Should such variables be found to influence test scores, regression equations generated from the general adult population, that uses their demographic characteristics as independent variables, would then help in the prediction of a client's likely test performance.

By substituting an individual's personal characteristics into such an equation, this method of quantifying deficit uses an individual's demographic characteristics to estimate the score that they should achieve upon administration of the test of interest. This procedure allows a client's predicted test score to be compared with their obtained test score, thus enabling the clinician to assess whether the observed difference in performance significantly exceeds that that was expected. Clearly, any significant discrepancy between the estimated and

[1] Unless otherwise indicated, all reference to the WAIS refer to the original Wechsler Adult Intelligence Scale

obtained scores, in favour of the estimated score, could indicate acquired neuropsychological dysfunction.

1.6 Estimating Premorbid Ability Combining Demographic Variables With The NART

Bearing in mind that both NART error score and an individual's demographic characteristics have been found to correlate with intelligence, Crawford, Stewart, Parker, Besson and Cochrane (1989c) investigated whether combining the two approaches would lead to a more accurate prediction of premorbid IQ when compared to each method alone. Using a stepwise procedure, Crawford and colleagues (1989c) reported that while NART error score was still the best predictor of WAIS IQs, the demographic variables age, sex, and social class increased (by 7%) the amount of explained variance to an impressive 73%. Consequently, the authors built multiple regression equations to enable the prediction of WAIS IQ scores based on a combination of NART performance and demographic variables.

Using an Australian sample, Willshire, Kinsella and Prior (1991) also found that combining the two approaches mentioned above substantially improved their predictive power on the WAIS-R. More recently, Knight, McMahon, Green and Skeaff (2006) used this approach to construct multiple regression equations that allow a prediction of premorbid test performance to be made on the The Rey Auditory Verbal Learning Test, The Trail Making Test and measures of semantic fluency. Using a healthy community sample of 272 older adults living in Dunedin, New Zealand, Knight and colleagues (2006) also found that

including NART error score and demographic information in the regression analysis significantly improved the prediction of test scores.

Bearing this in mind, the major aim of the present study is to test models of the influence of demographic variables and the NART on tests of executive function. Using this approach, hypotheses concerning the relationship of the NART and demographic variables on test performance will be evaluated, with a view to generating regression equations to allow a prediction of test scores based on a combination of relevant variables.

Of course, the influence of demographic variables such as, age, years of education, and social class on test performance is an important issue for all neuropsychological functions. However, in the present study it was decided to focus on the neuropsychological assessment of executive functioning in the general older adult population. The rationale for adopting this approach will now be outlined below.

1.7 Executive Functioning

The term 'executive function' is a relatively new one to clinical neuropsychology and as such has, until relatively recently, been comparatively under-represented in the neuropsychological literature. This is somewhat surprising, especially when we consider that descriptions of patients exhibiting symptoms associated with impaired executive functioning date back well over a century (e.g. Harlow, 1868). In contrast to the apparent lack of early focus on the subject, the twentieth century (and the last 30 years or so in particular) has witnessed an explosion of interest in the concept of executive functioning:

with numerous researchers having been seduced into studying it and whole books now being devoted to discussing the topic (Rabbitt, 1997). As investigations continue, theories expand, and our understanding of the critical role executive functions perform in contributing to human behaviour improves. In order to appreciate the role of executive functions it is worth exploring in some detail the capacities that are proposed to comprise this 'system' and, more specifically, how they contribute to behaviour.

1.7.1 What Are Executive Functions?

The term 'executive functioning' is, by definition, a rather poorly defined construct. The particular phenomena that are hypothesised to contribute to executive functioning are debated and a clear consensus on what executive functioning actually involves has yet to be reached (Salthouse, 2005). This point is perfectly illustrated in the following definitions of executive functioning put forward by different researchers who, over the years, have sought to investigate the core components that are presumed to contribute to this complex construct:

> 'The term executive function.....[is a] shorthand description of a multidimensional construct referring to a variety of loosely related higher-order cognitive processes including initiation, planning, hypothesis generation, cognitive flexibility, decision making, regulation, judgement, feedback utilization, and self-perception that are necessary for effective and contextually appropriate behaviour.'
>
> Spreen & Strauss (1998)

'Executive function refers to cognitive processes that control and integrate other cognitive activities.....and as such is conceptualised as a superordinate, or 'meta' cognitive activity...[More] specifically the term executive function has been used to describe a group of cognitive actions which include: dealing with novelty, planning and implementing strategies for performance, monitoring performance, using feedback to adjust future responding, vigilance, and inhibiting task-irrelevant information.'

Bryan & Luszcz (2000)

'The term executive functioning refers to those abilities that enable a person to determine goals, formulate new and useful ways of achieving them, and then follow and adapt this proposed course in the face of competing demands and changing circumstances..'

Burgess & Alderman (2004)

Clearly the above descriptions capture a broad range of conceptualisations. However, despite the apparent diversity in defining the specific components of executive functioning, a common theme or unifying concept that becomes evident in reading these various descriptions appears to recognise the value of the executive system as having an intimate role in the control and co-ordination of an array of higher level cognitive processes necessary for a range of everyday routine and complex behaviours. In recognition of this, the executive system is often described as fulfilling the role of an international business executive or company CEO (Lezak et al, 2004) who, rather than being responsible for the operation of one particular speciality is, instead, responsible for the smooth management and supervision of the whole organisation (Salthouse, 2001). This concept of the executive system as a CEO fits well with those processing theories that view the 'system' as the

brain's 'Central Executive' (Baddeley, 1986) or 'Supervisory Attentional System' (Shallice & Burgess, 1996).

As well as reportedly being responsible for the range of capabilities described above, executive functioning has also been implicated in the monitoring of behaviour in social settings and the selection of appropriate responses in particular social circumstances (Robbins, 1996). Appreciating the influential role of executive functions on human behaviour, Burgess (2003) comments that 'there is probably no activity beyond the most routinized and practised ones that does not to some extent involve executive processing'.

For the purpose of this study, executive functioning is defined as a higher-order cognitive construct critically involved in the co-ordination and supervision of a range of cognitive processes including the 'initiation' of activity, 'attention', 'strategic goal planning' and the 'regulation of goal-directed behaviour', 'vigilance and inhibiting task irrelevant information', 'self and social monitoring', 'cognitive flexibility', 'concept formation', 'abstract reasoning' and 'problem solving', 'prospective memory' and the 'ability to adaptively use information contained in working memory'. This description generally follows that put forward by Burgess and Shallice (1997), Rabbitt (1997) and Giancola (2000), who themselves draw upon the writings of other researchers such as Luria (1980) to form their own descriptions.

1.7.2 The Neuroanatomy of Executive Function

The historical roots of executive functioning and the biological or neuroanatomical structures proposed to mediate one's executive function abilities can be traced back to Harlow's (1868) classic descriptions of his now infamous patient Phineas Gage, who sustained a severe and significant brain injury to the left frontal cortex when a 3 foot long tamping iron accidentally blasted through his skull. Surprisingly, Gage survived this traumatic event. However, significant costs were involved. According to reports (Macmillan, 1986), there were rather dramatic changes in Gage's personality and behaviour post-injury: changes that saw Gage go from a previously highly regarded employee and extremely well-mannered young man, to someone who was unreliable, impatient, obstinate, disrespectful, and lacking in social skills. In this respect, it is remarked that those who knew him said that he was 'no longer Gage' (Harlow, 1868).

Following Harlow's (1868) early reports, most of the theoretical work aimed at unravelling the precise contribution of the frontal lobes to behaviour relied on clinical observations of patient's who had sustained damage to these structures (Bryan & Luszcz, 2000). Indeed, it was reports such as these that essentially paved the way for our modern day conceptualisation of executive function. More recently, methodological advances and the development of sophisticated non-invasive brain imaging techniques in particular, have made a significant and valuable contribution to our understanding of the brain's architecture and the specific neuroanatomical structures involved in mediating executive functions. For instance, numerous neuro-imaging studies involving healthy as well as brain damaged individuals have provided confirmation of the special relationship between the

frontal lobes and executive processes (Gunning-Dixon and Raz, 2003). In recognition of this, there is now widespread agreement that the frontal lobes, and the prefrontal cortex in particular, are intimately involved in the functioning of executive processes (Garden, Phillips & MacPherson, 2001).

However, it is important to note that a substantial body of evidence has emerged suggesting that impairments in executive functioning can also emerge following damage to brain regions other than the frontal lobes (Stuss, Eskes & Foster, 1994; Dujardon, 2000). This has led to the contemporary view that considers executive functions as emergent properties of a dynamic and distributed network (Mayes & Daum, 1997; Burgess, 2003). The network view suggested here is supported by the results of neuro-imaging studies that have linked regions of the frontal cortex to structures in many other parts of the brain including the limbic structures, the thalamus (Alexander, Delong & Strick, 1986), the basal ganglia and other subcortical structures (Mays & Baum, 1997). Bearing this in mind, while the frontal areas make a vital contribution to the operation of the executive system, it is important to appreciate the mediating effect of other cortical and subcortical structures in the successful execution of executive function.

Nonetheless, because many of the deficits shown by patients with frontal lobe dysfunction are often executive in nature (Robbins, 1996), this resulted in the term 'frontal lobe syndrome' being adopted to refer to clinical populations exhibiting such executive deficits. However, nowadays, the term Dysexecutive Syndrome (DES) is preferred, since it

emphasises the nature of the difficulties the patients have, rather than the area of the brain which is commonly damaged (Baddeley & Wilson, 1988).

1.7.3 Executive Dysfunction: Impairments in Executive Functioning

Bearing in mind the various skills and array of abilities that the executive system is said to subserve, it is hardly surprising to learn that damage to one's executive processes can result in an individual experiencing a wide range of difficulties in everyday life. While recognising that there may be considerable overlap in terms of the areas of psychosocial functioning affected, the constellation of symptoms that manifest can helpfully be classified in terms of their impact upon the individual's cognition, behaviour, personality and emotion.

1.7.3.1 The Impact of Executive Dysfunction on Cognition

Executive function deficits can affect cognitive functioning directly in any number of ways. Some of the most commonly reported cognitive difficulties noted in the literature include problems with planning, organising, decision-making, problem-solving, and attention or concentration (Burgess & Shallice, 1997). Problems with multi-tasking and abstract reasoning are also routinely reported (Lezak et al, 2004). More often than not, a patient's difficulties are not simply restricted to a single cognitive domain. Take any one of these problems in isolation and the individual is likely to experience difficulty completing a variety of everyday tasks.

Other problems including deficits with working memory, impaired mental flexibility, 'defective self-monitoring' and 'poor utilisation of feedback' can severely impair one's learning ability (Malloy, Cohen, Jenkins & Paul, 2006). As well as this, it is not uncommon for individual's with executive dysfunction to display a general lack of insight into their difficulties (Wilson, Alderman, Burgess, Emslie & Evans, 1996). These last two points obviously have serious implications for a patient's rehabilitation.

1.7.3.2 The Impact of Executive Dysfunction on Behaviour

Perhaps unsurprisingly, there is a close relationship between the type of cognitive deficits seen in patients with executive impairments and the behaviour problems frequently reported. These deficits also tend to show up in the course of daily living. Problems with motivation, initiating activity and perseveration, are often reported by the family of individuals with impaired executive function (Malloy et al, 2006). Deficits such as these might lead to social withdrawal, or a deterioration in grooming and self-care. An apparent lack of concern for social conventions or social rules can result in disinhibition and inappropriate social behaviours (Wilson et al, 1996). Such changes in behaviour can be especially difficult for families to live with. Therefore, helping families and carers cope with behavioural problems associated with executive dysfunction is often an important part of a patient's rehabilitation. Unfortunately, however, many of the symptoms such as lack of empathy or concern for others can be very difficult to treat.

1.7.3.3 The Impact of Executive Dysfunction on Personality and Emotion

We have already learned from Harlow's (1868) descriptions of the changes in Mr Gage's presentation the devastating impact that damage to the frontal lobes can have on one's personality and behaviour. Effects of changes in personality are naturally expressed in behaviour and emotional difficulties such as flattening of affect, emotional lability, and an increased tendency to become irritable or excitable (Wilson et al, 1996) can have a profound and negative impact on an individual's ability to form new social relationships and maintain those that already exist (Lezak et al, 2004).

For ease of reference, some of the most commonly reported symptoms of executive dysfunction affecting these competencies are presented in Box 1.

Box 1: Frequency of reporting of 20 of the most common symptoms of executive dysfunction. Results based on data gathered by Wilson et al, 1996.

Symptom	Percentage reporting problem	
	Carers	Patients
Planning problems	48	16
Distractibility	42	32
Lack of insight	39	27
Poor decision making	38	26
Unconcern for social rules	38	13
Euphoria	28	14
Restlessness	28	25
Apathy	27	20
Lack of concern for other's feelings	26	26
Perseveration	26	17
Aggression	25	12
Temporal sequencing problems	25	18
Social disinhibition	23	15
Shallow affect	23	14
Impulsivity	22	22
Response inhibition problems	21	11
Poor abstract thought	21	17
Knowing-doing dissociation	21	13
Variable motivation	15	13
Confabulation	5	5

Adapted from Burgess and Simons (2005)

Of course, this is by no means an exhaustive list of symptoms associated with the dysexecutive syndrome.

In considering the range of impairments associated with the 'syndrome', we can appreciate that executive deficit arising from damage to the frontal lobes could have a profound effect on a client. For example, negative changes in personality and an inability to perform simple everyday tasks could severely restrict one's quality of life. Therefore, it is clear that accurate diagnosis of executive dysfunction is crucial if a patient's living circumstances are to be improved through help and rehabilitation. However, given the variability of behavioural manifestations, there is no definite criterion for the diagnosis of executive dysfunction.

1.7.4 Neuropsychological Assessment of Executive Function

Nevertheless, a formidable body of literature is now emerging with regard to accurate quantification of executive dysfunction. Firstly, numerous researchers (Crawford et al, 1998; Hart & Semple, 1994, and Lezak et al, 2004) emphasise the important contribution of the clinical interview to the information gathering process. Indeed, a thorough exploration of the client's family and personal history, past psychiatric history, medical history, current mental state, and history of the presenting complaint(s) is crucial in providing a context to their difficulties. As well as this, reports from family members or carers, and observations of the client's behaviour during the assessment process also helps inform formulation.

O course, detailed assessment of a client's cognitive ability is a fundamental part of the assessment process. Bearing in mind the fact that executive functioning is recognised as a multifaceted construct incorporating a number of different components, it is clear that executive function cannot be assessed with a single test. Consequently, one can only assess

a certain aspect of behaviour with special interest for its executive component (Garden et al, 2001). Therefore, when involved in determining the nature and extent of executive problems it is crucial that assessments are based on evidence gathered from a number of measures of executive functioning.

Generally, there are a number of key neuropsychological tests that can be used to assess specific cognitive components of the executive system. A selection of the most commonly used tests of executive functioning together with a description of the cognitive function(s) they are proposed to assess is presented in Box 2.

Box 2: Neuropsychological tests of executive function and a description of the cognitive capacities they assess (Table based on information presented by Strauss et al, 2006).

Test	Capacity Assessed
Wisconsin Card Sort Test (Heaton, 1981)	Concept formation, abstract reasoning and ability to shift set (mental flexibility); also involves working memory
FAS Test (Benton, 1968)	Verbal (phonemic) fluency and mental flexibility
Behavioural Assessment of the Dysexecutive Syndrome (Wilson et al, 1996)	Various subtests assess: novel practical problem-solving, planning, self-directed organisation, set-shifting, inhibition, Intelligent guesswork and error checking
Test of Everyday Attention (Robertson, Ward, Ridgeway, Nimmo-Smith, 1994)	Various subtests examine sustained, divided and selective attentional abilities
Trail Making Test (Army Individual Test Battery, 1944)	Visual scanning, visuomotor tracking, speed of information processing, divided attention and cognitive flexibility
Hayling Sentence Completion Test (Burgess & Shallice, 1997)	Initiation, suppressing prepotent responses, control and flexibility of thought
Brixton Spatial Anticipation Test (Burgess & Shallice, 1997)	Rule or concept attainment and set-shifting
Delis-Kaplan Executive Function System (Delis, Kaplan & Kramer, 2001)	Battery of common executive tests listed here

Again, this is by no means an exhaustive list of the tests currently used in clinical practice. Investigations using these tests should also incorporate various disability rating scales, such as the Dysexecutive Questionnaire (DEX) (Wilson et al, 1996) or the Frontal Systems Behaviour Rating Scale (FrSBe) (Grace & Malloy, 2000), in order to identify executive deficits that may not be captured using formal tests of executive functioning (Crawford &

Henry, 2005). A further point worth mentioning relates to the fact that performance on a number of measures of executive functioning such as the WCST (Axelrod, Goldman, Heaton, Curtis, Thomson et al, 1996), FAS, (Benton, 1968) and the BADS (Wilson et al, 1996) has been found to be compromised in patient's with damage to brain areas out with the frontal lobes. This raises serious questions about the specificity and sensitivity of these tests, but at the same time perhaps lends some support to the network theory of executive function.

1.7.5 Executive Functioning in Healthy Older Adults: The Executive Decline Hypothesis

The relationship between age and differences in cognitive functioning has been documented since the early 1900's (Foster & Taylor, 1920) and is perfectly illustrated in the published standardization data used to develop test norms on a range of neuropsychological measures (e.g. the Wechsler Adult Intelligence Scales). The precise cognitive and neuroanatomical mechanisms proposed to mediate this relationship continues to be a source of considerable debate (Phillips & Della Sala, 1998).

For instance, Salthouse (1996) proposes that age-related differences in cognitive functioning can be largely explained by a deterioration in processing speed. In stating his position, Salthouse (1996) presents substantial evidence to support this theory and, in doing so, encourages researchers to consider speed of information processing as an important variable in contributing to age-related differences in cognition. At the same time, Salthouse (1996) emphasises that he is not proposing that processing efficiency is exclusively

responsible for these age-related differences, but simply a 'major contributor' to adult age differences on many measures of cognition.

In relation to this last point, an impressive body of evidence has emerged over the last 15 years or so demonstrating that executive functioning skills decline with advancing age (Phillips & Della Sala, 1998; Salthouse, Atkinson & Berish, 2003; West 1996). Bearing in mind the over-arching influence of the executive system on various aspects of cognitive functioning, this finding has led a number of researchers (West, 1996; Woodruf-Pak, 1997) to link cognitive decline in normal aging to a deficit in executive functioning. Commonly termed the 'executive decline hypothesis', this theory of cognitive aging proposes that adult age-related changes in cognitive functioning (including memory) may be due to a 'subclinical and selective decline in executive function' (Crawford, Bryan, Luszcz, Obonsawin & Stewart, 2000) that occurs as part of the normal aging process.

In support of this assumption, the findings from numerous studies into the neuropsychology of aging have reported a significant relationship between increasing age and deficiencies in performance on various neuropsychological measures of executive functioning (Andres & Van der Linden, 2000; Daigneault, Braun & Whitaker, 1992; Salthouse et al, 2003; van Hooren, Valentijn, Bosma, Ponds, van Boxtel & Jolles, 2006). The vast majority of the research conducted in this area tends to directly compare the performance of younger or middle-aged adults with the performance of older adults on selected neuropsychological tests of executive function.

For instance, Daigneault and colleagues (1992) reported an age-related decline in performance on a range of executive tests including the Wisconsin Card Sorting Test (WCST), Porteus Mazes, the Stroop interference task, verbal fluency, and self-ordered pointing. More recently, Salthouse and colleagues (2003) administered a battery of 30 neuropsychological tests to 261 adults aged between 18 and 84 years. The results of this impressive study not only found a significant age-related deterioration on cognitive ability tests that loaded on fluid intelligence, memory and perceptual speed factors, but also reported a clear and significant age effect on a number of measures of executive functioning (WCST, Tower of Hanoi, The Stroop, Figural fluency, and the Connections test) that are often used in clinical practice.

Combine the results of the studies listed above with numerous other investigations that have reported an age-related decline on tasks of executive function and the evidence stacks up in strengthening support for the hypothesis that age-related executive decline may contribute to age differences routinely observed on measures of cognitive functioning.

However, it is important to recognise that not every study that has explored the relationship between age and executive function has found a negative correlation (Garden et al, 2001; Wecker, Kramer, Wisniewski, Delis & Kaplan, 2000). For instance, in their assessment of 112 healthy adults aged 20 to 79 years, Wecker and colleagues (2000) found evidence for a significant age effect on the executive component of the Californian Stroop Test (Delis et al, 2001), but not on the Californian Trail Making Test (Delis et al, 2001). Interestingly, despite finding an age effect on executive test performance using the WCST and the

Self-Ordered Pointing task, Garden and colleagues (2001) failed to find an age-related decline on two 'real world' executive tasks that involved open-ended planning. Although this last study might be criticised for having a rather small sample (n = 40) and narrow age range (31 to 64 years), the results of both these studies still suggest that age differences may be evident on some, but not all tests of executive function.

1.7.6 The Neurobiological Integrity of the Frontal Lobes

However, further support for the executive decline hypothesis emerges when we consider findings from neurobiological studies of the aging brain, which suggest that age-related changes in the neurochemistry and neuroanatomy of the brain appear to be more pronounced in the frontal lobes in comparison to other brain regions (Woodruf-Pak, 1997). For example, a number of studies have reported age–related changes in the total volume of the frontal lobes (Haug & Eggers, 1991; Coffey, Wilkinson, Parashos, Soady, Sullivan et al, 1992). In relation to this, Haug and Eggers (1991) reported a total volumeric reduction of some 10% to 17% in the frontal cortex, compared to an estimated reduction of just 1% in the occipital, temporal and parietal cortices. It has been suggested that this reduction in volume might be due to a reduction in neuronal size rather than an actual loss of neurons (Haug & Eggers, 1991). However, evidence for an age-related decrement in both the size and number of neurons in the frontal lobes has been reported (Woodruf-Pak, 1997). According to Raz (2000), the dorsolateral prefrontal cortex shows the greatest age-related reduction in volume. Interestingly, a recent study by Gunning-Dixon and Raz (2003) reported an association between reduced volume in the prefrontal cortex and an age-related increase in perseverative errors on the WCST.

Studies using Positron Emission Topography (PET) neuro-imaging techniques also suggest that the frontal lobes exhibit some of the greatest differences when young and older people are compared: with an overwhelming reduction in cerebral blood flow and metabolic uptake becoming particularly evident in the prefrontal cortex (Woodruf-Pak, 1997). Advocates of the frontal decline hypothesis of cognitive aging argue that such dramatic brain changes are likely to negatively affect those cognitive executive abilities that are supported by this area of the cortex.

1.7.7 Executive Function, Memory and Dementia

It is well established that as humans age, memory complaints increase. In relation to this, Huppert and Kopelman (1989) found that normal aging produces a mild acquisition deficit, as well as an increase in the rate of forgetting. An age–related increase in word finding difficulties (Burke, Mackay, Worthley & Wade, 1991) and a reduction in speed of information processing (Laursen, 1997) have both been proposed to contribute to this deficit. However, it now appears to be well accepted within the literature on cognitive aging that executive functions make a major contribution to memory.

1.7.7.1 Executive Function and Memory

According to Mayes & Daum (1997), lesions of the frontal cortex produce 'at least two kinds of memory impairments': the first, they argue, is likely to be caused by a specific problem with the monitoring and evaluation of information that is retrieved from memory; and the second impairment, they suggest, is likely to be caused by a specific deficit in the creation and implementation of appropriate strategies that facilitate the efficient encoding

and retrieval of information from memory. If we consider these points for a moment and break the encoding and retrieval processes down into their component parts, then it becomes obvious that a disruption to any number of frontal-executive functions could seriously compromise several different aspects of memory function.

Take, for instance, the process of encoding information into memory. In order to successfully code information into memory the person has to first of all attend to the information in question. Once this has been achieved, several other processes come into play: attention has to be sustained and focused upon the information in order for it to be learned, therefore, the individual must filter out or suppress irrelevant information; the individual must then plan, develop and initiate an efficient encoding strategy (Shinamura, Janowsky & Squire, 1991); to be effective, the encoding strategy itself must successfully organise the information 'on-line'; and finally, there must be a certain level of self-monitoring occurring at the same time as these processes in order to ensure the efficient operation of the whole cognitive system. In this way, information should be appropriately encoded, adequately consolidated and successfully stored in memory.

Bearing this process in mind, we can see that executive deficits in initiation, attention, concentration, planning, organisation, co-ordination, working memory, inhibition, strategic thinking, cognitive flexibility or self-monitoring could seriously compromise the processing and encoding of information into memory (Mayes & Daum, 1997; Shinamura et al, 1991).

In line with this, a disruption to any of these or other relevant executive functions could also negatively influence the effective retrieval of information from memory. For instance, in order to successfully retrieve information from memory it is argued that a person must first decide to access the knowledge system and then plan, develop and initiate an efficient retrieval strategy (Shinamura et al, 1991). According to Shinamura and colleagues (1991), the retrieval strategy itself must be organised, and capable of identifying and selectively attending to relevant information in order to achieve its goal. Thus, the evaluation and manipulation of information contained in the knowledge system requires a high level of monitoring and a great deal of cognitive flexibility. Through the smooth operation of this complex cognitive process, the required information should be successfully accessed and retrieved from memory. Bearing this in mind, again we can see how deficits in executive functions such as the ability to make decisions, initiation, attention, planning, the co-ordination and monitoring of cognitive functions, inhibition, perseverance, strategic thinking, cognitive flexibility or self-monitoring, could result in severe difficulties with accessing and retrieving information from memory (Mayes & Daum, 1997; Shinamura et al, 1991).

In support of the proposed role of frontal-executive functions in the encoding and retrieval of information, Mayes and Daum (1997) report the results of two PET studies, which found the left frontal cortex to become activated during the encoding of information into memory, while the right frontal cortex was found to become active during retrieval.

Studies of patients with frontal lobe lesions appear to lend substantial support to the idea that frontal-executive functions are involved in normal memory performance. Janowsky, Shinamura, Kritchevsky and Squire (1989) for example, found that patients with frontal lobe lesions displayed a significant impairment on a test of free recall. Interestingly, the patient's performance on a test of recognition memory compared well with the performance of a healthy control sample. This suggests that a specific deficit in retrieving information from memory may have compromised the frontal lobe patient's free recall performance. In further studies of patient's with frontal lobe lesions the same collaborators also reported significant deficits in memory for temporal order and contextual or source memory (Shinamura et al, 1991).

Further evidence for the role of executive functioning in memory is provided in an interesting study by Crawford, Blackmore, Lamb and Simpson (2000) who found that group differences on the Californian Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan & Ober, 1987) between a sample of patient's with Huntington's disease and a healthy control sample were 'completely obliterated' when executive dysfunction was statistically controlled for. More recently, Kliegel, McDaniel and Martin's (2003) investigation into the prospective memory performance of 80 healthy adults across the lifespan (20 to 80 years) not only found age-related differences in prospective memory performance, but crucially, individual differences in executive functioning explained a significant proportion of the variance in prospective memory performance.

Therefore, it would appear prudent to include an assessment of executive function ability whenever a client complains of a deterioration in memory performance.

1.7.7.2 Executive Function and Dementia

It is well documented that the occurrence of dementia increases with advancing age (Jorm, 1990; APA, 1994). Although exact figures vary, it is generally recognised that dementia affects some 1-2% of people over the age of 65, 4% of people over the age of 70, rising to 13% in the those over the age of 80 and around 20% in the over 85 age group (Laidlaw, Gallagher-Thompson, Thompson & Siskin-Dick, 2003). Alzheimer's disease accounts for nearly two-thirds of all dementias with Rosser and Hodges (1994) estimating that at any one time over 400 000 people in the UK suffer from this debilitating and progressive illness. Given the generally poor prognosis, it is crucial that clinicians have a reliable means of diagnosing cognitive decline or suspected dementia in order to enable comprehensive and detailed rehabilitation/care packages to be developed.

It has been suggested that cognitive dysfunction associated with preclinical Alzheimer's disease may be apparent many years before a clinical diagnosis (Small, Molby, Laukka, Jones & Backman, 2003). Investigations into the cognitive profile of Alzheimer's disease have confirmed this and, at the same time, resulted in a growing body of evidence suggesting that deficits in executive functioning may be an important area of cognitive impairment that occurs early in the course of the disease (Grady, Haxby, Horwitz, Sundaram, Berg et al, 1988; Chen, Ratcliff, Belle, Cauley, DeKosky & Ganguli, 2000). For instance, Grady and colleagues (1988) found evidence for impaired episodic memory

and executive functioning early in the course of the disease in a sample of very mildly impaired patients. Similarly, Lafleche and Albert (1995) also reported a specific decline in executive functioning and memory in a sample of patient's with mild Alzheimer's disease.

More recently, Chen and colleagues (2000) compared the performance of 120 patients with presymptomatic Alzheimer's disease to 483 healthy controls on a range of neuropsychological measures, and found that a measure of executive functioning and delayed recall were the best at discriminating those with dementia from those without. Furthermore, performance on these measures were also best at predicting who would manifest Alzheimer's disease 18 months later and those who would not. Subtle deficits in executive functioning in patients diagnosed with 'mild cognitive impairment' have also been reported (Crowell, Luis, Vanderploeg, Schinka & Mullan, 2002). Meanwhile, a recent review by Amieva, Phillips, Della Sala and Henry (2004) suggests that inhibitory mechanisms are severely compromised in Alzheimer's disease and this may contribute to deficits in memory.

The results of these and other studies suggest that impaired executive function may be an early indicator of neurodegeneration associated with Alzheimer's disease. Bear this in mind, together with the fact that the elderly population is the fastest growing segment of society in the U.K, and it is clear that there is a pressing clinical need to find ways of distinguishing normal from abnormal executive functioning performance in the older adult population. Achieving this should help clinicians distinguish normal aging from presymptomatic Alzheimer's disease.

1.8 Summary

Deficits in frontal-executive functions can have a severe and negative impact on a person's psychosocial functioning and capacity for independent living. Evidence suggests that older adults may be particularly vulnerable to experiencing a decline in executive functions. Patients with presymptomatic Alzheimer's disease also appear to exhibit a selective decline in executive functioning. Bearing this in mind, there is a strong clinical need to accurately determine the extent of these executive deficits in the healthy older adult population in order to enable clinicians to more precisely classify what constitutes a normal performance and what is an unusual or abnormal performance. Unfortunately, the performance of healthy older adults on measures of executive functioning has only relatively recently begun to be addressed adequately in contemporary neuropsychological research. The present study will attempt to helpfully contribute to this emerging body of research by exploring the relationship between demographic variables and scores on tests of executive functioning in the older adult population. This is outlined in the following section.

1.9 Research Aims

A major aim of this study is to test and evaluate models of the influence of demographic, cognitive and mood variables on test performance on four neuropsychological tests of executive functioning administered to a healthy older adult population. As a result of this analysis, the second principal aim of the study is to develop a practical method of accurately quantifying deficits in performance in the individual case. Therefore, after determining which variables influence performance on the four tests, using a hierarchical procedure, regression equations will be constructed for predicting test scores from a

combination of relevant variables. Consequently, clinicians may be able to use the regression equations as part of a neuropsychological assessment and accurately quantify deficits in a client's executive function performance, by determining whether any difference between predicted and obtained scores is significant or not.

1.10 Hypotheses

Hypothesis 1: Increasing age will be associated with lower scores on all measures of executive function.

Hypothesis 2: Lower NART error scores will be associated with higher scores on tests of executive function.

Hypothesis 3: Years of education will be positively associated with higher scores on tests of executive function.

Hypothesis 4: Higher academic qualifications will be associated with higher scores on tests of executive function.

Hypothesis 5: Higher SES will be associated with higher scores on tests of executive function.

Hypothesis 6: Variables that are found to be associated with scores on tests of executive function will significantly contribute to the prediction of test scores on these measures.

Chapter 2: Methodology

2.1 Design

This large community based study utilised a simple cross-sectional repeated measures design: that is, all participants completed all test measures. The sample comprised a group of generally healthy community-dwelling older adults who were all living independently at home in the North East of Scotland. Employing such a design enabled an evaluation of the relationship between demographic, mood and cognitive variables to be undertaken.

2.2 Participants

To try and encompass as large a sample of the general older adult population as possible, participants were recruited from various commercial businesses, community activity centres and sports clubs. As well as this, the researcher's family and people from their extended social network also took part in the study. This ensured that a broad range of participants was recruited for the project. A short screening interview took place and persons suffering from a known medical, neurological or psychiatric disorder that might compromise their cognitive ability were excluded from the study. Focusing on the performance of healthy volunteers contributes to the study's main aim of developing a practical means for assessing the cognitive effects of illness, injury or suspected changes in neuropsychological functioning.

A total of 117 volunteers over the age of 55 years from Aberdeen and the surrounding area were recruited by the researcher through personal invitation, word-of-mouth, and a series of short presentations delivered to various community groups. All participants were British and spoke English as their first language. Eleven participants did not meet the strict inclusion criteria (detailed below) and were, therefore, removed from the analysis; 3 participants had had at least one stroke, 4 participants had a history of transient ischaemic attack, 2 participants were currently taking medication for a psychiatric problem, while 2 participants were excluded from the final analysis due to missing data (they did not complete one of the tests due to having difficulty understanding the test instructions).

Consequently, the final sample consisted of 106 participants with no known current or past history of disorders that might affect their cognition. All 106 were included in the data analysis. This self-selected sample comprised a total of 38 males and 68 females with an average age of 70 years (SD = 8.03 years; Range = 55 to 94 years). Given that the project is a population based study of older adults and there are well documented differences in life-expectancy between men and women (Office of National Statistics, 2007), it is unsurprising that the sample has a rather unbalanced gender distribution: with the proportion of women increasing with advancing age. The mean number of years of education was 12.84 years (SD = 3.13 years), with a range from 7 to 22 years. Participants were also asked about their educational attainment. In all, 17% had no formal qualification, 27.4% had general high school certificates, 5.7% had Scottish 'O' grades, 12.3% had Scottish Highers, 17.9% had Higher educational certificates (such as HNC/HND), and 19.8% had achieved at least a University Degree.

Each participant's social class was coded on the basis of their current occupation (or last occupation where a participant was retired or not employed) according to the Office of Population Censuses and Survey's (1980) Classification of Occupations. The average NART error score for participants was 21.5 (SD = 7.52). This equates to a predicted WAIS FSIQ score of 104.08 (SD = 9.30).

2.3 Inclusion and Exclusion Criteria

All volunteers over the age of 55 years were considered for participation in the study. Participants were excluded if, on the basis of their premorbid history, they met any of the following criteria:

1. A history of neurological (e.g. stroke, dementia, Huntington's disease) or psychiatric disorder (e.g. major depression, schizophrenia)

2. A history of moderate or very serious head-injury

3. A history of alcohol or drug abuse

4. Currently using psychotropic medication

5. Very serious visual or aural impairment that would negatively affect their ability to satisfactorily complete tasks or understand task instructions

A total of eleven participants were excluded as a result of these criteria.

2.4 Procedure

Potential participants were identified by their attendance at local authority day centres, and membership of community organizations and sports clubs. A letter outlining the purpose of the research and requesting permission to access their membership was sent to service managers (Appendix 1). With the permission of service managers the principal researcher then discussed with attendees (both individually and in groups) the study aims and rationale. The principal researcher then presented potential participants with a letter outlining the study aims and rationale (Appendix 2). A form requesting participant's contact details (Appendix 3) was attached to this letter along with a stamped addressed envelope, so that contact sheets could be posted back to the principal researcher by those who were volunteering to participate in the study.

The participant letter included both the principal researcher's and his supervisor's contact details. This enabled those who were interested in learning more about the study or who wished to participate in the study to contact them. When individuals expressed a desire to participate in the study following the initial discussion, they were asked to complete the form requesting their contact details. No other information was collected at this stage.

Once the principal researcher had received participant's contact details an appointment was made for a 45 minute testing session. Each participant was seen individually at a local community or sports centre at a time that was convenient for them. Upon meeting volunteers, and before commencement of testing, the purpose of the study and what people would be requested to do should they consent to participate was re-iterated. Individuals

were reminded that their participation was entirely voluntary and that they were free to decline to participate at any time without the need for an explanation. Following this, participants were asked if they still wanted to participate in the study and presented with a consent form to sign (Appendix 4).

Participants were then presented with a background information sheet (Appendix 3) in order to allow the researcher to gather the necessary demographic information that included data on a participant's gender, age, years of education, occupation and highest qualification. As well as this, participants were presented with a screening sheet (Appendix 5) asking if they had ever suffered from any of a number of listed psychiatric or neurological disorders. If a participant had suffered such problems their data was excluded from the final analysis.

Following this, each participant was presented with the NART word sheet (Appendix 6) and asked to read each word out aloud so that their responses could be recorded on a tape recorder. The Trail Making Test (TMT) (Appendix 7), the Hayling Test (record sheet in Appendix 8), the Brixton Test (record sheet in Appendix 9), the Six Elements Test (SET) (record sheet in Appendix 10), and the HADS (Appendix 11) were then administered. The Department of Adult Neuropsychology and Older Adult Psychology Service (both NHS Grampian) supplied all stimulus materials for the NART, TMT, Hayling Test, Brixton Test, SET and the HADS. In order to minimise distractions, participants were tested in a quiet room with only the principal researcher present. Tests were administered in the same order to all participants.

2.5 Potential Distress to Participants

It was recognised that, via the process of assessment, the study had the potential to identify individuals who may be suffering from psychological distress or showing symptoms/signs of abnormal cognitive decline. It was decided that data collected from such individuals would be excluded from subsequent analysis and a discussion with the participant about making a referral to appropriate services would take place. This would likely have involved a GP consultation, followed by a referral to the older adult psychiatry team. However, in the first instance, the principal researcher and his field supervisor were available to offer support and advice to such individuals.

It was also appreciated that participants may become distressed at their performance during the course of assessment. All participants would have been reminded that they were free to withdraw if they became distressed and that the principal researcher or his field supervisor would be available to discuss any concerns that they may have.

2.6 Informed Consent

Upon meeting interested individuals for the second time it was highlighted that individuals were free to decline to participate and that should they decline this would in no way affect their future involvement with the health service. The participant was then asked if they still wished to participate in the study and this being so they were presented with a consent form to sign. Because information on the study had already been presented prior to this meeting, consent had in effect been determined on two separate occasions.

2.7 Confidentiality

The confidential nature of all information collected as part of the study was emphasised to participants on the letter of invitation and during discussion. Each participant was assigned a number for the purpose of identification. All demographic data was then completely anonymised. This anonymised data was then transferred onto a password protected NHS computer. The participant's special identification number provided the only link to their personal information. Personally identifiable data (e.g. date of birth, name, address) was kept in a locked filing cabinet on NHS premises.

The principal researcher analysed the data. Analysis of data took place within the researcher's private consulting room using a password protected NHS laptop computer. No personally identifiable participant information was stored on this computer. Data were stored on a floppy disc and securely locked in a filing cabinet in the researcher's consulting room. Only the researcher and his supervisors had access to the data. Employing these processes ensured that the highest standards of confidentiality were adhered to.

Data from the study will be kept locked securely on NHS premises for 5 years in line with current research governance arrangements, before being destroyed.

2.8 Ethical Approval

An application was submitted to NHS Grampian's Local Research Ethics Committee on 28th September 2006, with confirmation of ethical approval received by letter on 9th January 2007 (Appendix 12). Following this, the study was registered with NHS Grampian's

Research and Development Office who, on the 26th March 2007, then gave their approval for the study to proceed (Appendix 13). Indemnity cover was provided by the University of Edinburgh prior to the research commencing (Appendix 14).

2.9 Sample size

Sample size estimation depends on the strength of relationship that we are trying to detect (effect size) and the amount of statistical power that we want in order to be able to detect such effects (Field, 2005). Allowing for a medium effect size and a high level of statistical power (0.8), using 4 variables (age, premorbid level of functioning, socio-economic status, and years of education) in the regression equation, Cohen's (1992) tables suggest an ideal population of 84 should be represented in the study. Having 106 participants in the final analysis ensured the study had sufficient power and as such, should be able to detect a relationship between variables if one exists in the population being studied.

2.10 Analysis

One of the principal aims of this study is to investigate the relationship between demographic variables and initial test performance on four tests of executive functioning. A second aim is to develop regression equations, using multiple regression analysis, to allow accurate prediction of an individual's premorbid test score by incorporating into the equation their NART error score and other relevant demographic characteristics as predictor variables.

In order to achieve these aims, the data collected from participants was analysed using a statistical software package developed for the social sciences (SPSS for Windows: Version 15). The data was initially explored using descriptive statistics. This was followed by correlation and multiple regression analyses.

2.10.1 Correlation Analysis

When we are interested in learning about the relationship between two variables (say for example age and test score) it is useful to plot this data on a simple graph. In SPSS this can be done using the 'Scatterplot' function. Scatterplots not only provide a visual representation of the data and a cursory glance of the type of relationship that exists between variables, but also assists with the identification of cases that are markedly different from others in the data set (outliers). Field (2005) points out that it is 'essential' that outliers be detected due to their ability to exert a powerful influence upon the correlation analysis that can lead to a misinterpretation of the data. Therefore, a series of Scatterplots were produced in order to identify any outliers.

Following this a correlation matrix was produced in order to measure whether there was a linear relationship between each variable and every other variable. Addressing one of the study's main aims, Pearson's product moment correlation coefficients were used to measure the strength of statistical association between NART error score, demographic variables, and mood and performance on the four tests of executive functioning. In correlation analysis the larger the value of the coefficient, the stronger the relationship

between variables (Kinnear & Gray, 1997). For instance, a correlation coefficient around 0 (zero) suggests no association, while a coefficient of 1 (one) suggests a perfect association.

2.10.2 The Regression Approach

Regression equations are frequently used in neuropsychological practice in order to provide an estimate of an individual's premorbid level of intellectual functioning (Lezak et al, 2004). These equations generally include a number of predictor variables including an individual's score on one of the so called 'hold' tests, and/or demographic characteristics such as age, years of education and social economic status. Knight and colleagues (2006) suggest that regression procedures provide a valuable alternative to the conventional norms based approach that is traditionally used when interpreting a person's test score. The same authors suggest that because the regression approach uses continuous (e.g. actual age) instead of grouped variables (e.g. age bands) and can produce a test score estimate that is based on more than one variable, the regression procedure holds some advantages over the traditional approach. The steps involved in conducting a regression analysis are outlined below.

2.10.3 The Regression Analysis

Assuming a statistical association is found between two variables, this information can be effectively exploited using regression analysis, to estimate the values of one variable (the dependent or outcome variable) from our knowledge of the values on other variables (the independent or predictor variables) (Kinnear & Gray, 1997). According to Field (2005), predicting a particular outcome from one or more independent variables is the 'essence' of

regression analysis. For instance, based on our knowledge of the strength of association between property prices, the size of a property and property location, we might reasonably be able to predict how much a home of a particular size in a particular neighbourhood will sell for. Thus, the rationale for the regression approach is relatively straightforward.

In order to draw accurate conclusions from the collected data a model that 'best fits' (or describes) the data must be generated. This is achieved using a mathematical technique known as 'the method of least squares' (Field, 2005). The method of least squares enables the line that best describes the data to be defined: this is a straight line that results in the smallest differences between plotted data points and the regression line (Field, 2005). These differences are commonly called 'residuals'. Squaring all the residuals and adding them together provides a statistical measure of how accurately a line fits the data (Kinnear & Gray, 1997).

Once the line of best fit has been found, Field (2005) points out that it is important to then ascertain how well the model 'fits the actual data', because the line of best fit may not necessarily fit the data all that well. One rather straightforward way of measuring the efficacy with which a particular model predicts the outcome variable is to calculate the correlation between the true values (y) of the outcome variable and the estimates (y_1) obtained when particular values are incorporated into the regression equation. This correlation is known as the 'multiple correlation coefficient R' (Kinnear & Gray, 1997) and should be interpreted in exactly the same way as Pearson's correlation coefficient (i.e. the larger the value of R the better the model predicts the observed data). Squaring R and

multiplying it by 100 provides a measure of the amount (or percentage) of variance in the outcome variable that is explained by the model (Field, 2005).

When entering predictor variables separately into the regression analysis it is important to measure the effect different predictor variables have in terms of the contribution they make to the predictive power of a model. We can determine the significance of the contribution made by each variable once they have been entered with reference to the F-ratio. A statistically significant F-ratio indicates that including the predictor variable in the regression model has significantly improved the accuracy with which it can predict the outcome variable (Field, 2005). The final model will be the one that accounts for the largest amount of variance in the outcome variable. This final model is represented visually by the regression line and mathematically by an equation. An example of a regression equation is presented below:

$$y_1 = b_o + b_1(X_1) + b_2(X_2) + \ldots\ldots\ldots + b_n(X_n)$$

In this equation, y_1 is the predicted outcome variable, b_o is the regression constant, b_1 is the coefficient of the first predictor variable (X_1), b_2 is the coefficient of the second predictor variable (X_2) and b_n is the coefficient of the nth predictor variable (X_n) (Field, 2005). Once the coefficients have been defined, different predictor variable values can be inserted into the equation in order to estimate the value (or test score) on the outcome variable. In clinical practice, a significant discrepancy between an individual's predicted and obtained score, in favour of the predicted score, suggests an unusual test performance. Crawford and

Howell (1998) have written a computer program that allows the abnormality of a person's obtained score to be determined.

Hierarchical linear regression was utilized for the purpose of the present study. Using this approach, equations were generated to allow prediction of test scores by incorporating multiple factors that could be important. In addition to entering participant's NART error score into the regression analysis, variables considered in the prediction model were age, total years of education, highest qualification, gender and social class. Predictor variables were chosen based on the findings of past research that utilized good methodology and sound theoretical principles. The final model in each case was the one that accounted for the largest proportion of unexplained variance in test performance.

2.11 Tests and Materials

Each participant was first presented with a background information sheet to complete, followed by the National Adult Reading Test (NART) (Nelson, 1982) the Trail Making Test (TMT) (Army Individual Test Battery, 1944), the Hayling sentence completion test (Burgess & Shallice, 1996), the Brixton spatial anticipation test (Burgess & Shallice, 1996), and the Six Elements subtest from the Behavioural Assessment of Dysexecutive Syndrome (BADS) (Wilson et al, 1996).

2.11.1 Demographic Characteristics

The researcher developed a brief background information sheet (Appendix 3) designed to include data on the participant's gender, age, total years of education and current

occupation or previous occupation if they were no longer employed. Gender was entered as a dichotomous variable, with values 1 and 2 representing males and females respectively.

Measure of Psychological Health

2.11.2 The Hospital Anxiety and Depression Scale

The Hospital Anxiety and Depression Scale (HADS) was developed by Zigmond and Snaith (1983) in order to detect the presence of anxiety and depression in general medical out-patient settings. It is a brief, self-report questionnaire that comprises a 7-item subscale designed to measure anxiety and a 7-item subscale designed to measure depression. To assess this, respondents are asked to read each item and indicate using a 4-point Likert scale the extent to which they felt that way during the previous week. Item scores range from 0 (zero) to 3. The HADS' developers classify a subscale score between 0 and 7 as 'Normal', between 8 and 10 as 'Mild', a score between 11 and 15 as 'Moderate', and scores ranging from 16 to 21 as 'Severe'. These clinically derived cut-offs can be used to distinguish normal or healthy psychological functioning from an abnormally elevated level of psychological distress.

The HADS is routinely used in both clinical practice and research settings. Each of the subscales is reported to have high internal consistency and good external validity (Herrero, Blanch, Peri, De Pablo, Pintor & Bulbena, 2003). Furthermore, the HADS has been found to reliably detect anxiety and depression, and display impressive sensitivity for symptom severity (Zigmond & Snaith, 1983). A particular advantage of the HADS stems from the

fact that it has been specifically designed to focus on the cognitive and emotional symptoms of anxiety and depression. By excluding items that ask about symptoms which can have a physical cause, it is proposed that the HADS should be relatively unaffected by a co-existing physical illness (Herrero et al, 2003). Given increasing rates of co-morbidity and somatic symptoms in the older adult population, it has been suggested that by factoring out physical symptoms not related to anxiety and depression the HADS design makes it particularly useful when assessing the elderly (Kenn, Wood, Kucyj, Wattis & Cunane, 1987).

Taking such factors into consideration, a recent publication by The British Psychological Society (*Measuring Psychosocial Treatment Outcomes with Older People*, 2004) suggests that the HADS is a valuable tool to utilise when screening for anxiety and depression in older adults.

Measure of Premorbid Intellectual Functioning

2.11.3 The National Adult Reading Test

The National Adult Reading Test (NART) is an oral word reading test consisting of 50 words that are irregular in their pronunciation (e.g. 'chord'). By convention, performance is expressed as the number of errors of pronunciation, with high scores reflecting poor performance. The NART test sheet (Appendix 6) was placed at a comfortable distance from each participant and they were given the following instructions orally: 'Please read aloud the words on the test sheet as clearly as possible. Some of the words may be unfamiliar to you, but try and pronounce them anyway. There are not time limits on this

test.' A participant's score was obtained by checking their responses for errors in pronunciation.

The NART as a Valid Measure of Intelligence

In relation to its construct validity, Nelson (1982) examined whether one's performance on the NART could be used as a valid estimate of intelligence on a shortened version of the Wechsler Adult Intelligence Scale (WAIS). Based on results obtained from a U.K. sample of 120 healthy individuals free of neurological disorder, Nelson (1982) generated regression equations to predict WAIS IQ from NART error score and found that the NART successfully predicted 55, 60 and 32 percent of the variance in the WAIS Full Scale (FSIQ), Verbal (VIQ) and Performance IQ (PIQ), respectively. More recently, Crawford, Parker, Stewart, Besson and De Lacey (1989a) looked at the predictive validity of the NART in a sample of 151 healthy individuals assessed using the WAIS. The amount of variance predicted by NART performance for WAIS FSIQ, VIQ and PIQ was 66%, 72% and 33% respectively. Therefore, although poor at predicting Performance IQ, the results do suggest that NART performance is a reasonable predictor of intelligence in the normal population.

In support of the NART's use as a valid measure of intelligence, a factor analytic study conducted by Crawford, Stewart, Cochrane, Parker & Besson (1989b) using the WAIS and the NART found that the NART loaded highly (0.85) on 'g' or general ability. Furthermore, Wiens, Bryan and Crossen (1993) noted NART errors to systematically decrease as WAIS FSIQ increased. Perhaps more significantly, a recent study by

Crawford, Deary, Starr and Whalley (2001) that followed up 179 individuals who had taken a 'mental ability test' (IQ) at the age of 11 found a correlation of 0.73 between scores at age 11 and NART scores at age 77. This result, coupled with the findings of other retrospective studies (Berry, Carpenter, Campbell, Schmitt, Helton & Lipke-Molby, 1994: Carswell, Graves, Snow and Tierney, 1997) suggests that the NART is a very good predictor of premorbid intelligence.

Reliability of The NART

However, in order to qualify as a valid psychometric measure of premorbid ability a test must also display adequate reliability (Crawford, 1992). In relation to this, Nelson (1982) reported a split-half reliability of 0.93 for the NART based on her standardization sample, while Crawford, Stewart, Garthwaite, Parker & Besson (1988a) obtained a similarly high split-half reliability (0.90) in their sample of 201 non-clinical participants. Based on these results, it would appear safe to conclude that the NART exhibits a high degree of internal consistency. As well as this, Crawford, and colleagues (1989a) examined the test-retest reliability of the NART and found the correlation between NART errors at test and retest to be 0.98. More recently, employing a 12-month test-retest interval Deary, Whalley and Crawford (2004) reported a test-retest coefficient of 0.89. Combined with inter-rater reliability correlations of between 0.88 and 0.98 (Crawford et al, 1989a; Riley & Simmonds, 2003; and Sharpe & O'Carroll, 1991), overall, the findings suggest that the NART is a very reliable instrument.

The Relationship of NART Scores to Psychiatric Illness and Neurological Impairment

Nevertheless, if a test is to be used as a valid measure of previous ability Crawford and colleagues (1998) critically point out that it must be resistant to the effects of neurological and psychiatric disorder. In relation to this, Crawford, Parker and Besson (1988) found that despite 'severe neuropathological and cognitive abnormalities' the NART performance of those patients suffering from either Alzheimer's disease (DAT), alcoholic dementia, multi-infarct dementia (MID), or Closed Head Injury (CHI) did not differ significantly from their respective sex, age and education match control groups. However, there did appear to be a decline in performance on the NART in individuals with Huntington's disease and Korsakoff's syndrome.

Impaired NART performance in Korsakoff's syndrome (O'Carroll, Moffoot, Ebmeier & Goodwin, 1992) and Huntington's disease (Blackmore, Crawford & Simpson, 1994) has been reported in subsequent studies. In addition to this, the NART has also been found to underestimate premorbid IQ in patients with schizophrenia (Crawford, Besson, Bremner, Ebmeier, Cochrane & Kirkwood, 1992; Kondel, Mortimer, Leeson, Laws & Hirsch, 2003). Moreover, a recent study by Morris, Wilson, Dunn and Teasdale (2005), suggests that the NART may also underestimate premorbid ability in patients who have sustained a head injury.

Interestingly, while numerous studies support Crawford and colleagues (1988) finding that NART performance is essentially unaffected in DAT (e.g. Maddrey, Cullum, Weiner & Filley, 1996; O'Carroll & Gilleard, 1986; and O'Carroll, Baikie & Whittock, 1987), a

number of studies have found NART performance to be significantly impaired in moderate to severe cases of dementia (e.g. Fromm, Holland, Nebes & Oakley, 1991; Patterson, Graham & Hodges, 1994; and Taylor, 1999). These results suggest that the NART performance may be compromised in moderate dementia and should only really be used as an estimate of premorbid ability in DAT patients who are mildly demented (O'Carroll, 1995).

More recently, Anstey, Luszcz, Giles and Andrews (2001) found performance on the NART to be relatively resistant to the effects of decline in old age. Brayne and Bearsdell (1990) also failed to find evidence for an age related decline in NART performance in a community sample of 358 older adults.

Bearing the above studies in mind, it would appear appropriate to use the NART as a valid measure of premorbid IQ in some organic conditions, but not others. In recognition of this, O'Carroll (1995) wisely recommends that the NART only be used as a premorbid measure if it has previously been found to be insensitive to the clinical condition being investigated. With this caveat in place, the impressive psychometric properties of the NART remain, and when we combine this with its ease of administration and marking, it is perhaps unsurprising to learn that the NART has become the test most widely used to estimate premorbid ability (O'Carroll, 1995). Indeed, the extensive use of NART based regression equations to estimate premorbid ability on various tests of interest is, in itself, testimony to its enduring popularity.

Neuropsychological Measures of Executive Function

When involved in determining the nature and extent of executive problems it is advisable that clinicians base their assessment of the individual on evidence gathered from a number of measures of executive functioning (Crawford and Henry, 2005). Consequently, four neuropsychological measures of executive function, which are widely used in clinical practice, were chosen for the purpose of the present study. The Trail Making Test (TMT) (Army Individual Test Battery, 1944), the Six Elements Test (Wilson et al, 1996), and the Hayling and Brixton Tests (Burgess & Shallice, 1996) were specifically selected because performance on these measures are considered to reflect different aspects of executive functioning. Furthermore, the cognitive abilities that have been proposed to be tapped by these tests have also been linked to the cognitive processes involved in memory functioning.

2.11.4 The Trail Making Test

The Trail Making Test (TMT) has been variously described as a visuomotor tracking task (Lezak et al, 2004), a test of information processing speed and focused/divided attention (Blackwell Dictionary of Neuropsychology, 1996), and cognitive flexibility (Rasmusson, Zonderman, Kawas & Resnick, 1998). The test is divided into two (Parts A and B) and requires a participant to rapidly scan and identify targets on a sheet of paper. Part A consists of circles numbered 1 to 25 randomly distributed around a sheet of A4 paper. Here, beginning at number 1, the circles have to be sequentially connected by a line as quickly as possible. In Part B the task is slightly more complicated with both numbers (1 to 13) and letters (A to L) inside circles. In this instance, the participant is required to again

connect the circles sequentially by a line beginning at number 1, but in this condition they are required to alternate between numbers and letters (first letter A) in ascending order until the task is complete. Thus, the sequence becomes 1-A-2-B-3-C-4-D and so on.

Participants were given a sample directly before the commencement of each part of the test in order to ensure that they understood the requirements of the test. The test was administered according to the strict standard instructions and the dependent measure for each of the two selections was the time required to completion.

Sensitivity of The Trail Making Test to Neurocognitive Deficits

Initially, developed by US Army psychologists (1944), the Trail Making Test (TMT) has been specifically selected because it has been reported as being particularly sensitive to detecting cognitive changes in speed of information processing, attention and mental flexibility associated with head-injury (Harnett, Godfrey & Knight, 2004), the normal aging process (Rasmusson et al, 1998) and presymptomatic Alzheimer's disease (Chen et al, 2000). The TMTs utility as an instrument for the detection of Traumatic Brain Injury (TBI) was recently demonstrated by Harnett and colleagues (2004) who found performance on both TMT Part A and TMT Part B to successfully discriminate severe head-injured patients from a matched control group ($p<0.01$). However, the TMTs ability to differentiate mild head-injured clients from healthy controls is questionable (Strauss et al, 2006), with findings proving inconsistent.

Nonetheless, both parts of the test have been found to correlate highly with progressive dementia and atrophy (Lezak, 1995). For instance, Rasmusson and colleagues (1998) not only reported that participants with dementia made more errors than controls on the both parts of the TMT, but dementia status itself accounted for a large proportion of the variance in TMT Part A (18%) and Part B (13%) even after controlling for the effects of gender, age and education. The potential utility of the TMT Part B in the early identification of preclinical Alzheimer's disease was recently demonstrated by Chen and colleagues (2000). Perhaps the most remarkable thing about Chen and colleagues (2000) study was their finding that performance on TMT Part B differentiated individual's with preclinical Alzheimer's disease more accurately than the Mini Mental State Examination (Folstein, Folstein & McHugh, 1975): a measure that it routinely used in clinical practice to screen for the presence of dementia. When involved in differentiating dementia from depression it is important to appreciate that evidence suggests performance on the TMT Part B can be severely compromised by late-life depression (Lockwood, Alexopoulos & van Gorp, 2002).

Interestingly, a recent study by Bell-McGinty, Podell, Franzen, Baird and Williams (2002) found performance on TMT Part B correlated significantly ($p<0.001$) with an individuals ability to perform a range of activities of daily living that included managing a home, money management, social adjustment, and health and safety skills/knowledge in a sample of 50 older adults. This suggests that the TMT could potentially be used to help predict functional status in an older adult population.

Validity of The Trail Making Test as a Measure of Executive Function

Sherman, Strauss and Spellacy (1997) found performance on the TMT to show small but significant correlations with scores obtained on the Paced Auditory Serial Addition Test (PASAT) (Gronwall & Sampson, 1974): the PASAT can be effectively employed to detect subtle deficits in information processing capacity (Strauss et al, 2006). As well as this, O'Donnell, MacGregor, Dabrowski, Ostreicher and Romero (1994) also found performance on the TMT Part B to correlate significantly with PASAT performance, with both tests loading substantially on an attention factor following Factor Analysis. More recently, Kortte, Horner and Windham (2002) investigated the construct validity of the TMT Part B in a sample of 121 patients referred for neuropsychological assessment and reported a significant association between measures of cognitive flexibility and performance on TMT B ($r = 0.59$; $p<0.01$).

Therefore, in terms of its validity, these findings appears to provide a degree of convergent evidence for TMT as a valid measure of information processing capacity and executive functioning.

Reliability of The Trail Making Test

In relation to its reliability, the TMT appears to demonstrate a high degree of test-retest consistency. In particular, Stuss, Stethem, Hugenholtz & Richard (1989) found correlations between first and second administrations of the test (spaced one week apart) to be highly significant ($p<0.001$), while Dikmen, Heaton, Grant and Temkin (1999) reported similarly

high correlations of 0.79 and 0.89 for the performance of 384 healthy adults (aged 15 to 83 years) on Part A and Part B respectively, when spaced 11 months apart ($p<0.01$).

The Influence of Demographic Variables on The Trail Making Test

Similar to the findings reported for other neuropsychological tests (Temkin et al, 1999), there is also a strong suggestion that variables such as general intelligence, age, and education may influence performance on both parts of the TMT.

Indeed, Tombaugh (2004) noted that education showed a significant negative correlation with performance on TMT Part A ($r = - 0.17$, $p<0.01$) and Part B ($r = - 0.25$, $p<0.01$) of the test when administered to a group of 911 healthy adults (aged 18-89 years). The same author also reported significant effect of age on TMT A ($r = 0.58$, $p<0.01$) and TMT B ($r = 0.62$, $p<0.01$). In total, age accounted for 31% of the variance on TMT Part A and 35% of the variance in TMT Part B., while education accounted for 3% on Part A and 7% on Part B. Taken together, these results suggest that performance on the TMT decreases with advancing age and fewer years of education.

More recently, Knight and colleagues (2006) reported a significant correlation between performance on the TMT and age ($p<0.01$, for Parts A and B), and TMT performance and general intelligence, as measured by the NART ($p<0.01$, for Parts A and B). However, including age and NART performance as predictor variables in a multiple regression equation still left a significant proportion of the variance on TMT Part A and Part B unexplained (82% and 75% respectively). The more impressive age effect reported in

Tombaugh's (2004) study could be due to Knight and colleagues specifically focusing on the performance of older adults (age range 65-90 years). Nonetheless, with results such as these, the contribution of demographic variables to TMT performance warrants further investigation.

More specifically, results indicating an age effect on the TMT in the context of 'normal' aging highlights a need for developing an accurate means of detecting abnormal performance on the test. Therefore, the present study shall examine whether factors such as general intelligence, level of education, age and mood affects performance on the TMT. Taking the results of this set of analysis into consideration, regression equations shall be generated to allow accurate prediction of test performance.

2.11.5 The Modified Six Elements Test

The Modified Six Elements Test (SET) is part of the Behavioural Assessment of the Dysexecutive Syndrome that was developed by Wilson and colleagues (1996) in order to provide a more ecologically valid assessment of executive functioning. Based on Shallice and Burgess' (1991) original Six Elements Test, successful performance on the SET is said to rely on a person's ability to effectively form and implement a plan of action, organise their activity and monitor their performance over an extended period of time (Strauss et al, 2006; Wilson et al, 1996). Participants are instructed to do three basic tasks (dictation, arithmetic, and picture naming). Each of these tasks is split into two parts (A and B). This equates to six subtasks in total. Participants are requested to make an effort to complete as much as possible from each of the six individual tasks within a period of 10-minutes. It is

emphasised to participants that the time set is insufficient to complete everything from each subtask. As well as this, participants are given a rule that they must not break: they are not permitted to work on the two parts of a task one after the other. For instance, they should not immediately switch from Arithmetic Part A to Arithmetic Part B, or visa-versa. Unusually, it is not important how well individuals perform on each of the six components. The crucial features relate to their ability to follow test rules, how well they organise their time and the number of subtasks attempted.

This version of the Six Elements Test was administered and scored according to Wilson and colleagues (1996) standard instructions. However, participant's raw scores (0 to 6) rather than their adjusted profile scores were used as the outcome measure.

Sensitivity of The Six Elements Test to Neurocognitive Deficits

Using the original SET, Shallice and Burgess (1991) reported below average performance in three patients with frontal lobe damage. They also described each of these patient's performance as 'qualitatively atypical' in that they tended to spend more time on one task compared to others and made significantly more rule breaks (more than 2 SDs worse than controls). However, Garden and colleagues (2001) reported similar behaviours in a sample of healthy adults. A recent study by Manly, Hawkins, Evans, Woldt and Robertson (2002) investigated the performance of ten traumatically brain-injured patients on the SET and found that, as a group, the patients performed significantly poorer than matched controls. However, 4 out of 10 patients achieved the maximum profile score of 4. This did not appear to be influenced by injury severity (as measured by estimated length of Post

Traumatic Amnesia). Nonetheless, this finding still raises questions about the sensitivity of the SET.

Using a larger sample of patients with acquired brain injury (n = 78) Wilson and colleagues (1996) found that healthy controls performed markedly better than the patient group on the SET ($t = 10.6$, $p<0.0001$). This finding is consistent with a similar comparative study conducted by Norris and Tate (2000). These authors also found their control group to perform significantly better than patients with acquired brain injury on other tests of executive function (Porteus Mazes, The Controlled Oral Word Association test, and three subtests from the BADS).

Validity of The Six Elements Test as a Measure of Executive Function

By reporting a statistically significant correlation between performance on the SET and participants performance on the Rey-Osterrieth Complex Figure Test (Bennett-Levy, 1984) and Porteus Mazes (Porteus, 1965), recent work by Norris and Tate (2000) provides a degree of support for the SET as a valid measure of executive functioning. In support of this, Burgess (1997) describes an innovative analysis of SET performance in which a sample of 50 brain-injured patients and 31 controls were assessed on their 'rule learning', 'planning', 'plan following', and 'monitoring' abilities prior to commencing the test. Using structural equation modelling they found that performance on the SET places significant demands on an individual's ability to plan, organise and monitor their behaviour. Performance on the SET is also reported to tap 'prospective memory': that is, the ability to remember to perform some action in the future.

Reliability of The Six Elements Test

The SET appears to demonstrate a high degree of inter-rater reliability. In relation to this, Wilson, Evans, Emslie, Alderman and Burgess (1998) reported an inter-rater reliability above 0.88 ($p<0.001$). These same authors retested 29 healthy volunteers between 6 and 12 months after first administration and found a test-retest correlation of 0.33 ($p>0.05$). It has been argued that a number of factors may have adversely affected the correlation including the small sample size, the group performing at near ceiling, and the loss of novelty on the second administration (Wilson et al, 1998). On the whole, however, there tends to be a slight improvement in performance at retest.

The Influence of Demographic Variables on The Six Elements Test

There appears to be a dearth of information available looking at the relationship between demographic variables and performance on the SET. Having said this, a significant effect of age has been reported in the literature with older adults reportedly performing much poorer than their younger counterparts ($F = 11.58$, $p<0.0001$) (Wilson et al, 1996). However, Garden and colleagues (2001) failed to find an effect of age group on the three critical measures (subtasks attempted, rule breaks, and time spent on subtask) of the SET. This finding is consistent with that reported by Levine, Stuss, Milberg, Alexander, Schwartz and MacDonald (1998) who also found no age difference between a group of younger (age 18 to 39 years) and older (age 63 to 79 years) adults on the SET. These results suggest that the SET performance of healthy older adults warrants further investigation. Furthermore, no useful normative data is currently available to help classify

normal and abnormal performance of older adults on the SET. This study intends to address both these issues.

2.11.6 The Hayling Sentence Completion Test

The Hayling Sentence Completion Test is a relatively new test that has been specifically designed to measure three abilities related to executive functioning: simple response initiation, inhibition of prepotent responses, and the efficiency and speed with which responses are produced (Burgess & Shallice, 1997). The test is also thought to measure word-finding deficits (Belleville, Rouleau & Van der Linden, 2006) and strategic thinking (Burgess & Shallice, 1996). The test is divided into two parts (Section 1 and Section 2). Both sections are administered to participants in the same order. Each section of the test comprises 15 sentences, each of which has the last word missing (for example, 'The old house will be torn.....'). In section 1, the administrator reads each sentence aloud to the participant who has been instructed to verbally produce a word that sensibly completes the sentence (for example, 'down' would sensibly complete the sentence given above). Participants are requested to generate the word as quickly as they can. The time taken to produce an answer on each sentence is summed and used as the outcome measure for Section 1. This provides a simple measure of initiation and response speed.

In Section 2, participants are read a series of different sentences. This time, however, the participant is required to generate a word that is totally unconnected to the sentence context in every way possible. For instance, 'The dough was put in the hot.....(participant says)....song'. In completing this task, participants have to inhibit or suppress a strongly

activated prepotent response (in this case 'oven') prior to generating a new unconnected response (in this example 'song'). Section 2 yields two scores: a measure of response speed and a total error score. Errors on Section 2 consisted of those responses that could plausibly complete the sentence (Category A errors) and responses that were somewhat, but not directly, connected to the sentence (Category B errors). Responses were categorised according to Burgess and Shallice's (1997) scoring criteria. Participant's performance on all three measures contributes to an overall efficiency score. The Hayling Test was administered according to standardised instructions.

Burgess and Shallice (1997) provide normative data for the Hayling. The authors used a sample of 118 healthy volunteers who had no documented history of psychiatric or neurological disorder. The authors excluded low NART performers from the standardisation sample due to 'greater variability' in their performance and a high level of overlap between their score distributions and those of a patient sample (Burgess & Shallice, 1997). Thus, the standardisation sample is not representative of the general adult population in terms of predicted IQ (Mean = 116; SD = 11.5). This appears to severely limit the utility of the Hayling test in clinical populations with lower IQ's. A further weakness of the standardisation data becomes obvious when we look at the age distributions more closely and learn that from the total sample of volunteers only 19 participants were over the age of 65 years. This raises the question of how appropriate it is to use the standardisation data as a meaningful method for comparison when assessing an older adults performance on this test.

Validity of The Hayling as a Measure of Frontal- Executive Function

Despite these inherent weaknesses, the Hayling has shown promise as a valid means of frontal-executive functioning. For instance, Burgess and Shallice (1997) compared the performance of a group of healthy controls with the performance of a group of patients with lesions involving the frontal lobes (classified as 'anterior' cases) and a group of patients with lesions elsewhere in the cortex (classified as 'posterior' cases). The authors reported highly significant differences between groups on all four of the Hayling measures ($p<0.001$). Post-hoc group comparisons found that the anterior group performed significantly poorer than controls on all the Hayling measures ($p<0.001$) and significantly poorer than the posterior group on 3 out of 4 of these measures ($p<0.01$): response time on section 1 just failed to reach significance. These results provide encouraging evidence for the Hayling's specificity for anterior lesions.

Evidence for involvement of the prefrontal cortex in the suppression of distracting information and word generation on Section 2 of the test is provided by functional imaging research that examined the Hayling performance of healthy volunteers (Strauss et al, 2006). However, Collette, Van der Linden, Delrue and Salmon (2002) examined inhibition deficits in a group of patients with Alzheimer's disease (n = 26) and using Positron Emission Tomography found that both posterior and anterior hypometabolism produced similar deficits in inhibitory function. Although there was a rather small number of patients in each group (n = 10), the findings do suggest that brain areas other than the frontal lobes may be involved in Hayling test performance.

A recent study by de Frias, Dixon and Strauss (2006) reported a modest correlation between participant's performance on the Hayling and scores on the Colour Trails Test Part 2 ($r = 0.20$, $p<0.001$) in a sample of 427 healthy older adults. Hayling error score has also been found to correlate with performance on the SET ($r = -.40$, $p<0.001$) (Clark, Prior & Kinsella, 2000), as well as initiation time on the Tower of London (Shallice, 1982) test ($r = 0.40$, $p<0.001$). These results provide a degree of convergent evidence for the Hayling as a valid measure of executive functioning.

Reliability of The Hayling Test

Relatively little is known about the reliability of the Hayling test. Based on data from their control sample Burgess and Shallice (1997) report a split-half reliability of 0.35 ($p<0.001$), 0.83 ($p<0.001$) and 0.41 ($p<0.001$) for Hayling Time 1, Hayling Time 2 and Hayling error score, respectively. Test-retest reliability has been assessed using a group of 31 healthy volunteers. Retest intervals varied from 2 days to 4 weeks after initial assessment. The reported reliabilities were generally more impressive than the split-half reliabilities (Hayling Time 1: $\alpha = 0.62$, $p<0.001$; Hayling Time 2: $\alpha = 0.78$, $p<0.001$; Hayling errors: $\alpha = 0.52$, $p<0.01$; and Hayling overall score: $\alpha = 0.76$, $p<0.001$), but with the exception of overall Hayling score and Hayling Time 2 score, still relatively modest. Inter-rater reliability values range from 96% (Belleville et al, 2006) to 75.5% (Andres & Van der Linden, 2000). Taken together, these results suggest that the Hayling displays less than ideal, but adequate, reliability.

The Influence of Demographic Variables on The Hayling

Hayling test performance has been found to correlate significantly with variables such as age and NART estimated IQ (Burgess & Shallice, 1997) suggesting that these variables may influence performance. Other studies that have investigated the effect of demographics on the Hayling (Anders & Van der Linden, 2000; Belleville et al, 2006; and Bielak, Mansueti, Strauss & Dixon, 2006) confirm this relationship. For instance, in their sample of 432 'typically aging' older adults (aged 53 to 90 years) Bielak and colleagues (2006) reported a significant correlation between a participant's age and their scores on all Hayling measures ($p<0.01$). The impact of age was greater on Section 2 of the test. Bielak and colleagues (2006) also reported a small, but significant education effect in response speed for Section 1 ($p<0.05$): with more years of education resulting in faster response times.

Belleville and colleagues (2006) found a significant age effect for response speed in the inhibition condition (Section 2). However, when they compared participant's error scores on Section 2, the performance of the elderly group did not differ from that produced by the young ($p>0.05$). Interestingly, these authors also compared the elderly samples performance with a group of patients with mild to moderate Alzheimer's disease and found that the patient group performed significantly worse than the healthy elderly group in all Hayling conditions ($p<0.01$) except response time on Section 1. This suggests the Hayling has potential for contributing to the diagnosis of Alzheimer's disease.

Recognising that existing normative data for the Hayling has limited utility when involved in interpreting the performance of older adults (the original standardisation sample included only a few (19) participants over the age of 65 years), Bielak and colleagues (2006) provide normative information based on their large sample (432) of Canadian older adults. These authors found that age accounted for 4.02 % and 10.23% of the variance on Hayling Time 1 and Hayling Time 2 scores, respectively. Age also accounted for 2.97% of the variance in Category B errors and just less than 1% of the total variance in Category A errors. However, the findings of this study are somewhat limited by the inclusion of participants with a range of chronic medical conditions (such as cancer, 'heart trouble' and depression) that could affect cognitive functioning.

2.11.7 The Brixton Spatial Anticipation Test

The final measure of executive function used as part of this study is a relatively new test of executive attention and concept (or 'rule') attainment (Burgess & Shallice, 1997) that has been specifically designed to examine an individual's ability to discover and apply logical rules. It consists of 56 A4 pages: each page showing the same basic array of ten circles set in two rows of five, with each circle numbered 1 to 10. On each page one of the circles is coloured blue, and the position of this filled circle moves around (on most presentations) from page to page accordingly to a specified pattern or rule. The participant is shown each page one at a time and asked to consider where the next filled position (i.e. blue circle) will be, by trying to abstract a rule based on what they have seen on previous pages. Each response is marked as either right or wrong with the total number of errors made on the test used as person's raw test score. Consequently, a high Brixton raw score reflects a poor

performance, while a low Brixton age-scaled score reflects a good performance. The Brixton Test was administered according to standard instructions.

Validity of The Brixton as a Measure of Frontal-Executive Function

Devised by Burgess and Shallice (1996), the Brixton is a theoretically driven test that was specifically designed to allow the performance of patients with frontal lobe damage on a rule detection task to be assessed. These authors found that patients with cerebral damage to anterior regions of the cortex that included the frontal lobes made more errors than individuals with posterior lesions, and were more inclined to guess or produce 'bizarre responses' when performing this rule detection task. As a result, it would appear that the Brixton not only measures a person's ability to detect and follow a rule, but according to Burgess and Shallice (1997) it may also detect tendencies towards very idiosyncratic and maladaptive behaviour, which has long been characteristic of the dysexecutive syndrome. However, contrary to this, Andres and Van der Linden (2002) found that the performance of their sample of patients with frontal lobe lesions did not deviate markedly from controls ($p>0.05$).

In sample of participants with an eating disorder, Tchanturia, Anderluh, Morris, Rabe-Hesketh, Collier and colleagues (2004) found that participants Brixton error score loaded on the same factor as the TMT Part B. In support of this finding, de Frias, and colleagues (2006) reported highly significant correlations between healthy older adults error score on the Brixton and the Colour Trails Test Part 2 ($p<0.001$). These results provide a degree of convergent evidence for the Brixton as a valid measure of executive functioning.

Reliability of The Brixton Test

However, in spite of these promising results, there is still very little known about the psychometric properties of the Brixton test. With an overall test-retest reliability of 0.71 ($p<0.001$), Burgess and Shallice (1997) have found performance on the Brixton to be reasonably reliable when administered to a group of healthy individuals tested up to four weeks apart. However, the split-half reliability is less impressive (0.62).

The Influence of Demographic Variables on The Brixton

Performance on the Brixton has been found to correlate significantly with variables such as age and NART estimated IQ (Burgess & Shallice, 1997) suggesting that these variables may influence performance. These early findings have been replicated in the handful of other studies that have investigated the effect of demographics on the Brixton (Anders & Van der Linden, 2000; Bielak, Mansueti, Strauss & Dixon, 2006; and de Frias et al, 2006). For instance, in their sample of 427 healthy older adults (aged 55 to 85 years) de Frias and colleagues (2006) reported a significant correlation between a participant's age and their error score on the Brixton ($r = -0.27$, $p<0.001$).

Similar to the Hayling test, existing normative data for the Brixton has limited utility when involved in interpreting the performance of older adults (the original standardisation sample included only a few (16) participants over the age of 66 years). Recognising this, Bielak and colleagues (2006) provide normative information based on a sample of 441 'typically aging' Canadian older adults (53 to 90 years). These authors found that age, education and gender accounted for 11%, 2.25% and 1.21% of the variance on Brixton performance,

respectively. However, the findings of this study are somewhat limited by the inclusion of participants with a range of chronic medical conditions (such as cancer, 'heart trouble' and depression) that could affect cognitive functioning.

Therefore, the present study shall use a healthy British sample of older adults in order to conduct an examination into the Hayling and Brixton's relationship with variables such as age, education, and intelligence. Variables that are found to influence performance on the task will be entered into a regression analysis for use as potential predictor variables in a regression equation.

Chapter 3: Results

The principal aim of the study was to investigate the relationship between demographic variables and neuropsychological test performance. However, before investigating this, the data were explored in order to check outcome variable distributions and identify any outliers or 'unusual' cases that could potentially bias the results of the subsequent analyses. The details of this exploratory analysis is outlined below.

3.1 Exploratory Analysis

Firstly, the distribution of the data was investigated by plotting histograms for each of the outcome variables. The reasonably symmetrical distributions presented in Appendix 15 suggest that the data are normally distributed. Although skewness values produced by SPSS suggested that each of the outcome variables was actually not normally distributed, this was not deemed to be too concerning bearing in mind the sound psychometric properties of the tests used and the large sample size.

Potential outliers were identified using scatterplots and boxplots (see Appendix 16 for an example). The results of this set of analysis highlighted a small number of extreme cases within each outcome variable. In order investigate the extent to which these cases deviated from normality each participant's test score was converted to a *z* score. Field (2005) points out that when the data is normally distributed we would expect around 5% of the sample to have *z* score values above 1.96, and 1% to have an absolute value above 2.58. Employing these criteria to the current data suggests that having more than five *z* scores above 1.96, and more than one *z* score above 2.58 would indicate proportionally more outliers than

expected. However, individual's *z* scores for each of the outcome variables fell within these strict parameters. Therefore, outlier scores were retained for analysis.

Nevertheless, a series of analyses both with and without the identified outliers were run in order to directly measure the influence of these outliers. The removal of outliers had a negligible effect on the resulting output (Appendix 17). This appears to vindicate the decision to retain all identified outliers.

3.2 Background Characteristics of Sample

The intention was to recruit as large a sample and as broad a range of participants as possible. The sample consisted of 106 participants: 38 male, 68 female. Table 1 displays the means, standard deviations and range for the demographic variables of (i) age of participants, and (ii) total years of education. Table 1 also presents basic descriptive information for the NART.

Table 1: Basic demographic characteristics of sample and information on the NART

Demographic Characteristic	Mean	SD	Min.	Max.
Age of Participants	70.71	8.03	55	94
Years of Education	12.84	3.13	7	22
NART Error Score	21.50	7.52	7	39
NART Predicted IQ	104.08	9.30	82	122

Based on the results presented in Table 1 it can be seen that the mean age of the sample was 70.71 years (SD = 8.03 years), with a range from 55 to 94 years. NART estimated

premorbid IQ scores ranged from 82 to 122. This suggests that participants were functioning within the normal range of intelligence (mean NART predicted IQ = 104.08, SD = 9.30).

Table 2 displays the distribution of age in the present sample using eight age-bands.

Table 2: Distribution of participants' age

	Age Band							
	55-60	61-65	66-70	71-75	76-80	81-85	86-90	90+
Number of Participants	12	16	28	16	22	10	1	1
Sample Percentage (%)	11.4	15.1	26.4	15.1	20.8	9.4	0.9	0.9

Based on the results presented in Table 2 it can be seen that the majority of participants (68%) were under the age of 76 years. With the exception of the final two age bands (86-90 and 90+) a reasonable number of participants were represented in each band.

Each participant's highest qualification was recorded. This information is displayed in Table 3.

Table 3: Participants' qualification

Qualification	Number	%
0 = No Formal Qualifications	18	17.0
1 = Apprenticeship, Clerical qualifications, etc	29	27.4
2 = 'O' Level, 'O' Grade	6	5.7
3 = 'A' Level, Higher, ONC, OND, etc	13	12.3
4 = HNC, HND, Teaching, Nursing, Midwifery, etc	19	17.9
5 = Degree	21	19.8

Table 3 highlights that a fair proportion of participants in the sample (27.4%) had obtained some basic qualifications (coded 1) that related to working in administrative roles or completing an apprenticeship in various occupations. Eighteen (17%) participants reported having obtained no formal qualifications, while 13 (12.3%) participants had achieved either higher school grades or ordinary national certificates. A high proportion of participants (19.8%) reported having obtained a university degree, while 19 participants (17.9%) had obtained either a higher national certificate, nursing or teaching degree.

Table 4 displays the distribution of occupational codes in the present sample.

Table 4: Distribution of occupational codes (SES) for participants

	Social Economic Status (SES)				
	1	2	3	4	5
Number of Participants	5	43	40	12	6
Sample Percentage (%)	4.7	40.6	37.7	11.3	5.7

The information displayed in Table 4 highlights that most participants were from social class group 2 (40.6%) and 3 (37.7%). This is a common finding when conducting neuropsychological tests with normal populations, as people from higher socio-economic groupings are generally more likely to volunteer to participate in such research.

3.3 Tests of Executive Functioning

Out of all the 106 volunteers that took part in the study only one participant had missing data from one measure of interest (the Six Elements Test). Therefore, all statistics reported for the Six Elements Test is based on a sample of 105 participants. Table 5 displays basic descriptive information that includes the means, standard deviations and ranges for participant responses on the Trail Making Test, the Hayling test, the Brixton test, and the Six Elements Test.

Table 5: Means, standard deviations, and minimum and maximum values for test scores on the Trail Making Test, the Hayling test, the Brixton test and the Six Elements test

Test	Mean	SD	Min.	Max.
Trail Making Test Part A (TMT A)	35.07	11.03	15	81
Trail Making Test Part B (TMT B)	85.34	37.95	27	224
TMT B – TMT A	50.27	30.45	7	167
Hayling Test Time 1	8.66	8.85	0	44
Hayling Test Time 2	46.61	41.57	0	259
Hayling Total Response Error Score	4.11	3.62	0	13
Hayling Total Scaled Score	16.20	3.54	6	21
Brixton Error Score	19.34	7.15	9	42
Brixton Scaled Score	4.89	1.96	1	8
Six Elements Raw Score	5.37	0.99	2	6

3.3.1 Descriptive Information for the Trail Making Test (TMT)

Based on the results presented in Table 5 it can be seen that the mean response time on TMT Part A (35.07 seconds, SD = 11.03 seconds) was quicker than participant's mean response time for TMT Part B (85.34 seconds, SD = 37.95 seconds). The difference between TMT Part A and TMT Part B (B-A) is reported to factor out the influence of visuomotor tracking and processing speed, and therefore measure executive functioning more accurately (Hashimoto, Meguro, Lee, Kasai, Ishii and Yamaguchi, 2006). As with TMT Part A and Part B, a broad range of scores was evident on this measure (7-167).

Table 6 and Table 7 display the proportion of errors produced on TMT Part A and TMT Part B, respectively.

Table 6: Errors produced on the Trail Making Test Part A (TMT Part A)

	Trail Making Test Part A Errors		
	0	1	2
Number of Participants	87	17	2
Sample Percentage (%)	82.1	16.0	1.9

The majority of participants (82.1%) made no errors on TMT Part A. However, Table 6 highlights that approximately 17.9% of the total sample produced at least one error on TMT Part A.

Table 7: Errors produced on the Trail Making Test Part B (TMT Part B)

	Trail Making Test Part B Errors						
	0	1	2	3	4	5	6
Number of Participants	59	30	9	6	0	1	1
Sample Percentage (%)	55.7	28.3	8.5	5.7	0.0	0.9	0.9

Participants produced substantially more errors on TMT Part B than they did on TMT Part A. This is illustrated in Table 7.

3.3.2 Descriptive Information for the Brixton Test

Two primary outcome measures were used for the Brixton test: Brixton total error score and Brixton scaled score. The mean number of errors made by participants on the Brixton test is presented in Table 5. Using the test author's qualitative descriptions of test performance a mean score of 19.34 (SD = 7.15) would classify the sample within the

'moderately average' range of ability. This categorisation is consistent with the sample's Brixton scaled score (M = 4.89, SD = 1.96). In order to explore the proportion of participant's scoring below average on the Brixton test participant's scaled scores were analysed at the individual level. The results from this analysis are reported in Table 8.

Table 8: Participants' Brixton error scaled scores

	Brixton Error Scaled Scores*									
	1	2	3	4	5	6	7	8	9	10
Number of Participants	9	11	5	12	13	35	19	2	0	0
Sample Percentage (%)	8.5	10.4	4.7	11.3	12.3	33.0	17.9	1.9	0.0	0.0

* 1 = Impaired, 2 = Abnormal, 3 = Poor, 4 = Low Average, 5 = Moderate Average, 6 = Average, 7 = High Average, 8 = Good, 9 = Superior, 10 = Very Superior

Based on the information presented in Table 8 we can see that that most participant's scores fell within the 'average' (33.0%) to 'high average' (17.9%) range of functioning. However, nearly a fifth of the sample's scores fell within the 'impaired' (8.5%) to 'abnormal' (10.4%) range of functioning. Only two participants (1.9%) scores were classified as being above average. No participants achieved a superior performance.

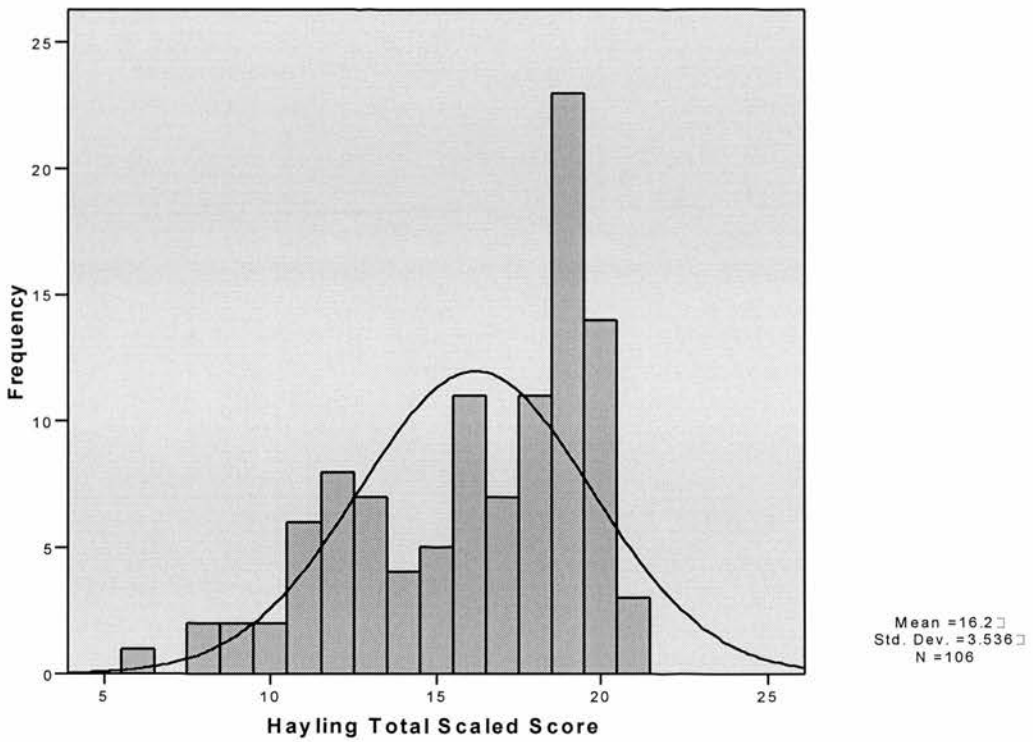
3.3.3 Descriptive Information for the Hayling Test

As recommended by Burgess and Shallice (1997), participant responses on each of the 15 sentences in the two parts of the Hayling test were rounded down to the nearest second (i.e. a response time between 1 and 1.99 seconds was rounded down to 1 second). Summing the time taken to respond on each of the 15 sentences that contributes to that section produced participant's total response time for each section of the test. Table 5 highlights that overall,

participants were faster at responding in Section 1 (M = 8.66, SD = 8.85) than in Section 2 (M = 46.61, SD = 41.57).

Based upon normative data presented in the test manual, an analysis of participant's scaled scores revealed that the sample was generally functioning within the average range on the Hayling test. This is illustrated in the samples' mean total Hayling scaled score of 16.20 (SD = 3.54) presented in Table 5. However, in order to fully explore the proportion of participant's scoring below average on the Hayling test participant's scaled scores were analysed at the individual level. The results from this set of analyses are reported in Figure 1, Table 9, and Table 10.

Figure 1: Participants' Hayling total scaled scores*



* 10< = Impaired, 10 = Abnormal, 11-12 = Poor, 13-14 = Low Average, 15-16 = Moderate Average, 17-19 = Average, 20 = High Average, 21 = Good, 22 = Superior, 23 = Very Superior

An individual's Hayling total scaled score is derived from summing their Section 1 and Section 2 scaled scores together with their Hayling error scaled score. The results presented in Figure 1 indicate that the majority of participants were functioning within the 'average' (n = 41) to 'high average' (n = 14) range of ability. Sixteen participant's (15.1%) performances placed them in the 'moderate average' range of functioning, while 11 participant's (10.4%) scores placed them in the 'low average' range. Meanwhile, 14 participant's (13.2%) performances were classified as 'poor'. Two participant's (1.9%)

scores saw their performance categorised as 'abnormal', while 5 participants (4.7%) fell within the 'impaired' range of functioning.

Table 9: Hayling Section 1 scaled scores

	Hayling Section 1 Scaled Scores*						
	1	2	3	4	5	6	7
Number of Participants	0	0	9	2	21	71	3
Sample Percentage (%)	0.0	0.0	8.5	1.9	19.8	67.0	2.8

* 1 = Impaired, 2 = Abnormal, 3 = Poor, 4 = Low Average, 5 = Moderate Average, 6 = Average, 7 = High Average

Table 9 indicates that most participants' (67.0%) response times on Section 1 of the Hayling test were within the 'average' range of functioning. Around a fifth of the sample's (19.8%) response times were in the moderate average range. Two participants (1.9%) were classified as being in the 'low average' range of functioning, while 9 participants (8.5%) produced a 'poor' performance on this measure of initiation and response speed.

The results presented in Table 10 highlight that the majority of participants' (54.7%) response times on the inhibition section of the Hayling test were also within the 'average' range of functioning. However, the performance of six (5.7%) participants was classified as 'poor', while one participant's performance was 'abnormal' and three (2.8%) participants' scores were categorised as 'impaired'.

Table 10: Hayling Section 2 scaled score

	Hayling Section 2 Scaled Scores*							
	1	2	3	4	5	6	7	8
Number of Participants	3	1	6	21	11	58	5	1
Sample Percentage (%)	2.8	0.9	5.7	19.8	10.4	54.7	4.7	0.9

* 1 = Impaired, 2 = Abnormal, 3 = Poor, 4 = Low Average, 5 = Moderate Average, 6 = Average, 7 = High Average, 8 = Good

Participants' responses in Section 2 of the Hayling were categorised according to Burgess and Shallice's (1997) scoring criteria: with a plausible sentence completion categorised as a type A error, and a word completion that was somewhat connected to the sentence categorised as a type B error. The proportion of response errors made by participants on Section 2 is presented in Table 11 (category A errors) and Table 12 (category B errors).

Table 11: Hayling Section 2 category A response errors

	Hayling Category A Error Scores					
	0	1	2	3	4	5
Number of Participants	57	16	15	10	5	3
Sample Percentage (%)	53.8	15.1	14.2	9.4	4.7	2.8

Table 11 indicates that the majority of participants (53.8%) did not make any category A errors on Section 2 of the Hayling test. However, a substantial proportion of participants made at least one category A error.

Meanwhile, the results presented in Table 12 highlight that most participants' (84.0%) committed at least one category B error on Section 2 of the Hayling test. Nearly two-thirds of the sample (64.2%) made two or more category B errors.

Table 12: Hayling Section 2 category B response errors

	Hayling Category B Error Scores									
	0	1	2	3	4	5	6	7	8	9
Number of Participants	17	21	16	10	12	9	6	8	5	2
Sample Percentage (%)	16.0	19.8	15.1	9.4	11.3	8.5	5.7	7.5	4.7	1.9

Figure 2 displays the total number of errors produced by participants on Section 2 of the Hayling test.

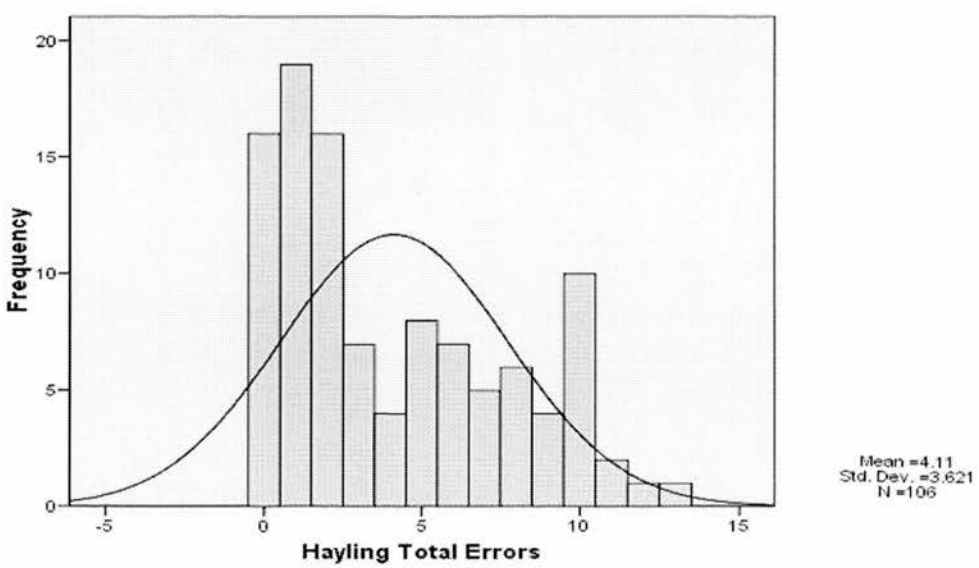


Figure 2: Participants' total number of response errors on the Hayling test

The information presented in Figure 2 illustrates that only 16 participants (15.1%) did not produce a response error on Section 2 of the Hayling test. In order to investigate the proportion of participant's producing an abnormally high response error score participant's scaled scores were analysed at the individual level. These scores are displayed in Table 13.

Table 13: Hayling Section 2 total response error scaled score

	Hayling Section 2 Total Response Error Scaled Scores*							
	1	2	3	4	5	6	7	8
Number of Participants	7	16	5	4	4	18	37	15
Sample Percentage (%)	6.6	15.1	4.7	3.8	3.8	17.0	34.9	14.2

* 1 = Impaired, 2 = Abnormal, 3 = Poor, 4 = Low Average, 5 = Moderate Average, 6 = Average, 7 = High Average, 8 = Good

An individual's response error scaled score on the Hayling test is derived from a sum of the weighted values ascribed to category A errors and category B errors. The more errors one produces in each category the higher this value will be: with category A errors being given more weight than a category B error. Table 13 highlights that a high proportion of participant's were functioning above average in this domain: 34.9% in the 'high average' range and 14.2% classified as 'good'. The performance of 16 participant's (15.1%) was categorised as 'abnormal', while seven (6.6%) participant's scores placed them in the 'impaired' range of functioning.

3.3.4 Descriptive Information for the Six Elements Test (SET)

The minimum and maximum scores that can be achieved on the SET are 0 (zero) and 6, respectively. Based on the results presented in Table 5 on page 96, it can be seen that at the group level of analysis the sample was performing at near ceiling levels (M = 5.37, SD = 0.99). This is illustrated in Table 14, which indicates that the vast majority of participants (87) scored 5 or above on the SET.

Table 14: Participant's raw score values on the Six Elements Test (SET)

	Six Elements Test Raw Score						
	0	1	2	3	4	5	6
Number of Participants	0	0	1	8	9	20	67
Sample Percentage (%)	0.0	0.0	0.9	7.5	8.5	18.9	63.2

3.4 Psychological Health

In order to investigate participants' psychological well-being, means were calculated for each sub-scale of the Hospital Anxiety and Depression Scale (HADS). These results are presented in Table 15.

Table 15: Participant's Hospital Anxiety and Depression Scale (HADS) sub-scale scores

HADS Sub-scale	Mean	SD	Min.	Max.
Anxiety	5.23	3.01	0	15
Depression	2.75	2.40	0	11

Employing the authors recommended cut-off scores (see page 67) it can be seen from the results presented in Table 15 that when taken as a group the present sample's mean sub-

scale scores (Anxiety = 5.23, Depression = 2.75) did not reach a clinical level of significance on either of the HADS' sub-scales.

The proportion of participants reporting an unhealthy level of psychological distress on each sub-scale of the HADS was explored at the individual case level. This is presented in Table 16.

Table 16: Participants reported levels of psychological distress on the HADS

	Level of Caseness			
HADS Sub-scale	0 – 7 **(Normal)**	8 – 10 **(Mild)**	11 – 15 **(Moderate)**	16 – 21 **(Severe)**
Anxiety	83 (78.3%)	17 (16.0%)	6 (5.7%)	0 (0.0%)
Depression	99 (93.4%)	6 (5.7%)	1 (0.9%)	0 (0.0%)

Based on the results presented in Table 16 it can be seen that the majority of participant's scores on both the HADS Anxiety and Depression sub-scales fell within 'normal' limits. No participant reported experiencing severe levels of anxiety or depression. Therefore, each participant's scores on the HADS fell within a range of psychological functioning that was acceptable enough to warrant their inclusion in the data analyses.

3.5 Correlational Analysis

One of the study's main aims was to investigate the relationship between demographic variables and neuropsychological test performance. Therefore, Pearson's product-moment correlation coefficients were used to measure the strength of statistical association between NART error score, demographic variables, mood and performance on the four tests of executive functioning. The raw correlations between scores on the Trail Making Test, Brixton test, and Six Elements Test and these variables are presented in Table 17. Table 18 displays the raw correlations between demographic variables, NART error score, mood and Hayling test scores.

Table 17: Pearson product-moment correlations for test scores of the Trail Making Tests (TMT), Brixton test, and Six Elements Test with demographic variables, the NART, and the HADS

Test	Age	Gender	Years of Education	Social Economic Status	Qualification	NART Error Score	HADS Anxiety	HADS Depression
TMT Part A	.498**	.175*	-.190*	.202*	-.210*	.163*	.036	.061
TMT Part A Errors	.051	.023	-.216*	.132	-.194*	.058	.123	.126
TMT Part B	.634**	.108	-.413**	.385**	-.461**	.409**	.005	.070
TMT Part B Errors	.432**	.083	-.415**	.366**	-.472**	.357**	.051	-.015
TMT B – TMT A	.610**	.072	-.447**	.407**	-.499**	.451**	-.006	.065
Brixton Error Score	.365**	.282**	-.381**	.422**	-.423**	.374**	.102	-.024
Brixton Scaled Score	-.381**	-.265**	.368**	-.414**	.424**	-.378**	-.088	.006
SET Raw Score	-.285**	-.046	.366**	-.313**	.370**	-.306**	.007	-.109

**correlation significant beyond 1% level
*correlation significant beyond 5% level

Table 18: Pearson product-moment correlations for test scores of the Hayling test with demographic variables, the NART, and the HADS

Test	Age	Gender	Years of Education	Social Economic Status	Qualification	NART Error Score	HADS Anxiety	HADS Depression
Hayling Time 1	.393**	.085	-.325**	.326**	-.312**	.388**	-.062	.013
Hayling 1 scaled score	-.381**	-.076	.329**	-.280**	.332**	-.361**	.106	.043
Hayling Time 2	.264**	-.162*	-.298**	.264**	-.292**	.344**	.097	.172*
Hayling 2 scaled score	-.292**	.123	.291**	-.253**	.287**	-.281**	-.077	-.166*
Hayling 2 Type A errors	.286**	.209*	-.375**	.457**	-.320**	.342**	.231**	.134
Hayling 2 Type B errors	.246**	.084	-.202*	.242**	-.134	.191*	.089	.125
Hayling total error score	.285**	.138	-.290**	.348**	-.219*	.267**	.152	.141
Hayling error scaled score	-.266**	-.147	.283**	-.333**	.204*	-.274**	-.175*	-.154
Hayling total scaled score	-.383**	-.070	.380**	-.385**	.328**	-.379**	-.115	-.151

**correlation significant beyond 1% level
*correlation significant beyond 5% level

3.5.1 Results of Correlation Analyses for the Trail Making Test (TMT)

Based on the correlation data presented in Table 17 it can be seen that age was more highly correlated than any other variable with scores on the TMT Part A (r = .498, p<0.01), TMT Part B (r = .634, p<0.01), and the TMT difference score (TMT B – TMT A), (r = .610, p<0.01). Furthermore, gender (r = .175), years of education (r = -.190), qualification (r = -.210), socio-economic status (r = .202) and participant's NART error score (r = .163) were all associated with performance on the TMT Part A (all ps<0.05). In line with this, years of education, qualification, socio-economic status and NART error score were also associated with performance on the TMT Part B (all ps<0.01), and the TMT difference score (TMT B – TMT A) (all ps<0.01).

Although the majority of participants (82.1%) made no errors on the TMT Part A (see Table 6), Table 17 highlights that educational status (as measured by qualification and years of education) was associated with error rate (both ps<0.05). Table 17 also suggests that educational achievement is associated with error rate on the TMT Part B (qualification, r = -.472; years of education, r = -.415). Age (r =.432), socio-economic status (r = .366) and estimated IQ (r = .357) were also significantly associated with errors on the TMT Part B (all ps<0.01).

There was no evidence for a statistically significant relationship between mood and performance on the TMT (p>0.05).

3.5.2 Results of Correlation Analyses for the Brixton test

The results presented in Table 17 show a statistically significant relationship between all demographic variables, estimated IQ and Brixton error scores (all *p*s<0.01). As the Brixton scaled score is derived from the Brixton error score it is perhaps unsurprising that the strength of association between demographic variables, estimated IQ and these two outcome variables are strikingly similar (see Table 17): bearing in mind that a higher Brixton scaled score equates to a better performance. There was no evidence for a statistically significant relationship between mood and Brixton performance ($p>0.05$).

3.5.3 Results of Correlation Analyses for the Hayling test

Based on the correlation data presented in Table 18 it can be seen that a statistically significant relationship was found between all demographic variables and Hayling test performance. As expected, age was associated with performance on each of the Hayling test variables listed in Table 18 (all *p*s<0.01). In relation to the main Hayling outcome variable selected for the purpose of this study (Hayling Time 1, Hayling Time 2, Hayling total error score, and Hayling total scaled score), years of education, qualifications, socio-economic status, and NART estimated IQ were all associated with response times on sections 1 and 2 of the Hayling test (all *p*s<0.01). In addition to this, gender was also associated with response times on section 2 of the Hayling test ($r = -.162$, $p<0.05$).

As well as highlighting a relationship between age and error rate on section 2 of the Hayling test ($r = .285$, $p<0.01$), Table 18 also indicates that years of education ($r = -.290$), socio-economic status ($r = .348$) and estimated IQ ($r = .267$) were all significantly

associated with error rate on section 2 of the Hayling test (all $ps<0.01$). In addition to this, educational achievement (i.e. qualifications) was also associated with Hayling response error score ($r = -.219$, $p<0.05$). A similar pattern of results was obtained in relation to participant's Hayling test total scaled scores.

3.5.4 Results of Correlation Analyses for the Six Elements Test (SET)

The correlation data presented in Table 17 illustrates a statistically significant relationship between all demographic variables (with the exception of gender) and performance on the SET (all $ps<0.01$). These results are in line with the results reported for the other tests of executive functioning.

3.5.5 Correlations Between Demographic Variables

The information presented in Table 19 displays the correlations amongst demographic variables. A statistically significant relationship was found between age and years of education ($r = -.280$, $p<0.01$), and age and qualification ($r = -.288$, $p<0.01$). Although rather modest associations, the results suggest that younger participants generally had more years of education and higher educational achievements. On the whole, being male was associated with higher socio-economic status ($r = .264$, $p<0.01$). Higher socio-economic status was associated with qualification ($r = -.708$), higher estimated IQ ($r = .619$), and more years of education ($r = -.741$) (all $ps<0.01$). More years of education was also correlated with higher qualifications ($r = .885$, $p<0.01$) and higher estimated IQs ($r = -.711$, $p<0.01$). Table 19 also suggests that individuals with higher qualifications generally have higher estimated IQs ($r = -.668$, $p<0.01$).

Table 19: Pearson product-moment correlations between demographic variables, the NART, and the HADS

	Age	**Gender**	**Years of Education**	**Social Economic Status**	**Qualification**	**NART Error Score**	**HADS Anxiety**
Age							
Gender	-.003						
Years of Education	-.280**	-.114					
Social Economic Status	.133	.246**	-.741**				
Qualification	-.288**	-.133	.885**	-.708**			
NART Error Score	.109	-.013	-.711**	.619**	-.668**		
HADS Anxiety	-.132	.076	-.153	.152	-.219*	.200*	
HADS Depression	.075	-.069	-.120	.046	-.183*	.047	.497**

**correlation significant beyond 1% level
*correlation significant beyond 5% level

3.6 Regression Analysis

The purpose of this section of the analysis was to develop a practical method for clinicians to accurately estimate a client's expected or premorbid level of functioning on the four tests of executive function. Therefore, the aim was to build regression equations for the prediction of an individual's initial test scores based on a combination of relevant factors that may be important. Potential predictors in the multiple regression analysis were an individual's NART error score, the HADS constructs of Anxiety and Depression, and the demographic variables age, total years of education, qualification and social class. Predictor variables were chosen based on the findings of past research. The correlations between the predictor and outcome variables entered into the regression analysis are presented in Tables 17 and 18. The correlations between predictor variables are presented in Table 19.

Hierarchical linear regression was utilized. As age has previously been found to influence performance on the tests used in the present study this important variable was entered into each model first. Based on the observed relationship between an individual's IQ score and test performance, participant's NART error score was then entered into the regression model in order to examine whether this variable significantly improved the models predictive power. Following this, other demographic variables were entered into the model in order to determine if they significantly improved the models ability to predict the outcome variable. Only those variables that contributed significantly to the models predictive ability were retained in the model. The final model in each case was the one that accounted for the largest proportion of variance in test performance.

The results of the multiple regression analyses are presented in Table 20 and Table 21. These tables highlight that age made a significant contribution to the prediction of all test scores. However, we can see that the addition of specific demographic variables and/or estimated IQ (NART error score) had a significant effect upon prediction of the test scores on all tasks. The change in R^2 is relatively modest for some of these regression models (e.g. the addition of the gender to the regression model for TMT Part A changes R^2 by 3.1%), while more substantial for others (e.g. the addition of NART error score to the regression model for the Hayling Time 1 changes R^2 by 12.1%).

The final model parameters including the values of the constant (or intercept), the regression coefficients (labelled B), and the significance values of the regression coefficients (Sig.) are presented in Table 22 and Table 23. The regression equations incorporating demographic variables and other important variables that improve test prediction accuracy are presented in Table 24. Table 24 also reports the standard errors of estimate for each model.

Table 20: The Effect of Adding Demographic Variables to Regression Models for the Trail Making Test and the Hayling test

Test	Predictor Variables	R	R^2	Std. Error of the Estimate	R^2 Change	*p*
TMT Part A	Step1 ; Age	.498	.248	9.610	.248	$p<.001$
	Step2 ; Gender	.528	.279	9.455	.031	$p<.05$
TMT Part B	Step1 ; Age	.634	.402	29.488	.402	$p<.001$
	Step2 ; NART Error Score	.721	.519	26.570	.117	$p<.001$
TMT B - A	Step 1; Age	.610	.372	24.246	.372	$p<.001$
	Step 2; NART Error Score	.722	.522	21.264	.150	$p<.001$
Hayling Time 1	Step 1: Age	.393	.154	8.174	.154	$p<.001$
	Step 2: NART Error Score	.524	.275	7.606	.121	$p<.001$
Hayling Time 2	Step 1; Age	.264	.069	40.290	.069	$p<.01$
	Step 2: NART Error Score	.412	.170	38.234	.101	$p<.001$
Hayling total error score	Step 1; Age	.285	.081	3.488	.081	$p<.01$
	Step 2; Socio-Economic Status	.423	.179	3.312	.098	$p<.001$
Hayling total scaled score	Step 1; Age	.383	.147	3.282	.147	$p<.001$
	Step 2; NART Error Score	.512	.262	3.067	.115	$p<.001$

Table 21: The Effect of Adding Demographic Variables to Regression Models for the Brixton test and the Six Elements Test

Test	Predictor Variables	R	R^2	Std. Error of the Estimate	R^2 Change	*p*
Brixton Error Score	Step 1; Age	.365	.133	6.690	.133	$p<.001$
	Step 2; NART Error Score	.496	.246	6.269	.113	$p<.001$
	Step 3; Gender	.573	.328	5.946	.082	$p<.001$
Brixton Scaled Score	Step 1; Age	.381	.145	1.819	.145	$p<.001$
	Step 2; NART Error Score	.509	.259	1.702	.114	$p<.001$
	Step 3; Gender	.577	.333	1.623	.073	$p<.001$
SET Raw Score	Step 1: Age	.285	.081	0.956	.081	$p<.01$
	Step 2; Highest Qualification	.417	.174	0.911	.093	$p<.001$

Table 22: Coefficient Values of the Final Regression Model s for the Trail Making Test and the Hayling test

Test	Predictor Variables	B	Std. Error	Beta	t	Sig.
TMT Part A	(Constant)	-19.987	8.768		-2.280	$p<.05$
	Step1 ; Age	0.685	0.115	0.499	5.961	$p<.001$
	Step2 ; Gender	4.031	1.915	0.176	2.105	$p<.05$
TMT Part B	(Constant)	-151.366	23.507		-6.439	$p<.001$
	Step1 ; Age	2.820	0.325	0.597	8.679	$p<.001$
	Step2 ; NART Error Score	1.737	0.347	0.344	5.009	$p<.001$
TMT B - A	(Constant)	-135.732	18.812		-7.215	$p<.001$
	Step 1; Age	2.152	0.260	0.567	8.276	$p<.001$
	Step 2; NART Error Score	1.575	0.277	0.389	5.676	$p<.001$
Hayling Time 1	(Constant)	-27.785	6.728		-4.130	$p<.001$
	Step 1: Age	0.391	0.093	0.355	4.200	$p<.001$
	Step 2: NART Error Score	0.411	0.099	0.349	4.140	$p<.001$
Hayling Time 2	(Constant)	-75.074	33.826		-2.219	$p<.05$
	Step 1; Age	1.185	0.467	0.229	2.535	$p<.05$
	Step 2: NART Error Score	1.763	0.499	0.319	3.534	$p<.001$
Hayling total error score	(Constant)	-6.976	2.921		-2.388	$p<.05$
	Step 1; Age	0.109	0.041	0.243	2.695	$p<.01$
	Step 2; Socio-Economic Status	1.228	0.350	0.316	3.507	$p<.001$
Hayling total scaled score	(Constant)	30.416	2.714		11.208	$p<.001$
	Step 1; Age	-0.152	0.038	-0.346	-4.061	$p<.001$
	Step 2; NART Error Score	-0.160	0.040	-0.341	-4.008	$p<.001$

Table 23: Coefficient Values of the Final Regression Model s for the Brixton test and the Six Elements Test

Test	Predictor Variables	B	Std. Error	Beta	t	Sig.
Brixton Error Score	(Constant)	-15.327	5.630		-2.723	$p<.01$
	Step 1; Age	0.293	0.073	0.329	4.025	$p<.001$
	Step 2; NART Error Score	0.325	0.078	0.342	4.186	$p<.001$
	Step 3; Gender	4.260	1.204	0.287	3.537	$p<.001$
Brixton Scaled Score	(Constant)	14.550	1.537		9.468	$p<.001$
	Step 1; Age	-0.084	0.020	-0.344	-4.228	$p<.001$
	Step 2; NART Error Score	-0.089	0.021	-0.344	-4.223	$p<.001$
	Step 3; Gender	-1.101	0.329	-0.271	-3.349	$p<.001$
SET Raw Score	(Constant)	6.520	0.875		7.674	$p<.001$
	Step 1: Age	-0.025	0.012	-0.200	-2.135	$p<.05$
	Step 2; Highest Qualification	0.171	0.051	0.316	3.379	$p<.001$

3.6.1 Results of Regression Analyses for the Trail Making Test (TMT)

Based on the data presented in Table 20 it can be seen that age and gender exerted a significant influence on performance of TMT Part A, accounting for 24.8% ($p<0.001$) and 3.1% ($p<0.05$) of the variance respectively. Prior to entering gender into the regression analysis NART error score was entered into the model in order to determine whether this significantly improved the predictive ability of the model. However, the relative contribution of NART error score did not reach statistical significance ($p>0.05$). Therefore, NART error score was removed from the analysis. Furthermore, the addition of other demographic variables did not significantly improve the regression model ($p>0.05$).

Table 20 indicates that age and NART error score make a significant contribution to an individual's performance on the TMT Part B, with age accounting for 40.2% ($p<0.001$) of unexplained variance and NART error score explaining 11.7% ($p<0.001$) of the variance. The addition of other demographic variables did not contribute significantly to the model's predictive ability.

Similar results were obtained in relation to the regression analysis for the TMT difference score (TMT B – TMT A). Again, the other demographic variables did not significantly improve the regression model ($p>0.05$).

The coefficient values for TMT Part A, TMT Part B, and TMT B- A are presented in Table 22. These values are incorporated into the regression equations presented in Table 24.

3.6.2 Results of Regression Analyses for the Hayling test

The information displayed in Table 20 illustrates that age and NART error score exerted a significant influence on Hayling test response times. For Hayling time 1, age accounted for 15.4% ($p<0.001$) of the variance and NART error score explained 12.1% ($p<0.001$) of the variance in performance. For Hayling time 2, age accounted for 6.9% ($p<0.01$) of the variance, while NART error score accounted for a further 10.1% ($p<0.001$). The addition of other demographic characteristics did not contribute substantially to the models predictive ability for each of these outcome variables.

Table 20 also highlights that age (8.1%, $p<0.01$) and socio-economic status (9.8%, $p<0.001$) were the only predictor variables that made a significant contribution to the prediction of Hayling total error scores. Before entering socio-economic status into the regression analysis NART error score was entered into the model in order to determine whether this variable significantly improved the model. However, the contribution of NART error score did not reach statistical significance ($p>0.05$). Therefore, NART error score was removed from the analysis.

Looking at the model for Hayling total scaled score (Table 20) it can be seen that age and NART error score make a significant contribution to the prediction of an individual's performance on this outcome variable, with age accounting for 14.7% of the variance and NART error score explaining 11.5% of the variance (both $ps<0.001$). The addition of other demographic variables did not contribute significantly to the model's predictive ability ($p>0.05$).

The coefficient values for Hayling time 1, Hayling time 2, Hayling total error score, and Hayling total scaled score are presented in Table 22. These values are incorporated into the regression equations presented in Table 24.

3.6.3 Results of Regression Analyses for the Brixton test

The results presented in Table 21 indicate that age, NART error score, and gender all made a significant contribution to an individual's performance on the Brixton test. In relation to the Brixton error score, age accounted for 13.3% of the variance in performance, NART error score explained 11.3% of the variance, and gender accounted for a further 8.2% (all $ps<0.001$). Similar results were obtained for the Brixton scaled score, with age, NART error score, and gender accounting for 14.5%, 11.4%, and 7.3% of the variance, respectively (all $ps<0.001$). Again, the addition of other demographic characteristics did not contribute substantially to the models predictive ability for each of these outcome variables.

The coefficient values for the Brixton error score and Brixton scaled score are presented in Table 23. These values are incorporated into the regression equations presented in Table 24.

3.6.4 Results of Regression Analyses for the Six Elements Test (SET)

The information displayed in Table 21 indicates that age (8.1%, $p<0.01$) and highest qualification (9.3%, $p<0.001$) were the only predictor variables that made a significant contribution to individuals' performance on SET. Before entering highest qualification into the regression analysis NART error score was entered into the model in order to determine whether this variable significantly improved the model. The addition of

NART error score did not reach statistical significance ($p>0.05$). Therefore, NART error score was removed from the analysis.

The coefficient values for SET raw score are presented in Table 23. These values are incorporated into the regression equations presented in Table 24 below.

Table 24: Regression Equations for the prediction of test scores based on relevant demographic variables and NART Error score

Test	Regression Equations	Std. Err. Est.
TMT Part A	-19.987 + (0.685 x Age) + (4.031 x Gender)	9.46
TMT Part B	-151.366 + (2.820 x Age) + (1.737 x NART Error)	26.57
TMT B – TMT A	-135.732 + (2.152 x Age) + (1.575 x NART Error)	21.26
Hayling Time 1	-27.785 + (0.391 x Age) + (0.411 x NART Error)	7.61
Hayling Time 2	-75.074 + (1.185 x Age) + (1.763 x NART Error)	38.23
Hayling total error score	-6.976 + (0.109 x Age) + (1.228 x Socio-Economic Status)	3.31
Hayling total scaled score	30.416 + (-0.152 x Age) + (-0.160 x NART Error)	3.07
Brixton Error Score	-15.327 + (0.293 x Age) +(0.325 x NART Error) + (4.260 x Gender)	5.95
Brixton Scaled Score	14.550 + (-0.084 x Age) + (-0.089 x NART Error) + (-1.101 x Gender)	1.62
SET Raw Score	6.520 + (-0.025 x Age) + (0.171 x Highest Qualification)	0.91

The standard error of estimate for each test was multiplied by z values of 1.03, 1.64 and 2.32 to derive 85%, 95% and 99% confidence intervals. These values can be used to measure 'extreme deviations' from predicted test performance (Crawford & Howell,

1998). Because it is assumed that clinicians using these equations would have a directional hypothesis about change in a client's level of performance (i.e. predicting a decline in an individual suspected to be suffering from neurological disease progression), these values are for a one-tailed significance test. The critical values are presented in Table 25.

Table 25: Critical values for regression equations using demographic characteristics and IQ (NART Error) as predictor variables

Task	85%	95%	99%
TMT Part A	9.74	15.51	21.95
TMT Part B	27.37	43.58	61.64
TMT B – TMT A	21.90	34.87	49.32
Hayling Time 1	7.84	12.48	17.66
Hayling Time 2	39.38	62.70	88.69
Hayling total error score	3.41	5.43	7.68
Hayling total scaled score	3.16	5.03	7.12
Brixton Error Score	6.13	9.76	13.80
Brixton Scaled Score	1.67	2.66	3.76
SET Raw Score	0.94	1.49	2.11

An example of how to use these regression equations in clinical assessment is presented in the Discussion section of this paper.

3.7 Summary of Results in Relation to Hypotheses

Hypothesis 1: Increasing age was associated with lower scores on all measures of executive function. Therefore, the findings of this study support Hypothesis 1.

Hypothesis 2: Lower NART error scores were associated with higher scores on all tests of executive function. Therefore, the findings support Hypothesis 2.

Hypothesis 3: Years of education was positively associated with higher scores on all tests of executive function. Therefore, the results presented here support Hypothesis 3.

Hypothesis 4: Higher academic qualifications were associated with higher scores on all tests of executive function. Therefore, the results support Hypothesis 4.

Hypothesis 5: Lower SES was associated with higher scores on all tests of executive function. Therefore, the findings presented here support Hypothesis 5.

Hypothesis 6: Not every variable that was found to be associated with scores on tests of executive function contributed significantly to the prediction of test scores. Therefore, Hypothesis 6 is not supported.

Chapter 4: Discussion

The fundamental purpose of the present study was to provide clinicians with a means of accurately quantifying deficits in a client's performance on four neuropsychological tests of executive function. This was integrated within two main objectives. The first aim was to investigate which factors or variables should be considered when predicting initial test score on the Trail Making Test (TMT), the Modified Six Elements Test (SET), and the Hayling and Brixton tests. It is known that demographic variables such as age, years of education and social class often influence performance on neuropsychological tests (Temkin et al, 1998). Bearing this in mind, the inclusion of these variables may improve the reliability when quantifying deficits in an individual's neuropsychological test performance. Therefore, the second objective was to evaluate models representing the influence of demographic, cognitive (premorbid intelligence as estimated by the NART) and mood variables (HADS constructs of anxiety and depression) on test performance on the four neuropsychological measures of executive function.

By determining which variables influence performance on the four tests, regression equations were built to allow prediction of test scores based on a combination of relevant variables. Through comparing an individual's expected test score with their obtained test score, the abnormality of any observed difference between these scores can be determined with reference to a table of critical values. This method of evaluation provides the clinician with an individualised comparison standard and offers an alternative to the more conventional approach of assessing a client for acquired

neuropsychological dysfunction, which traditionally involves consulting tables of normative values.

It is relevant to mention here the expected unique contribution of age to test performance. According to the executive decline hypothesis, executive functioning skills decline with advancing age in the 'normal' older adult population. Therefore, it was hypothesised that increasing age would be associated with poorer executive function test performance. By recruiting a sample of participants drawn from the general older adult population it was intended to incorporate normal degrees of age-related change into the prediction equations.

Tables displaying the regression equations and critical values for assessing whether observed differences between predicted and obtained test scores are out-with the normal range are presented in the Results section of this report. The potential use of these regression equations in clinical practice is illustrated later in this section where demographic variables are included in the analysis.

4.1 Interpretation of Results

The main outcome measures used for the purposes of the present study were completion time on the TMT Part A, TMT Part B, Hayling test Section 1 and Hayling test Section 2. The TMT difference score (TMT B – A), Hayling total error score, Hayling total scaled score, Brixton error score, Brixton scaled score and the SET raw score were also utilised as primary outcome measures.

4.1.1 A Brief Summary of The Main Research Findings

As expected, increasing age was associated with poorer test performance on all primary outcome measures (all *p*s<0.01). The strength of the relationship between age and test scores varied form test to test, with the strongest correlation evident between age and performance on TMT Part B ($r = 0.634$, $p<0.01$) and the weakest correlation between age and time to completion on Section 2 of the Hayling test ($r = 0.264$, $p<0.01$). These findings replicate the results of other studies, such as Salthouse and colleagues (2003) who also reported a significant relationship between increasing age and deficiencies in executive functioning test performance. Furthermore, the results from this set of analyses lend support to executive decline hypothesis of cognitive aging.

However, the relationship between age and poorer test performance was not unique. Indeed, for each of the primary outcome measures used, poorer test performance was also associated with fewer years of education, lower educational achievements (i.e. qualifications), lower socio-economic status, and lower IQ (as estimated by the NART). Again, the strength of the relationship between demographic variables and test scores varied. For instance, a modest relationship was observed between IQ (NART error score) and the amount of errors produced on the Hayling ($r = 0.267$, $p<0.01$), while a much stronger relationship was found between educational achievement and the difference score on the TMT (TMT B – TMT A) ($r = -0.499$, $p<0.01$). Moreover, a small, but significant effect of gender was also occasionally observed. For example, being male was associated with better test performance on the TMT Part A ($p<0.05$) and the Brixton test ($p<0.01$). Overall, the results of this set of analyses suggest that those demographic characteristics listed above should be taken into consideration when interpreting a client's score on the tests used in this study.

The investigation of the effects of adding demographic variables (i.e. age, total years of education, and social class), the measure of general intelligence (NART error score) and the HADS mood constructs (anxiety and depression) to regression models revealed, as expected, that age was a significant predictor of test score on all four tests of executive function. The proportion of variance explained by age varied for each outcome measure. For instance, age alone accounted for 40.2% of the variance in performance on the TMT Part B, but only 8.1% of the variance on the SET. Nonetheless, this set of results also replicates the findings of other regression-based studies (e.g. Tombaugh, 2004) that have found the inclusion of age to improve the prediction of test scores and, in doing so, appears to provide further support for the hypothesis that normal aging is associated with a decline in frontal executive functioning.

However, as previous researchers such as Heaton and colleagues (1996) and Temkin and colleagues (1999) have noted, it was found that the addition of NART error score and other demographic variables to the regression analysis significantly improved prediction accuracy of test scores by reducing the amount of unexplained variance in performance. It is important to point out though, that the results of the regression analyses indicate that variables that correlate with baseline test performance do not necessarily contribute to the prediction of test scores. For example, having more years of education was significantly associated with faster response times on the TMT Part B (r = -0.413, p<0.01), but adding years of education to the TMT Part B regression model did not improve the models predictive ability. Bearing this in mind, the findings will now be discussed in relation to those variables that were found to exert a significant influence upon the regression models ability to explain scores on the tests of interest.

4.2 Findings From The Regression Analysis

4.2.1 The Hayling Test

Despite the statistically significant correlations between demographic variables and Hayling test performance noted in Table 18, the results of the regression analyses suggests that only age and premorbid intelligence or socio-economic status, are significant predictors of Hayling test scores. In relation to Hayling response times, age uniquely accounted for 15.4% of the variance on section 1 of the test and 6.9% of the variance on section 2. Adding NART error score (i.e. estimated IQ) to the regression model significantly improved the prediction of both section 1 (12.1%, $p<0.001$) and section 2 (10.1%, $p<0.001$) test scores. These results suggest that task performance declines with advancing age. More specifically, older participants produce significantly slower response times than younger participants on both sections of the Hayling test, while individuals with higher estimated intelligence appear to respond quicker than those of lower general intelligence.

Given such results, and the fact that the Hayling scaled score is derived from a participants' performance on section 1 and section 2 of the test, it is perhaps unsurprising that increasing age and lower estimated intelligence is associated with poorer overall test performance, with age and NART error score accounting for 14.7% and 11.5% of the variance, respectively.

In addition to this, increasing age and lower socio-economic status were found to have a negative effect on the proportion of response errors produced on section 2 of the Hayling: with older participants and those from poorer socio-economic backgrounds generally producing significantly more connected (category A errors) and somewhat

connected (category B errors) response errors. Age alone accounted for 8.1% of the variance in the Hayling error score. However, the inclusion of socio-economic status in the regression model brought about a substantial change in R^2 (0.098).

Taken together, these results suggest that younger older adults and those with higher general intelligence are quicker at responding and more likely to be able to successfully inhibit a strongly activated response when compared to their more senior counterparts. From a qualitative point of view, it is interesting to note that those older adults who performed best on the executive component (section 2) of the Hayling test appeared to utilise some kind of strategy to assist them to successfully complete the task. For instance, participants often finished sentences with an unconnected word by naming objects that were present in the environment in which they were being tested. Based on this observation, it would seem reasonable to propose that a specific deficit in developing an appropriate strategy, rather than an inhibition deficit per se, may have negatively affected older participants' and less intelligent individuals' performance on this task. Burgess and Shallice (1996) observed a similar deficit in strategy application in a group of patients with frontal lobe lesions, suggesting frontal lobe dysfunction may compromise one's strategic thinking skills.

Overall, the influence of increasing age and IQ on Hayling test performance reported here is generally consistent with the findings of previous research (e.g. Bielak et al, 2006; Burgess & Shallice, 1997) and lends support to the hypothesis that executive functioning abilities decline in older adulthood. Furthermore, the results presented here suggest that a clinician should take account of a client's demographic characteristics (i.e. age and socio-economic status) and level of intelligence (NART error score) when

attempting to reliably estimate an older adults score on the Hayling test. Incorporating relevant variables into regression equations for the Hayling should help clinician's assess the abnormality of an individual's actual test score.

4.2.2 The Brixton Test

With respect to the Brixton test regression equations, the addition of age alone accounted for 13.3% ($p<0.001$) of the variance in Brixton error scores and 14.5% ($p<0.001$) of the variance in Brixton scaled scores. This time, however, it was found that adding the variables gender and NART error score to the regression models significantly improved the prediction of test performance. Indeed, the addition of gender brought about a substantial change in R^2 for both the Brixton error model and the Brixton scaled score model (0.082 and 0.073, respectively). The change produced in R^2 by adding NART error score to the Brixton error and Brixton scaled score models was more impressive (0.113 and 0.114, respectively). The relationship between NART error score and performance on the Brixton reported here supports the findings of Burgess and Shallice (1997) who also found that those with higher estimated intelligence produced fewer errors than individuals with lower general intelligence.

In relation to the inclusion of age and gender, Bielak and colleagues (2006) have also demonstrated an effect of these two variables on Brixton test scores: with older participants performing significantly worse than their younger counterparts and being female associated with an increasing error rate. However, the amount of variance explained by gender in this study is substantially more than that reported by Bielak and colleagues (2006) (8.2% versus 1.2%, respectively). Nonetheless, the effect of gender on Brixton test performance is an interesting result, and could reflect the hypothesised

discrepancy in non-verbal reasoning skills that is proposed to exist between men and women.

To summarise, the findings from the analyses of Brixton scores suggest that the Brixton is sensitive to normal age-related changes in executive functioning. The effect of advancing age on performance lends support to the executive decline hypothesis. Moreover, the results indicate that the ability to detect and apply logical rules is negatively affected by lower general intelligence. On the other hand, being male appears to place individuals at an advantage when it comes to discovering and following the rules presented on this task. Overall, the results suggest that taking account of a client's age, estimated level of intelligence, and gender will significantly improve the prediction accuracy of an individual's test score on the Brixton.

4.2.3 The Trail Making Test (TMT)

Similar results were obtained for the regression equations generated for the TMT Part A and B. However, on this occasion, it was the addition of age and gender to the equation for Part A that was found to improve prediction accuracy, while it was the addition of age and NART error score (i.e. IQ) that was found to improve the prediction accuracy on TMT Part B.

In relation to the TMT Part A, age alone accounted for 24.8% of the variance in performance. Adding gender to the regression analysis brought about a small, but significant change in R^2 (0.031, $p<0.05$). These findings replicate the results of other studies, such as Hester and colleagues (2005) who also reported an effect of age and gender on the TMT Part A: with older participants completing Part A significantly

slower than younger participants and being female also associated with slower psychomotor speed. While the effect of age on TMT Part A is generally accepted, the influence of gender on this part of the test is more controversial as other studies (Rasmusson et al, 1998; Tombaugh, 2004) have failed to demonstrate that sex influences performance. The gender effect found in the present study may, in part, be influenced by the fact that substantially more females than males are represented in the present sample.

The relationship between age and IQ and performance on the TMT Part B reported here is supported by the results of previous studies that have also found age (Tombaugh, 2004) and NART error score (Knight et al, 2006) to significantly influence one's performance on this part of the test. Overall, the inclusion of age and then the NART error score brought about a substantial change in R^2 (0.402 and 0.117, respectively). With older participants performing significantly worse than younger participants on the TMT Part B, and those with higher estimated intelligence performing better than those of lower general intelligence, these results suggest that a clinician should take account of a client's age and NART error score (intelligence) when attempting to reliably estimate an older adult's score on this part of the TMT. This information can then be used to assess the abnormality of an individual's actual TMT Part B test score.

Likewise, the inclusion of age and NART error score brought about a substantial improvement in the regression model produced for the TMT difference score (TMT B – A). Indeed, the results presented in Table 20 highlight that the variables age (37.2%, $p<0.001$) and NART error score (15.0%, $p<0.001$) together accounted for a significant proportion (52.2%) of the variance in the TMT difference score. Similar to the results

obtained on Part B of the test, advancing age was again found to have a negative effect on the TMT B – A difference score, while those with higher estimated IQs were found to score better than those with lower estimated IQ scores. Therefore, it would appear that the inclusion of these variables into the regression equation should significantly improve the accuracy with which a clinician can reliably estimate an individual's TMT Part B – A score ($p<0.001$).

In summary, the results from the analyses of TMT scores suggest that an older adult's demographic characteristics and level of general intelligence significantly influences their test performance. More specifically, the findings suggest that increasing age negatively influences psychomotor speed. Being female also appears to result in slower response times on the TMT Part A. Meanwhile, older adult's ability to shift cognitive set appears to be adversely affected by increasing age and lower levels of premorbid intelligence: with slower completion times on TMT Part B associated with increasing age and lower estimated intelligence. This last result provides support to the executive decline hypothesis and suggests that a clinician should take account of a client's age, estimated level of intelligence, and gender when interpreting their performance on the component parts of the TMT.

4.2.4 The Modified Six Elements Test (SET)

It was found that adding the variables age and qualification (i.e. highest educational achievement) to the regression model contributed significantly to the prediction of test scores on the SET. In relation to the inclusion of age, other studies (Wilson et al, 1996) have also demonstrated an effect of age on SET performance: with older participants performing significantly worse than their younger counterparts. This finding contrasts

with the results of Garden and colleagues (2001) who found no age difference between a group of younger and older adults in terms of their performance on the SET. However, it should be noted that the present study has a significant advantage over Garden and colleagues (2001) study, through having recruited a larger sample of participants and a broader age range of older adults.

Previous studies do not appear to have investigated the effects of other demographic variables on SET performance. However, this study found that educational achievement exerts an influence on SET performance. With respect to this, the regression analysis indicates that the higher an individual's educational achievements, the better they are likely to score on the SET. This is an important finding, which suggests that a clinician should take account of a client's level of education when interpreting their performance on the SET.

Overall, the findings presented here indicate that an older adult's ability to successfully complete a real-life task that involves planning, organisation and monitoring of performance is negatively affected by advancing age and lower educational achievements. Although the proportion of variance explained was relatively modest when age (8.1%, $p<0.01$) and then qualification (9.3%, $p<0.001$) were incorporated into the regression equation, the significance values do suggest that the consideration of these variables will substantially improve the accuracy of prediction of an individual's score on the SET.

4.2.5 End Summary: General Findings From The Regression Analysis

In sum, although age was a significant predictor of initial test performance on the Trail Making Test, the Hayling test, the Brixton test, and the Modified Six Elements Test, other factors in the regression models did increase the prediction accuracy to some extent. In general, the most important of these predictors was a measure of general intelligence (NART error score), which significantly improved prediction accuracy on all test measures with the exception of the SET. However, other demographic characteristics also improved prediction accuracy on some of the tests. Poor test performance was not associated with negative affect (as measured by the HADS). The regression equations presented in Table 24 represents the relationship between predictor variables and scores on each of the tests of interest.

It should be noted that where variables are not included in the regression equations, this does not imply that an individual's other personal characteristics and abilities do not correlate with test performance. Indeed, as Tables 17 and 18 indicate, variables such as total years of education, social class and educational achievement do appear to influence initial test performance on some measures even although they are not incorporated into the regression equations. However, the regression analysis tells us that these variables either (a) do not explain a significant proportion of the variance in test performance ($p>0.05$), or (b) where they do help explain test performance this characteristic is shared with other independent variables (i.e. their contribution is not unique).

A hypothetical case scenario that a clinician may be faced with is presented below in order to illustrate how these equations could be used in clinical practice. Using the information in Table 24 and 25, the inclusion of demographic variables into the

equations should make it more likely that a clinician will be able to detect true declines in an older adults cognitive functioning when compared to using existing normative data.

4.3 Applying Regression Equations in Clinical Practice

Suppose, for instance, that a client suspected to be suffering from Dementia of the Alzheimer Type (DAT) is sent to a clinician for assessment. Using the regression equation presented in Table 24, the clinician can calculate the client's estimated error score on the Brixton by substituting into the equation the client's age, gender and their NART error score as follows:

$$\underline{\text{Predicted Brixton Error Score}} = -15.327 + (0.293 \times \text{Age}) + (0.325 \times \text{NART Error}) + (4.260 \times \text{Gender})$$

If the client is a 55 year-old male and scored 10 errors on the NART, this would yield an estimated initial test score of 8.3 (or 8 if we round the figure down accordingly).

$$\text{i.e. } \underline{\text{Predicted Brixton Error Score}} = -15.327 + (0.293 \times 55) + (0.325 \times 10) + (4.260 \times 1)$$

The difference between this estimate and the client's obtained Brixton error score of 18 is 9.7 (or 10). This suggests that the client may have an acquired deficit in rule detection/concept formation, as it can be seen from Table 25 that less than 5% of the healthy older adult sample would be expected to exhibit a discrepancy of this magnitude in Brixton test score. In other words, a discrepancy of 10 between predicted and

obtained Brixton error scores is sufficient to exceed 95% of the expected sample and would imply that there has been a genuine decline in the client's cognitive functioning.

However, referring to the normative data published in the author's test manual the client's Brixton error score of 18 would place him within the 'moderate average' range of functioning. Under normal circumstances such a performance may not be deemed too concerning. Therefore, it can be seen that by using the data presented in the test manual the clinician could arrive at a different conclusion about the client's test performance. In other words, because the normative data presented in the test manual does not take account of the moderating effect of age, gender, and premorbid intelligence on Brixton error scores, the performance of a 55 year-old gentleman with a low NART error score (i.e. high premorbid intelligence) is imprecisely classified as generally within 'normal' limits, when in reality his performance most likely represents a deterioration in functioning.

Bearing this in mind, the multiple regression approach illustrated above appears to hold a distinct advantage over the more traditional comparative approach by improving the accuracy with which the clinician can detect an abnormal test performance in the individual case. This, in turn, improves the sensitivity of the test and its potential contribution to the diagnostic process (Knight et al, 2006).

4.4 Clinical Implications

Taking this into consideration, the results presented here could have significant implications for treatment and clients' rehabilitation. For instance, improving the precision with which deficits in older adults' executive functioning abilities can be

detected should help ensure that effective interventions are formulated and implemented in a timely manner. Such interventions could involve providing psychoeducation to a client's family and close friends. Discussing a client's cognitive difficulties in relation to their everyday functioning provides a context that can help explain their behaviour and why there may be changes in their ability to complete specific tasks of daily living. Increased understanding could help preserve relationships and prevent a decline in family functioning.

In addition to this, accurate quantification of executive impairments would allow the clinician to develop an individualised programme for cognitive rehabilitation aimed at remediation of the executive deficits previously identified. This could involve problem solving therapy (Evans, 2003) or self-instructional training to help reduce impulsivity (Cicerone & Wood, 1987). Furthermore, the clinician can use the information from assessment to make recommendations to other health professionals about ways of modifying their therapeutic approach in order to provide the client with the optimum environment that should help them realise their rehabilitation potential.

In the context of a progressive neurological disorder, accurate identification of the client's difficulties at an earlier stage in the disease process would allow pharmacological interventions to be considered as a potential treatment sooner than what otherwise might have been. From a practical point of view, timely identification of deficits in this manner would provide clients with an early opportunity to discuss legal matters or money issues and thus ensure that their affairs are put in order while they are still cognitively able.

4.5 Theoretical Implications

The theoretical implications of this study have been addressed throughout the discussion section of this manuscript. Suffice to say that there is a need to consider an individual's demographic characteristics when involved in interpreting a client's test scores on the measures of executive function used in this study. Crucially, the results presented lend support to hypothesis that executive function skills decline in older adulthood. Furthermore, by accurately identifying executive skills deficits that have been proposed to be intimately involved in memory functioning, a clinician can use the information presented in this study to more precisely measure whether impairments in a client's executive functions may be contributing to a deterioration in their memory performance.

4.6 Strengths and Limitations of the Study

Given that data drawn from samples of convenience place severe restrictions on the potential application of the results drawn from such studies, the present study attempted to obtain as broad a sample of community-dwelling older adults as possible in terms of sex, age and social class distribution. Although the present sample size (n=106) was relatively modest, the final sample of participants incorporated a broad cross-section of society. Therefore, the inclusion of psychologically stable participant's with widely varying demographic characteristics and levels of baseline test performance represents a particular strength of the study.

A number of other advantages of this study are also worth mentioning. Firstly, the study incorporated four psychological measures of executive function that are used routinely in neuropsychological clinical and research applications. Two of these tests

(the Hayling and Brixton) are relatively new and the information presented here appears to offer a valuable contribution to the research literature on these tests through the provision of regression equations based on a UK older adult population. However, the major advantage of the present study lies in the presentation of demographically and IQ based regression equations which provide a set of continuous norms that neuropsychologists can use to determine with more precision the degree to which an older adult's executive function test score reflects an abnormal performance. As previously discussed, this method of detecting cognitive impairment has some clear advantages over more traditional means of comparison.

In line with this, there is strength in the fact that the sample consists solely of older adults, as the data presented significantly contributes to addressing the lack of existing normative data for evaluating this population on the measures of neuropsychological functioning used in this study.

However, as with all research projects, the findings reported in this study are constrained by a number of limitations. Firstly, the study was conducted in the North East of Scotland and comprised a British sample of white ethnic origin. This obviously places restrictions on the generalisation of the results and suggests that the equations should be used with caution in people from other cultural backgrounds. Furthermore, only two participants were over the age of 86 and because all participants were living independently in the community the findings may be limited by the selection of a sample of 'successfully aging' older adults, rather than a 'typically aging' cross-section of the older adult population.

Having said this, given the relative increase in dementia with advancing age, it is feasible that a proportion of the sample is in a prodromal phase of the disease (Backman, Wahlin, Small, Herlitz, Winblad & Fratiglioni, 2004) and this could account for a portion of the age-related variance in test performance. Unfortunately, it was not possible for the researcher to review volunteer's medical notes or screen them for dementia prior to their participation in the study. Subjecting participants to a psychiatric and/or neuropsychological dementia screening assessment would have been unrealistic due to time demands. In order to address this limitation, the researcher sent a short screening questionnaire to all volunteer's GPs (Appendix 18) requesting basic medical information which the participant had agreed could be shared. However, at the time of writing only eight (7%) GPs had responded with this information.

Numerous researchers (e.g. Bryan & Luszcz, 2000; Garden et al, 2001) point out that successful performance on tasks of executive function (including those utilised in the present study) relies on a number of cognitive processes. For instance, performance on the TMT Part B depends on an understanding of task instructions, psychomotor speed, visual scanning ability, attention, memory, sequencing, and mental flexibility. This can cause interpretative problems, as a low score on this task may be due to impairment in any one of these component processes, rather than impaired executive functioning. This highlights the importance of assessing individuals on a range of tests of executive function rather relying on a single measure from which to draw conclusions. Furthermore, in the absence of corroborating evidence, say from the results of neuroimaging investigations, it would be inaccurate to conclude that poor executive functioning is synonymous with frontal lobe impairments, as we know that damage to

regions of the brain other than the frontal lobes could account for deficits in executive task performance (Salthouse, Fristoe & Rhee, 1996).

4.7 Future Research

An important finding to emerge from the study concerns the influence of various demographic variables and estimated general intelligence on the tests of executive function utilised in this study. Consequently, it would seem a worthwhile task to endeavour to investigate whether such effects are also evident with other samples and with other neuropsychological measures of executive functioning.

Meanwhile, the different clinical interpretations that can be made of the same test score when relying on either the regression based approach described here or traditional comparative standards, suggests that developing adequate test norms for the older adult population should be viewed as a priority. With respect to this, it would have been desirable to assess the validity of the regression equations generated in the present study by recruiting a new sample of participants that matched the present sample in terms of IQ and demographic characteristics. For instance, comparing healthy volunteers predicted and obtained test scores would have allowed the accuracy of the regression equations developed here to be measured. Surprisingly few cross-validation studies appear to be represented in the literature where regression equations have been produced. However, adding this extra dimension to the study would be a time consuming venture and perhaps this more than any other reason accounts for the lack of such investigations.

In addition to this, it would be interesting to investigate whether the influence of demographic variables and general intelligence also influence participants scores at retest. Bearing in mind that a diagnosis of probable dementia should only really be made after repeated assessments (Lezak et al, 2004), it would be worthwhile documenting whether these variables also affect follow-up test performance.

Finally, it would be worth repeating the study using a larger and broader sample of community-based older adults. Recruiting a high and roughly even number of participants for each of the age bands represented in Table 2 and each of the socio-economic groups represented in Table 4, would improve the reliability of subsequent findings and the extent to which generalisations can be made.

4.8 Conclusion

Using multiple regression analysis this study presents a practical means by which clinicians can determine whether the difference between a client's expected and obtained test performance on four neuropsychological measures of executive function is significant or not. In particular, the study found that variables that correlate with initial test performance do not necessarily contribute to the prediction of test performance. However, as discussed, the results suggest that adding age, a measure of intelligence and other relevant demographic characteristics to the regression equations can significantly improve the accuracy of predicting a client's expected test score. Perhaps significantly, through the illustration of a hypothetical case scenario it was found that using regression equations in clinical practice could improve the accuracy with which a deficit in neuropsychological test performance can be detected. Consequently, it was

noted that it would be beneficial to investigate whether such effects are evident on other measures of neuropsychological functioning, especially if using them to address changes in cognitive ability.

Overall, the findings presented here appear to provide further support for the hypothesis that normal aging is associated with a decline in frontal executive functioning.

Of course it is not the intention here to claim that the methods described in this study will lead to optimal validity when it comes to quantifying deficits in a client's test performance using the values presented in the tables. Rather, the methods for measuring deficits in test performance presented in this study illustrate that they may be a potentially valuable clinical tool when trying to detect *true* changes in neuropsychological functioning.

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Appendix 1

Letter to Service Managers

Department of Clinical Psychology
Elmwood
Royal Cornhill Hospital
Cornhill Road
Aberdeen AB25 2ZH
Telephone: 01224 557130

30th January 2006

Dear

Quantifying Change in Neuropsychological Functioning in the Older Adult Population

I am a 4th year Trainee Clinical Psychologist hoping to do a piece of research for my final year thesis that involves measuring the performance of older adults on a small battery of intellectual tests. For this piece of work to be viable, I will need to collect data from about 100 adults over the age of 55.

Bearing this in mind, I would be most grateful if you would allow me the opportunity to invite members of the ..... Club who are aged 55 and over to participate in the study. Should you find this request acceptable, then with your permission, it would be my intention to attend the centre at a suitable time in order to deliver a short 5 minute presentation on the study. This presentation will inform potential participants of the study aims, objectives and what they would be required to do should they agree to participate. Please note that I do not require the names of individual members.

If you would like any further information about the project, and its potential for contributing to service development, please contact me directly on the telephone number listed below. I look forward to your response.

Yours sincerely

Bruce Downey
Trainee Clinical Psychologist
(01224 557148)

Dr Angus Lorimer
Clinical Psychologist
(01224 557130)

Appendix 2

Letter of Invitation to Participants

Department of Clinical Psychology
Elmwood
Royal Cornhill Hospital
Cornhill Road
Aberdeen AB25 2ZH
Telephone: 01224 557148

10th March 2007

Measuring Change in Functioning in the Older Adult Population

You are being invited to take part in a research study. Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask me if there is anything that is unclear or if you would like more information. Take time to decide whether you wish to take part and thank you for reading this.

What is the purpose of the study?

As part of my Doctorate training in Clinical Psychology I am currently carrying out a study that involves looking at the performance of people aged 55 years and over on specific ability tests. Given that reports of changes in ability increase with advancing age, it is increasingly important to know how the healthy older adult population performs on these tasks. Unfortunately, the information that is currently available on this is of limited value.

Therefore, this project plans to develop an accurate means of detecting abnormal test performance in people aged 55 years and over. Consequently, the results of this project should provide valuable information that will inform the diagnostic process when a change in ability in an older adult is suspected.

Why have I been chosen?

In order to investigate this we need to recruit a group of people that **do not** have memory problems and are aged 55 years or over. You are being invited to participate because you fit these criteria.

(please turn the page)

What will I be asked to do?

Should you agree to participate in the study, you will be asked to complete 3 short paper and pencil tasks. This will help determine your current level of ability. You will also be asked to complete a short questionnaire. This will be used to assess mood. You will be assessed on these measures once. Completing these assessments should take no longer than 30 minutes.

Do I have to take part?

No. It is up to you to decide whether to take part. Should you decide not to take part in the study this will not affect your current or future NHS care. If you decide to take part, please could you complete the attached contact sheet and return to me in the stamp addressed envelope provided.

Confidentiality

Each participant's identity will remain completely anonymous and all information provided will be treated in the strictest confidence. If you agree to take part your GP will be contacted. This will be done in order to confirm the medical information that you provide.

What will happen to the results of the study?

The results from this study will be written up and submitted for academic review in accordance with my obligations as a Trainee Clinical Psychologist on the University of Edinburgh's DClinPsych course.

If you would like any further information about the project, and how it might be helpful to other people, please contact me directly on the telephone number listed below.

Yours Sincerely

Bruce Downey
Trainee Clinical Psychologist
Telephone: 01224 557148 (9am to 5pm)
Telephone: 01224 484041 (after 5pm)

Dr Angus Lorimer
Clinical Psychologist
Telephone: 01224 557130

Appendix 3

Contact Details and Background Information Sheet

BACKGROUND INFORMATION

1. Name _____

2. Address _____

_____

_____

3. Telephone Number _____

4. Age (in years) _____

5. Gender: Male Female

6. What is your highest qualification? _____

7. Total years of education? _____

8. What is your occupation (or previous occupation if no longer in employment)?

If you have never been in paid employment please write 'home'. (Here are some examples of the levels of detail we require: chemical engineer, labourer in building industry, sales assistant in department store, etc)

_____

Please could you complete this sheet and return to me at the following address:

Bruce Downey
Department of Clinical Psychology
Elmwood
Royal Cornhill Hospital
Cornhill Road
Aberdeen AB25 2ZH

Thank you.

Appendix 4

Consent Form

Quantifying Change in Neuropsychological Functioning in the Older Adult Population

Name: .....

Address: .....

Contact telephone number: .....

I have read the information sheet on the above named study. I have had the opportunity to contact Bruce Downey, Trainee Clinical Psychologist, to discuss the details.

I have agreed to take part in the study as it has been outlined to me. I understand that I am completely free to withdraw from the study at any time, without having to give a reason.

I grant Mr Downey permission to contact my GP in order to verify my medical history.

I hereby fully and freely consent to my participating in the study, which is outlined on the enclosed information sheet.

Signature of Named Individual:.....

Date: .....

I wish to receive a copy of the findings of this study Yes No
(delete as appropriate)

Appendix 5

Screening Sheet

Do you suffer from a neurological illness such as,
Parkinson's Disease
Huntington's Disease
Dementia

Have you ever suffered from,
A stroke
A head Injury in which you were unconscious and hospitalised

Have you ever suffered from a major psychiatric illness that involved hospitalisation?

Have you ever suffered from an alcohol or drug problem that involved hospitalisation?

Are you currently receiving medication for a psychological problem?

Appendix 6

NART Word Sheet

National Adult Reading Test (NART)
Word Card

CHORD	SUPERFLUOUS
ACHE	SIMILE
DEPOT	BANAL
AISLE	QUADRUPED
BOUQUET	CELLIST
PSALM	FACADE
CAPON	ZEALOT
DENY	DRACHM
NAUSEA	AEON
DEBT	PLACEBO
COURTEOUS	ABSTEMIOUS
RAREFY	DETENTE
EQUIVOCAL	IDYLL
NAIVE	PUERPERAL
CATACOMB	AVER
GAOLED	GAUCHE
THYME	TOPIARY
HEIR	LEVIATHAN
RADIX	BEATIFY
ASSIGNATE	PRELATE
HIATUS	SIDEREAL
SUBTLE	DEMESNE
PROCREATE	SYNCOPE
GIST	LABILE
GOUGE	CAMPANILE

Published by The NFER-NELSON Publishing Company Ltd., Darville House, 2 Oxford Road East, Windsor, Berkshire SL4 1DF.

1 (7.86) 1104

Appendix 7

The Trail Making Test

TRAIL MAKING

Part A

SAMPLE

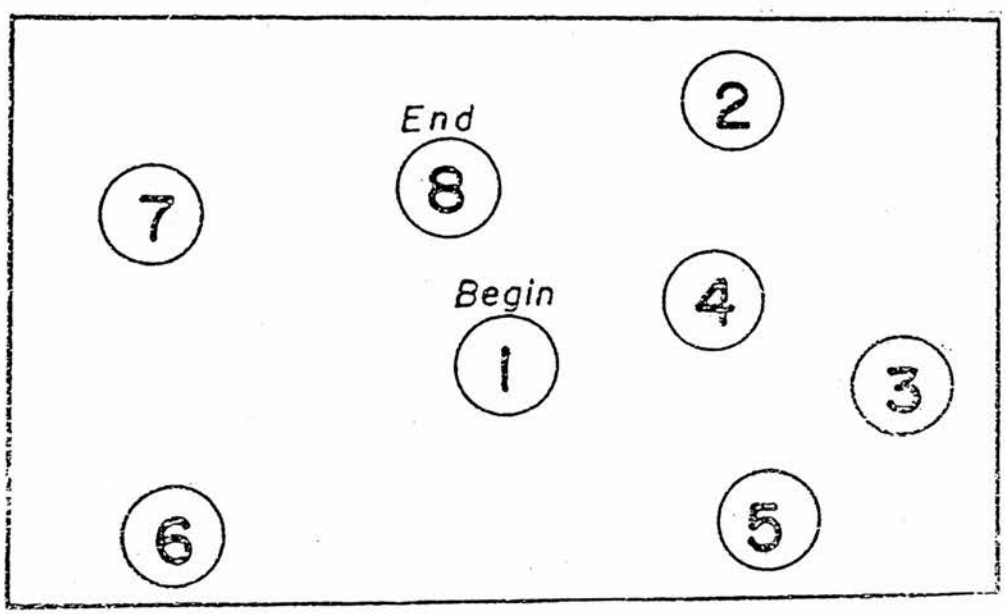


Table 17-6 Distribution of Trail Making Test Scores (in Seconds) for Normal Control Subjects for the Six Decades Beginning with Age 20

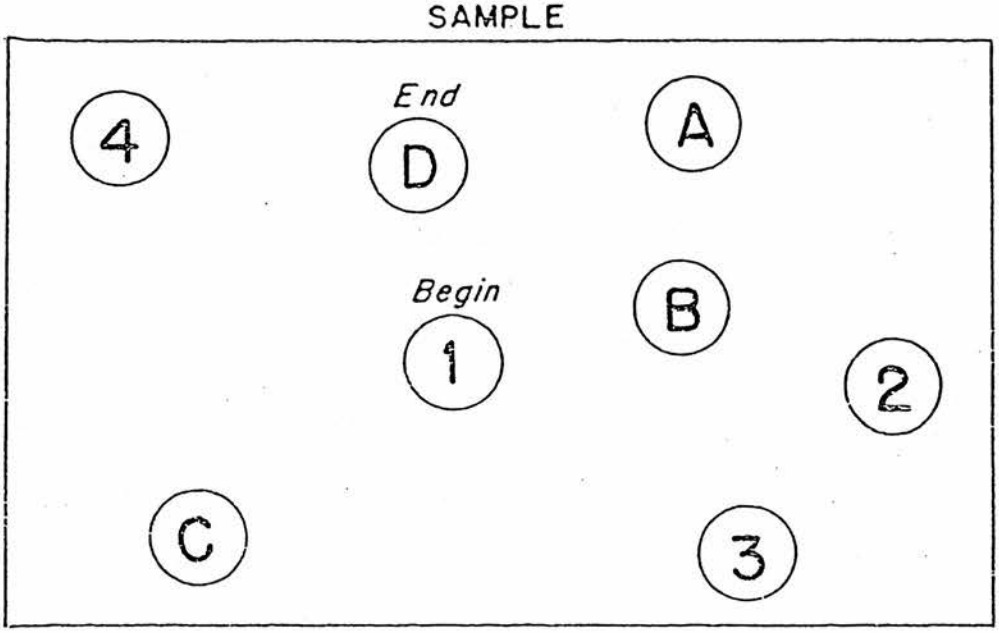
Age	20 to 39 (n = 180)		40 to 49 (n = 90)		50 to 59 (n = 90)		60 to 69 (n = 90)		70 to 79 (n = 90)	
Part	A	B	A	B	A	B	A	B	A	B
Percentile										
90	21	45	22	49	25	55	29	64	38	79
75	26	55	28	57	29	75	35	89	54	132
50	32	69	34	78	38	98	48	119	80	196
25	42	94	45	100	49	135	67	172	105	292
10	50	129	59	151	67	177	104	282	168	450

(Adapted from Davies, 1968)

TRAIL MAKING

Part B

SAMPLE



Appendix 8

The Hayling Test Recording Sheet

the **Hayling** and **Brixton** tests — Scoring sheet

TVTC
Thames Valley Test Company

Subject and test details

		Further details
Name		
Age		
Date of test		

The Hayling Sentence Completion Test

Score summary

Box A		Box B		Box C		Total scaled scores
	+		+		=	→
(Section 1 Scaled score)		(Section 2 Scaled score)		(Section 2 Errors scaled score)		

Table E		
Total scaled scores	Overall scaled score	Classification
23	10	Very superior
22	9	Superior
21	8	Good
20	7	High average
17–19	6	Average
15–16	5	Moderate ave.
13–14	4	Low average
11–12	3	Poor
10	2	Abnormal
<10	1	Impaired

Hayling overall scaled score

Hayling Section 1: sensible completion

- *In a moment I am going to read you a series of sentences, each of which has the last word missing from it. I want you to listen carefully to each sentence, and when I have finished each one, your job is to give me a word which completes the sentence. Do you understand?*

Practice

- *Before we start, I'll give you a couple of practice sentences so that you can get the hang of it. Are you ready?*

	Response	Time
P1 The rich child attended a private		
P2 The crime rate has gone up this		

Test

- *OK, that's the end of the practice items. The next few sentences I'll read aren't really any more difficult than the two you've just done. But the important thing is that I want you to give me your answer as quickly as you can – the faster the better. Is that clear?*

1 He posted a letter without a *or:* He mailed a letter without a		
2 In the first space enter your *or:* In the first blank enter your		
3 The old house will be torn		
4 It's hard to admit when one is		
5 The job was easy most of the		
6 When you go to bed turn off the		
7 The game was stopped when it started to		
8 He scraped the cold food from his		
9 The dispute was settled by a third		
10 Three people were killed in a major motorway *or:* Three people were killed in an interstate		
11 The baby cried and upset her		
12 George could not believe that his son had stolen a		
13 He crept into the room without a		
14 Billy hit his sister on the		
15 Too many men are out of		
Total time (raw score)		→
Scaled score (transfer this to box A in score summary above)		

Table A		
Raw score	Scaled score	Comment
0	7	High ave.
1–9	6	Average
10–18	5	Moderate ave.
19–22	4	Low ave.
23–50	3	Poor
51–60	2	Abnormal
>60	1	Impaired

Hayling Section 2: unconnected completion

Now we are going to move on to the second section of the test. In this section I will read you a set of sentences with the last word missing just like the ones you have already done, but this time I want you to give me a word which does not fit at the end of the sentence – I want the word you give me to be completely unconnected to the sentence in every way. Do you understand?'

Practice

Before we start, I'll give you a couple of practice sentences so that you can get the hang of what is required'.

	Response	Time
P1 London is a very busy		
P2 Her new shoes were the wrong		

If the subject makes an error refer to instructions in Manual (page 8).

Test

'OK, that's the end of the practice items. Remember that the words you give me must be unconnected to the sentence, and that it is important for you to give me your answer as quickly as you can. Are you ready?'

The captain wanted to stay with the sinking		
They went as far as they		
Most cats see very well at		
Jean was glad the affair was		
The whole town came to hear the mayor		
Most sharks attack very close to		
None of the books made any		
The dough was put in the hot		
She called the husband at his		
All the guests had a very good		
He bought them in the sweet *or:* He bought them in the candy		
His leaving home amazed all his		
At last the time for action had		
The dog chased our cat up the		
At night they often took a short		

Total time (raw score) ←

led score (transfer this to box B in score summary on page 1)

Table B		
Raw score	Scaled score	Comment
0	8	Good
1–2	7	High average
3–50	6	Average
51–60	5	Moderate ave.
61–100	4	Low average
101–120	3	Poor
121–130	2	Abnormal
> 130	1	Impaired

Correct (unconnected)

Category A error (connected)

A score

Category B error (somewhat connected)

B score

Total Category A errors	A score
1	3
2	6
3	10
4	14
5	18
6	24
7	30
8	36
9	42
10	48
11	54
12	60
13	66
14	72
15	78

Total Category B errors	B score
1	1
2	2
3	3
4	4
5	9
6	14
7	19
8	24
9	29
10	34
>10	50

Total Cat. A errors | **A score** | Total Cat. B errors | **B score** | **Converted score** (A score + B score)

Table C		
Converted score	Scaled score	Comment
0	8	Good
1–3	7	High average
4–9	6	Average
10–12	5	Moderate ave.
13–14	4	Low average
15–17	3	Poor
18–29	2	Abnormal
≥ 30	1	Impaired

Hayling 2 errors scaled score (transfer this to box C in score summary on page 1)

Appendix 9

The Brixton Test Recording Sheet

The Brixton Spatial Anticipation Test

- *'There are many pages here which all have the same basic design on them. There are always ten positions, and one of them is always coloured blue'* [point to filled circle on page one]. *'However the coloured one moves around according to various patterns that come and go without warning. These numbers* [point to numbers underneath the circles] *are just here to refer to the position – there is nothing complicated or mathematical about this test'.*
- *'Now, as I turn the pages over, your job is to pick up on the pattern as best you can, and point to where you think the blue one is going to be on the next page. It's not guess-work – you can work it out. For instance, imagine the blue one was here* [point to position 6], *and then when I turn the page it goes to 7, and then to 8, then to 9 – you might reasonably expect it next to go to 10'.*
- *'From time to time the pattern changes without warning, and then it is your job to pick up on the new pattern as best you can. Do you understand?'*
- Give further assistance if necessary
- *'Obviously the first time you have nothing to go on, so your first answer will have to be a guess – have a guess as to where the blue one will be next'*

Item/ page	Correct answer	Subject's response	Correct/ incorrect
1	any		
2	3		
3	4		
4	5		
5	6		
6 *	7		
7	4		
8	3		
9	2		
10	1		
11	10		
12 *	9		
13	10		
14	5		
15	10		
16	5		
17	10		
18	5		
19 *	10		
20	7		
21	8		
22	9		
23	10		
24	1		
25	2		
26 *	3		
27	10		
28	9		
29 *	8		
30	1		
31	2		
32	3		
33	4		
34 *	5		
35	4		
36	10		
37	4		
38	10		
39	4		
40	10		
41 *	4		
42	9		
43	9		
44	9		
45	9		
46	9		
47	9		
48 *	9		
49	9		
50	8		
51	9		
52	8		
53	9		
54	8		
55	9		

Total number of errors (raw score)

Scaled score

Table D

Raw score	Scaled score	Classification
0–7	10	Very superior
8	9	Superior
9–10	8	Good
11–13	7	High average
14–17	6	Average
18–20	5	Moderate ave.
21–23	4	Low average
24–25	3	Poor
26–31	2	Abnormal
> 31	1	Impaired

Appendix 10

The Six Elements Test Recording Sheet

st 6: Modified six elements

full text and procedure see Manual p. 10

ange the test materials.

u get ten minutes for this next test, and in this test you will be ing three different kinds of task...'

through each task with the subject.

ring the next ten minutes I would like you to try to complete at ast some of each of the six individual parts...'

wever, there is one rule you must obey...'

w, tell me what you must do.'

t the timer for 10 minutes.

art the stopwatch and timer.

ecord the order of sub tasks attempted
d the subject's start and stop times

b task	Time started	Time stopped	Time on subtask

ummary of time spent on each sub task
nd number of correct responses

ub task	Total time on sub task
ictation A	
ictation B	
ictures A	
ictures B	
rithmetic A	
rithmetic B	

umber of sub tasks attempted (max = 6) ☐

Minus number of sub tasks where rules were broken (max = 3) ☐

Raw score ☐

Raw score	Profile score
6	4
4 or 5	3
2 or 3	2
≤ 1	1

Profile score ☐

f total time on any one sub task is greater than 271 econds, subtract 1 from profile score – ☐

Total profile score ☐

Thames Valley Test Company
7–9 The Green, Flempton
Bury St Edmunds
Suffolk IP28 6EL England

ISBN 1 874261 95 4

Appendix 11

The Hospital Anxiety and Depression Scale

Hospital Anxiety and Depression Scale (HADS)

Name: _____ Date: _____

Clinicians are aware that emotions play an important part in most illnesses. If your clinician knows about these feelings he or she will be able to help you more.

This questionnaire is designed to help your clinician to know how you feel. Read each item below and **underline the reply** which comes closest to how you have been feeling in the past week. Ignore the numbers printed at the edge of the questionnaire.

Don't take too long over your replies, your immediate reaction to each item will probably be more accurate than a long, thought-out response.

FOLD HERE

FOLD HERE

A D

I feel tense or 'wound up'
- Most of the time
- A lot of the time
- From time to time, occasionally
- Not at all

I still enjoy the things I used to enjoy
- Definitely as much
- Not quite so much
- Only a little
- Hardly at all

I get a sort of frightened feeling as if something awful is about to happen
- Very definitely and quite badly
- Yes, but not too badly
- A little, but it doesn't worry me
- Not at all

I can laugh and see the funny side of things
- As much as I always could
- Not quite so much now
- Definitely not so much now
- Not at all

Worrying thoughts go through my mind
- A great deal of the time
- A lot of the time
- Not too often
- Very little

I feel cheerful
- Never
- Not often
- Sometimes
- Most of the time

I can sit at ease and feel relaxed
- Definitely
- Usually
- Not often
- Not at all

I feel as if I am slowed down
- Nearly all the time
- Very often
- Sometimes
- Not at all

I get a sort of frightened feeling like 'butterflies' in the stomach
- Not at all
- Occasionally
- Quite often
- Very often

I have lost interest in my appearance
- Definitely
- I don't take as much care as I should
- I may not take quite as much care
- I take just as much care as ever

I feel restless as if I have to be on the move
- Very much indeed
- Quite a lot
- Not very much
- Not at all

I look forward with enjoyment to things
- As much as I ever did
- Rather less than I used to
- Definitely less than I used to
- Hardly at all

I get sudden feelings of panic
- Very often indeed
- Quite often
- Not very often
- Not at all

I can enjoy a good book or radio or television programme
- Often
- Sometimes
- Not often
- Very seldom

Now check that you have answered all the questions

A D

TOTAL

Code 4460 01 4 Printed in Great Britain 1(6.94)

Appendix 12

Letter of Approval From Local Research Ethics Committee

NHS
Grampian

Grampian Local Research Ethics Committee (2)
Summerfield House
2 Eday Road
Aberdeen
AB15 6RE

Telephone: 01224 558480
Facsimile: 01224 558609

09 January 2007

Mr Bruce Downey
Trainee Clinical Psychologist
NHS Grampian
Department of Clinical Psychology
Elmwood, Royal Cornhill Hospital
AB25 2ZH

Dear Mr Downey

Full title of study: **Quantifying Change in Neuropsychological Functioning in the Older Adult Population**

REC reference number: **06/S0802/129**

Thank you for your letter of 19 December 2006, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information was considered at the meeting of the Sub-Committee of the REC held on 09 January 2007. A list of the members who were present at the meeting is attached.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised.

- We would like to suggest that you check the insurance covers the study as it is not a clinical trial.

- In the patient information sheet and slides please could you remove "revised 01/12/06" from the text

Ethical review of research sites

The Committee has not yet been notified of the outcome of any site-specific assessment (SSA) for the research site(s) taking part in this study. The favourable opinion does not therefore apply to any site at present. I will write to you again as soon as one Local Research Ethics Committee has notified the outcome of a SSA. In the meantime no study procedures should be initiated at sites requiring SSA.

Appendix 13

Letter of Approval From Local Research and Development Office

Research and Development

Foresterhill House Annexe
Foresterhill
Aberdeen
AB25 2ZB

NHS Grampian

Date 26/03/07
Ethics 06/S0802/129
R&D Ref: 2007MH002

Mr Bruce Downey
Department of Clinical Psychology
Elmwood
Royal Cornhill Hospital
Aberdeen
AB25 2ZH

Enquiries to Katy Booth
Extension 54656
Direct Line 01224 554656
Email k.booth2@nhs.net

Dear Mr Downey,

Project title: Quantifying Change in Neuropsychological Functioning in the Older Adult Population.

Thank you very much for sending all relevant documentation. I am pleased to confirm that the project is now registered with the NHS Grampian Research & Development Office. The project has R & D Management Approval to proceed locally.

Please note that if there are any other researchers taking part in the project that are not named on the original Ethics application, please advise the Ethics Committee in writing and copy the letter to us so that we may amend our records and assess any additional costs.

Wishing you every success with your research

Yours sincerely

Katy Booth
Data Co-ordinator

Appendix 14

Letter of Indemnity Provided by the University of Edinburgh

COLLEGE of
MEDICINE and VETERINARY MEDICINE OFFICE

Room E1.06
The Queen's Medical Research Institute
University of Edinburgh
47 Little France Crescent
Edinburgh EH16 4TJ
Scotland UK

Tel. (0131) 242 9262
Fax (0131) 242 9301
Email marise.bucukoglu@ed.ac.uk

14 March 2007

Mr Bruce Downey
Department of Clinical Psychology
Elmwood, Royal Cornhill Hospital
Aberdeen
AB25 2ZH

Dear Mr Downey

06/S0802/129
Quantifying change in neuropsychological functioning in the older adult population

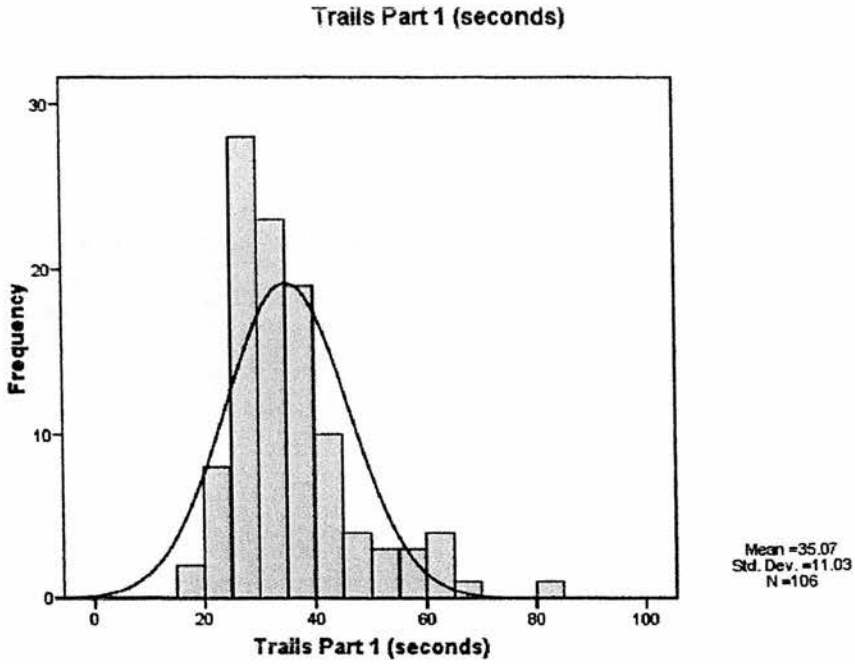
The University of Edinburgh agrees to be Sponsor for this project under the requirements of the Scottish Executive Health Department's Research Governance Framework for Health and Community Care in Scotland.

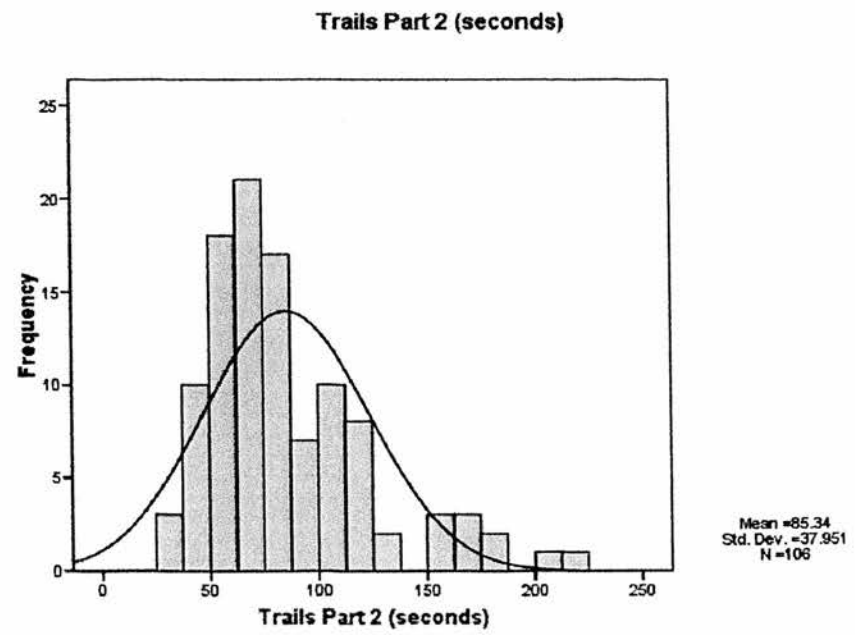
Yours sincerely

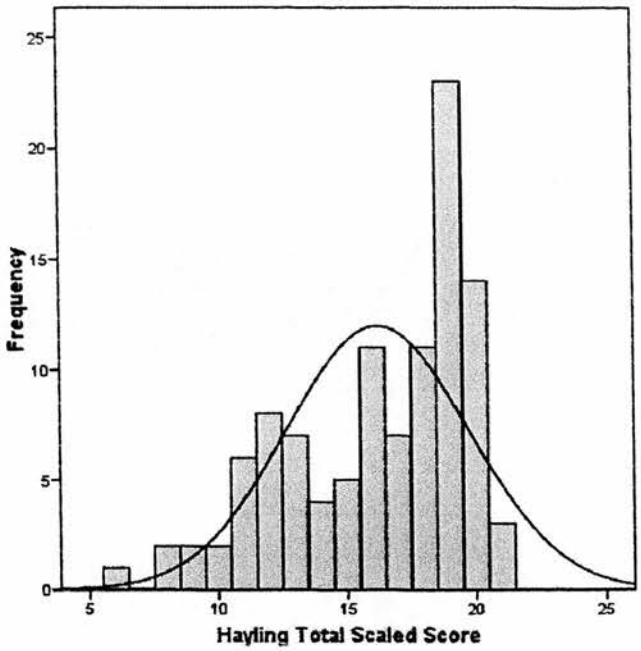
Marise Bucukoglu
Clinical Trials & Research Governance Manager

Appendix 15

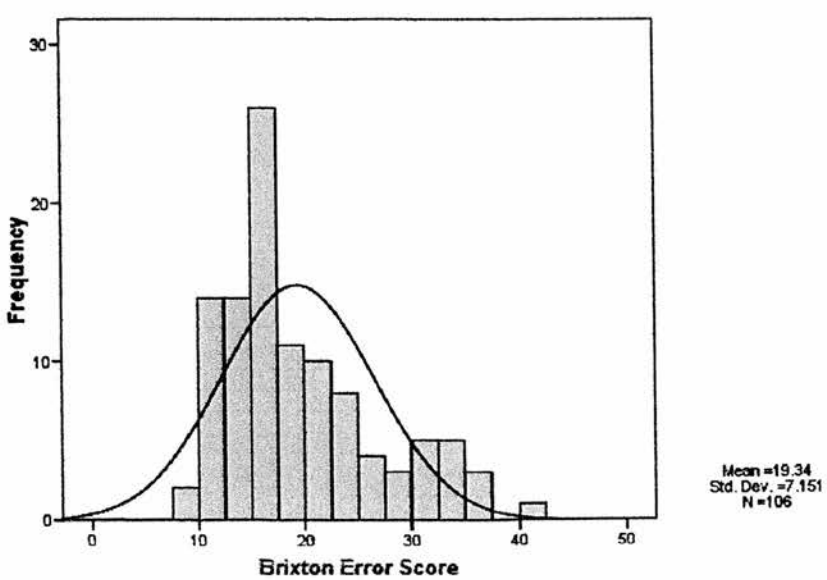
Histograms Displaying The Distribution of Scores on The Trail Making Test, Six Elements Test, and The Hayling and Brixton Tests


Trails Part 1 (seconds)
Frequency
30
20
10
0
0
20
40
60
80
100
Trails Part 1 (seconds)
Mean =35.07
Std. Dev. =11.03
N =106


Trails Part 2 (seconds)
Frequency
25
20
15
10
5
0
0
50
100
150
200
250
Trails Part 2 (seconds)
Mean =85.34
Std. Dev. =37.951
N =106

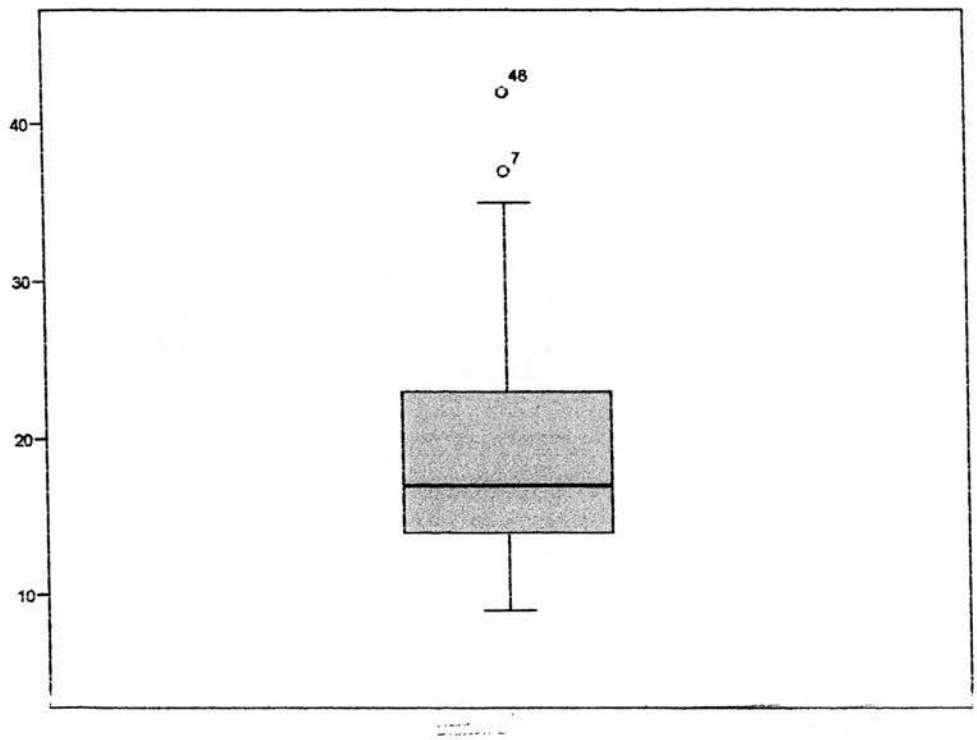


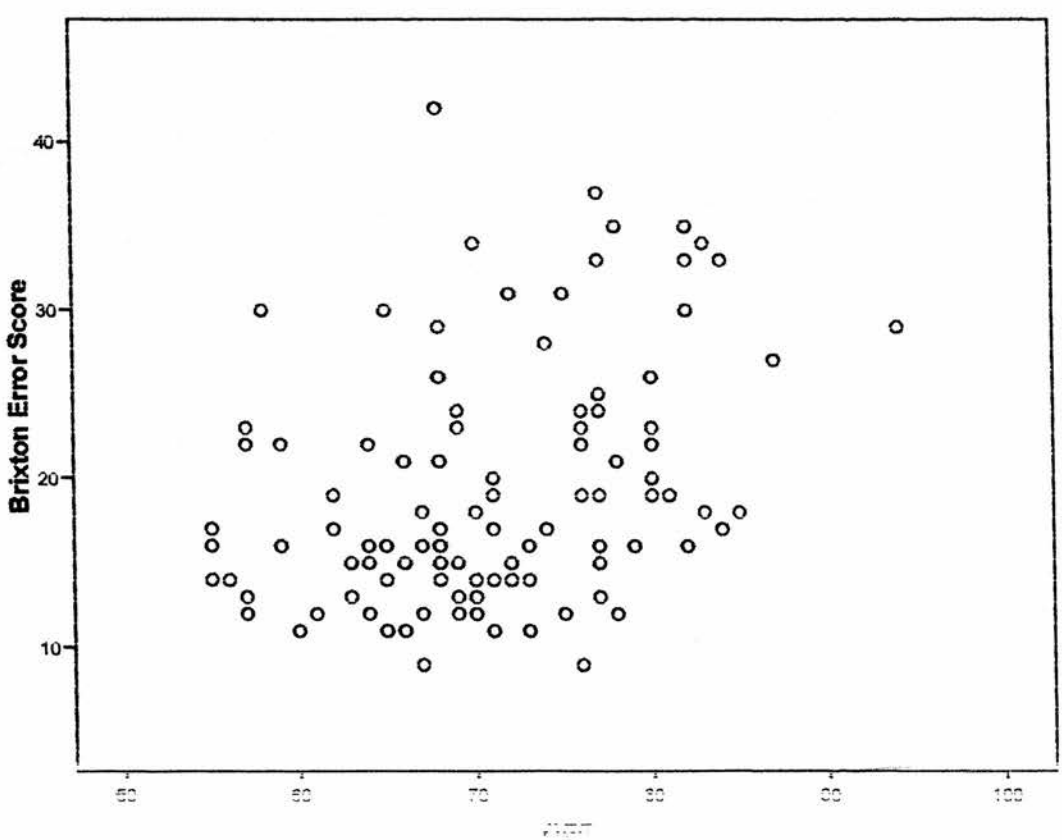
Brixton Error Score



Appendix 16

Scatterplot and Boxplot for The Brixton Test Error Score


48
7
40
30
20
10


Brixton Error Score
40
30
20
10
60
70
80
90
100

Appendix 17

Table Showing The Correlations between Age and Test Scores With and Without Outliers

Table: Pearson product-moment correlations for test scores of the Trail Making Tests (TMT), Brixton test, and Six Elements Test with age: both with and without outliers

Test	Age Correlation with outliers p-value*	Age Correlation without outliers p-value*
TMT Part A	.498	.480
TMT Part B	.634	.567
Hayling Time 1	.393	.436
Hayling Time 2	.264	.296
Brixton Error Score	.365	.395
SET Raw Score	-.285	-.308

* All ps<0.001

Appendix 18

Letter to Participants GPs