THE EFFECTS OF AGE AND EDUCATION ON SELECTED COGNITIVE TESTS: THE TRAIL MAKING TEST, THE DIGIT SYMBOL SUB-TEST, AND THE FINGER TAPPING TEST

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ABSTRACT

Numerous studies have suggested that neuropsychological test performance is affected by demographic variables such as age and education. This study examined the effects of age and education on the Trail Making Test, the Digit Symbol Sub-Test, and the Finger Tapping Test in a non-clinical sample of community dwellers with a relatively low level of education (8 to 12 years) in South Africa. The sample consisted of 161 participants across six age groups: 20-39, 40-59, 69-69, 70-79, 80-89 and 90-95 years. Results were examined for mean age effects and variability trends. Highly significant age effects were present across the age groups for all tests, however, there was no uniform pattern of variability across the tests. The Digit Symbol Substitution Test and the Finger Tapping Tests showed a pattern of increasing variability with increasing age, followed by a decrease in very old age while no trend was evident for the Digit Symbol extensions (the Immediate and Delayed Recall tests). The Trail Making Test, Parts A and B, showed a consistent trend of increasing variability across the age groups.

Data from the present study was compared with existing data from two relatively high education samples, with equivalent age groupings, to examine education effects. Results showed an education effect for all tests with the high education groups outperforming the low education groups. Although the effects of education became less potent with advancing age, the mean performance of the oldest (80-89 years) high education age group was superior to that of the equivalent low education age group. Comparison of variability trends across both samples showed that the highest variability (the shuttle bulge) was present at the same point along the age axis, or at a later point, for the low education group, as that for the high education group. This finding is inconsistent with Jordan's (1997) 'shuttle model of variability' which predicts an earlier occurrence of the shuttle bulge (left shuttle shift effect) for a low education sample.

This study demonstrated that performance on neuropsychological tests is influenced by age and education and highlighted the dangers inherent in unquestionably applying norms, which have not been corrected for age and education, when assessing the older adult.

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CHAPTER 1: INTRODUCTION

"...neuropsychological tests are not exclusively sensitive to brain pathology. It has long been realised that performances on most of these instruments are strongly related to age and education..." (Heaton, Grant & Matthews, 1991, p.3)

Over the last century, larger and larger proportions of the population are living past age 65 years. Older age is a known risk factor for normal cognitive decline and age-dependent brain pathology such as Alzheimer's Disease (AD) (La Rue, 1992). Many elderly people, consulting medical doctors for physical problems, show signs of cognitive impairment and are referred to a neuropsychologist for further investigation. The challenge for the specialist is to differentiate between changes compatible with normal aging and those due to pathology (Tuokko & Hadjistavropoulos, 1998). This is a difficult task as the neuronal loss, neurofibrillary tangles and senile plaques which represent the morphological substrate of behavioural changes in AD patients are also found, to a lesser extent, in the brains of healthy individuals over 65 years (Scheibel, 1996). Likewise, the memory problems which are usually the early symptoms of dementia, are also found in normal older adults (La Rue, 1992). Clearly, there is a critical need for early identification of age-related cognitive pathology to allow for the treatment of reversible conditions and the possible reduction of symptoms in more chronic conditions such as Alzheimer's Disease (Birren & Schroots, 1996).

Assessment of neuropsychological status includes the administration of psychometric tests which measure cognitive functioning, with normative comparison standards being the most frequently used method of determining deficits (Lezak, 1995). However, the scarcity of older age norms for many commonly used tests makes the task of differential diagnosis very difficult (Naugle, Callum & Bigler, 1990).

It is widely acknowledged that many neuropsychological functions show age-related declines (Albert, 1981; Ardila & Rosselli, 1989; Benton, Eslinger & Damasio, 1981; Heaton, Grant & Matthews, 1986, 1991; Lezak, 1983, 1995). Such decline is more marked on the performance of some tasks than on others. Tasks involving complex problem solving, visuo-spatial perception, delayed recall and psychomotor skills have been found to correlate negatively with increasing age (Naugle et al., 1990). Lezak (1995) maintains that interpreting test scores of older adults is impossible, particularly for speeded tests, without age-graded norms. In recent times, the influence of age on test performance has been taken into account in many normative studies (Axelrod & Goldman, 1996).

However, correction for age may not be sufficient as literature shows that educational level can also have a marked influence on test performance (Groth-Marnat, 2000; Heaton et al., 1986, 1991; Lezak, 1983, 1995). Age corrected normative data for one educational level may not be appropriate for use with individuals who have a higher or lower level of education and runs the risk of misclassifying persons as either normal or impaired. Moreover, interaction effects between age and education may be present for some tests thus complex corrections may be necessary for persons who have different levels of each of these variables (Tuokko & Woodward, 1996).

Clearly, the availability of normative data, stratified for age and education would enhance the diagnostic efficiency of the assessment measures used to screen older adults.

1.1 BROAD AIMS OF THE THESIS

The broad aim of this thesis was to generate normative data for a non-clinical South African sample of relatively low education across six age groups spanning the 20's to the 90's on the Finger Tapping Test, the Digit Symbol Substitution Test, and the Trail Making Test. In addition, data was collected on two recent extensions to the Digit Symbol Test: the Incidental Recall (Immediate and Delayed) Tests.

All the tests used in this study are reported to be highly sensitive to the effects of aging (Groth-Marnat 1997; Lezak, 1995), are frequently used in the assessment of older adults, yet there is a paucity of published age-stratified normative data, particularly for the oldest old (80+years). Data, which is available, is derived from American and British populations and as such may not be appropriate for use with South African populations. The only available South African normative data for older adults, was derived from two white, English speaking, high education populations.

Data generated in this study, on a non-clinical sample, will therefore be valuable for diagnostic purposes in the practice of clinical neuropsychology. Additionally, data from the present study will extend the available normative data for an English speaking white group across educational levels. It will also allow for an investigation of education effects, on these tests, through a comparison of these data with the existing high education data.

1.2 STRUCTURE OF THE THESIS

The report begins with a discussion of what aging is, and why it should be studied. A brief overview of the three major perspectives on aging namely, biological, psychological and social is provided to demonstrate the difficulties involved in defining aging. The point is made that aging is not, in fact, a single process but rather a number of processes. The implications, for societies, of an increasing elderly population is suggested as a reason for aging research.

Chapter 3 discusses the neuropsychological approach to aging and the methods used in the assessment of cognitive behaviour. This is followed by a review of what is known about the effects of normal aging on cognitive functioning and on the brain, the organ of cognition. Education is considered as a major extrinsic factor which affects both cognitive performance and brain functioning.

Chapter 4 looks at issues relating to the assessment of older adults. In particular, it notes how effective assessment requires normative data which takes account of age and educational attainment in order to prevent errors in diagnosis. Attention is also drawn to the importance of the variability pattern in normative data as this may be more informative, than the mean performance, with regards to normal aging. This chapter also highlights the need for brief dementia screening devices.

In Chapter 5, the cognitive tests selected for this study are discussed with particular reference to the functions measured by the test, the age and education sensitivity of the test, and the available normative data for each test. Chapters 6 to 9 comprise the Methodology, the Results and Discussion sections of the present study, which served to test the research hypothesis.

CHAPTER 2: AGING

Aging is a complex process involving many factors. Despite extensive research there is as yet no full understanding of all the mechanisms involved in this process. It is therefore, very difficult to provide a definitive definition of the concept of aging. Within the literature, the given definition depends on the perspective from which the concept is being considered, for example, biological, psychological, or social. Each of these perspectives makes different assumptions, ask different questions, and develop different models to explain the normal aging process (Ferraro, 1997). For example, with regards to when aging begins, Woodruff-Pak (1997) proposes that it "begins at different points of the life span depending on wether one is dealing with biological, psychological, or social age" (p.9).

2.1 BIOLOGICAL, PSYCHOLOGICAL, AND SOCIAL AGING

Biological aging is considered to be partly intrinsic (genetic) and partly a response of the organism to environmental insults eg. disease, injuries or inadequate nutrition. The biological perspective examines genotypes for aging and the different degenerative physiological changes associated with aging and which ultimately end at the point of death (La Rue, 1992). From this perspective, aging begins after biological maturity has been reached and the physical and cognitive decline, associated with advancing age, is continuing and unrelenting.

A definition widely accepted by biologists is that aging involves "a gradual deterioration in function and in the capacity of the body's homeostatic systems to respond to environmental stresses" (Vander, Shermon & Luciano, 1990, p.146). Griffiths (1997) however, finds this definition too pessimistic and suggests rather that: (i) our bodies are 'overbuilt' which means that most systems and organs have a substantial reserve capacity; (ii) the rate and degree of decline of homeostatic responses varies widely among individuals and; (iii) the rate of decline can be accelerated by non-age-related factors such as disease, unhealthy life-styles and work environments which expose persons to pollutants. His stance is supported by Baltes and Graf (1996) who say that although the biology of old age is characterised by a deterioration of systems in the human body and inevitably leads to death, psychological and socio-cultural components of aging can help compensate for many of these biological deficits.

Psychological aging "pertains to changes in self-regulatory processes, including cognition and personality" (La Rue, 1992, p. 12) and may begin at different times depending on what behaviour is being assessed. Cognitive changes in later life have been extensively studied and are discussed fully in Section 3.1. Although less research has been conducted on the effects of increasing age on personality, literature suggest patterns of both stability and change.

McCrae and Costa (1984) suggest that basic personality dispositions develop during childhood and persist throughout life. However, there is also evidence that change can occur in adult personalities. La Rue (1992) proposes that individual and social influences may combine to bring about personality change in people as they move through different life stages. This view concurs with Erikson's (1959) theory which depicts development as a progression through eight life stages from infancy to late adulthood with the possibility of gains at each stage. The gain resulting from successful resolution of the eighth stage, Integrity versus Despair, is wisdom. Psychological aging therefore includes incremental changes such as maturity and wisdom as well as decremental changes such as senility. Clearly, this perspective permits a more positive picture of aging than does the biological one (France & Alpher, 1997; La Rue, 1992).

Social aging is seen as "a life-course process of growing up and growing *older* from birth to death, not simply growing *old* beyond some arbitrary point in the life course" (Riley, Johnson & Foner, 1988, p. 246, italics added). The basic premise of this dimension is that humans are social creatures so aging does not occur in a social vacuum. Within most societies there are normative expectations for persons of certain ages to fulfil certain roles thus it could be argued that social aging begins as soon as there are such expectations (Woodruff-Pak, 1997). For older adults, normative expectations result in many changes such as retirement from the workforce which may be accompanied by a reduction in social and financial status. Other changes associated with advancing age may include a loss of spouse and a reduction in social network. This perspective therefore considers the impact of these social changes on the normal aging process (Ferraro, 1997).

Woodruff-Pak (1997) notes that the definition of aging at one level, i.e. biological, psychological or social, may not be appropriate when applied to another level. Moreover, the unique interaction of biological, psychological and social forces can result in different patterns of aging in different individuals. Birren and Cunnigham (1985) suggest that aging is not, in fact, a single process but rather that it consists of three distinct processes: primary, secondary, and tertiary.

2.2 AGING PROCESSES AND PATTERNS OF CHANGE

Primary, or normal aging is described as disease free aging. It refers to the inevitable, irreversible changes which are intrinsic to the aging process. Many biological, psychological and social changes accompany older age, for example, physical deterioration, cognitive decline, and the loss of family and friends (Cavanaugh & Blanchard-Fields, 2002).

Patterns of aging in psychology have been studied mainly in relation to cognitive changes that occur with advancing age and these studies support a pattern of primary aging. The Seattle Longitudinal Study (SLS), one of the most extensive studies, found that "although decline in cognitive functioning occurs for many individuals as the sixties are reached, such decline is differential in nature. Virtually none of the individuals ....showed universal decline in all abilities monitored, even by the eighties (Schaie, 1990, p. 114). Birren and Schroots (1996) suggest that education level, occupation, and cardiovascular disease are plausible determinants of maintenance and decline of cognitive functioning.

Secondary aging refers to changes caused by disease processes that are correlated with age. Examples of secondary aging are Alzheimer's disease and other forms of dementia which cause progressive loss of intellectual abilities and, the many medical conditions such as hypertension and diabetes which affect physical well-being and brain functioning. However, some of these illnesses may be preventable or reversible, for example, individuals who keep physically fit, eat sensibly, avoid smoking and so forth can often postpone or stave off the secondary effects of aging .

With regards to this conceptual distinction between primary and secondary aging, Birren and Schroots (1996) point out that it is not as clear cut as it may appear. There is, in fact, an ongoing debate regarding the relationship between aging and disease and it has been suggested (Rowe & Khan, 1987) that this relationship can be conceptualized along a continuum. At one end, aging and disease can be clearly separated but at the other end the age-dependant physiological changes become indistinguishable from disease. Given the high incidence of chronic disease in older age it is understandable that conceptions of primary aging are strongly associated with aspects of illness and decline. Evan (1998) has argued that "to draw a distinction between disease and normal aging is to attempt to separate the *undefined from the indefinable*" (p. 40, italics added). Birren and Schroots maintain that attempts to distinguish between primary and secondary patterns of aging have not been very successful and that further study is required to examine the extent to which nonpathological age changes influence one's vulnerability to disease. However, despite the controversy regarding the conceptual dictinction between primary and secondary aging, the concepts are widely used in aging literature.

Tertiary aging refers to the marked physical and cognitive deterioration which occurs shortly before death. According to Berg (1996) many changes in physical and cognitive functioning are related to the distance to death rather than being correlated with chronological age. An example of tertiary aging is the phenomenon known as terminal drop, in which intellectual abilities show a notable decrement in the last few years before death.

Ferraro (1997) contends that perceptions of the aging process can be distorted if researchers do not distinguish between normal age-related effects and the effects of terminal drop on cognitive test performance. Riegel and Riegel (1972) suggest that if the test results, of research participants who did not survive at least five years after testing, were removed from the data analysis of age group differences, many of the observed age-related declines would diminish or vanish.

Differential aging and chronological age: Chronological age refers to the time, days, months and years, which have elapsed since birth and while this definition provides useful information about how old an individual is, chronological age, in and of itself, does not explain anything about the aging process (Birren & Schroots, 1996). However, it may be useful to have some marker of when 'old age' begins as many social policy decisions are based on age, e.g. retirement and pensions (Woodruff-Pak, 1997).

Throughout the literature on aging, chronological definitions of aging predominate. For example, in most countries, the standard retirement age is 65 years and this is seen as a convenient point for defining the onset of old age. Additionally, women at age 60 and men at 65 years are entitled to 'old age' pensions and being a 'pensioner' has become socially defined as being old. Moreover, researchers frequently use 65 years as the lower age limit for inclusion of participants in aging research studies thus 65 has come to be regarded as an operational definition of aged (La Rue, 1992).

A review of current literature on aging indicates that gerontologists are dissatisfied with the use of chronological age as the research variable in aging research, as it promotes the notion that all older persons of a certain age (for example, all 70 year olds) are equivalent in all respects (Birren & Schroots, 1996; Hertzog, 1996; La Rue, 1992; Morse, 1993; Rabbitt, 1993; Tuokko & Hadjistavropoulos, 1998; Woodruff-Pak, 1997). Numerous studies, reported and discussed in these texts, support the idea that "aging is a highly individualised process" (Shock, 1985, p.738). These studies have demonstrated that the onset, rate and direction of cognitive and physical changes occurs differentially among individuals. In other words, increasing age is associated with increased inter-individual and intra-individual variability in functional abilities rather than by homogeneity. According to Birren and Schroots (1996), this differential pattern of aging is found for all the aging processes, i.e. primary, secondary and tertiary aging.

While the chronological definition of age may be the one most easily operationalised for research purposes, it is clearly an imperfect marker of age associated changes. Birren and Schroots (1996) suggest that chronological age be used "implicitly as a dummy variable that stands not for a single underlying aging process, but for a host of processes" (p.8). They emphasize how these processes may act on their own, or in combination with each other, to bring about the changes we understand as aging. The present study uses chronological age, as a research variable, to examine age difference on cognitive performance across the adult age span. However, in light of the many processes which influence age associated changes, variability within and between each age group will also be examined.

2.3 WHY STUDY AGING IN SOUTH AFRICA?

During the past two decades, gerontology, the study of the aged, has become one of the fastest growing areas, within medicine and other health related professions including psychology. This growth is evidenced by the dramatic expansion of research on aging and the accompanying increase in the publication of literature on aging (Birren & Schroots, 1996). A major reason for the increasing interest in this field is the changing global demographics.

2.3.1 Population trends

Throughout the twentieth century the proportion of people aged 65 years and above has steadily increased throughout the world. Older adults are the only portion of the population predicted to show substantial growth in the next 50 years (La Rue, 1992). It is further predicted (Malmgren, 2000) that the 85+ group, as a proportion of the 65+ group, will be one of the fastest growing this century. This trend, initially characteristic of industrial countries has, for the past few decades, also been evident in developing countries such as South Africa. The 1996 population census data (Central Statistical Services, 1997), indicated that 4.76% (2 million) of the total South African population were aged 65 and above with the proportion of 85 years and older as 7.1% (140000) of this group. The percentages of older women in the total population was reported as: 60%, 61% and 67% for the 6th, 7th and 8th + decades respectively which concurs with the well documented findings that, in all regions of the world, women live longer than men.

2.3.2 Implications of the 'greying of the population'

The changing population demographics have numerous implications for individuals and societies (Coleman, Bold, & Peace, 1993). While old age is not synonymous with ill-health, it is associated with an increase in medical problems, most commonly, high blood pressure, ischaemic heart disease, arteriosclerosis, diabetes and psychological problems such as depression. These medical and psychiatric conditions may affect the brain directly (for example, stroke) or indirectly through hypoxia or renal failure. Moreover, the medications required to treat these conditions may give rise to cognitive disturbances as drug metabolism changes with age (Birren & Schroots, 1996).

Aging is also a known major risk factor for Alzheimer's Dementia (AD) and the AD risk increases with each decade of life. The current global prevalence of AD (Miller & Gustavson, 2000), is approximately 6.2% for those aged 65+, 20% for those 80+, and 45% for those over 95. Additionally people with Alzheimer's disease can live for 10-20 years so there is a cumulative proportion of the older population who are demented. Green (2000) estimates that by the year 2030 the global prevalence of dementia among 65+ individuals will be as high as 25% thus constituting a major public health burden.

Malmgren (2000) believes that the 'greying of the population' is one of the world's major health and welfare challenges. Due to the increased incidence of chronic medical problems, older people make greater demands on health care services, including residential care needs, than young people and a steadily increasing proportion of social welfare budgets are being allocated for the payment of old age pensions. This challenge is particularly relevant for developing countries such as South Africa that have limited health and welfare resources and limited institutional facilities for the frail or ill elderly.

While the aging of the population has been evident for most of the 20th century, policy planners in most countries have only recently begun to take it seriously (Coleman et al., 1993: La Rue, 1992). The consequent lack of preparedness, has resulted in a tendency to perceive the growing number of elderly people as a social problem, or more dramatically, as a 'disaster' or an 'impending crisis' which, in turn, leads to negative attitudes towards the aged. This ageism results in older people being seen, not as individuals but, as a homogeneous group who can be discriminated against. Such attitudes affect individuals approaching old age: instead of perceiving long life as an achievement to be enjoyed, most people experience fear and uncertainty about growing old. Coleman et al. propose that, in order to meet the challenges facing societies and older individuals, there is a need for a greater understanding of aging. There is therefore, an need for ongoing aging research to determine what patterns of change, associated with increasing age, are typical or normative.

CHAPTER 3: NORMAL AGING: A NEUROPSYCHOLOGICAL APPROACH

As noted earlier, age can be studied from a wide variety of perspectives such as biological, psychological and social. These different approaches focus on a specific dimension of aging whilst omitting certain other dimensions so there is no holistic approach to aging. For this study, which focuses on the cognitive aspect of normal aging, a neuropsychological approach has been chosen. This approach investigates how biological and psycho-social factors interact to produce cognitive behaviour (Groth-Marnat, 1997). The neuropsychological approach is based on the assumption that there is an underlying neurological substrate on which cognitive functioning is ultimately dependent. Although, to date, there is no tight correlation between changes in the brain and changes in cognitive functioning there is sufficient evidence that the two are linked (Lezak, 1995).

The neuropsychological approach to the study of aging focuses on identifying differences between normal and pathological aging. Identifying pathology requires research findings which establishes normal parameters for older adults. Neuropsychological research has generated data on normal age-related changes in cognition by means of psychometric testing of older adults who have no evidence of clinical disease which could impair cognitive functioning. These findings are reported and discussed in the major texts in this field (for example, Bengtson & Schaie, 1999; Birren & Schaie, 1990, 1996, 2001; Boller & Grafman, 1991; Craik & Salthouse, 1992; Green, 2000; Heaton, Ryan, Grant, & Matthews, 1996; Lezak, 1983, 1985; Spreen & Strauss, 1991, 1998; Tuokko & Hadjistavropoulos, 1998). Data pertaining to normal age-related brain changes is continually being generated by both neuropsychological and cognitive neuroscience research.

Advances in non-invasive neuroscience techniques such as computerised tomography (CT), positron emission tomography (PET) and magnetic resonance imaging (MRI) have made it possible to examine the anatomical and physiological characteristics of the brain *in vivo*. This is particularly advantageous for the study of aging as it allows neuropsychologists to determine wether brain changes occur in the absence of pathology and, if so, how these changes are related to alterations in cognition (Albert & Killiany, 2001). Neuropsychologists are interested in finding correlations between normal age-related brain and behaviour changes (Lezak, 1995) and imaging techniques have shown that brain changes are, at least in part, responsible for age-related cognitive decline (Woodruff-Pak, 1997). The neuropsychological approach to normal aging can therefore be seen to encompass two broad perspectives, psychometric and biological.

3.1 COGNITIVE AGING: A PSYCHOMETRIC PERSPECTIVE

The psychometric approach to aging relies on the results of psychometric tests to identify cognitive differences between individuals at various developmental periods (Berg, 1992).

3.1.1 Measurement of intelligence and cognitive abilities

Cognitive abilities were initially attributed to a single function, *intelligence* which, it was believed, could be quantitatively measured by standardised psychometric tests. The IQ (intelligence quotient) score, a composite of performances scores on several different test, was used to predict academic success (Lezak, 1995). During the period when intelligence tests were being developed, and for many decades afterwards, no attempt was made to associate performance on IQ tests with brain functioning (Woodruff-Pak, 1997).

During the past two decades, the concept of intelligence has been redefined. According to Lezak (1995), neuropsychological studies have shown that there is no general intellectual or cognitive function, but rather "many discrete ones, that work together so smoothly when the brain is intact that cognition is experienced as a single, seamless attribute" (p. 23). (Groth-Marnat, 1997). Prominent neuropsychologists (such as, Albert & Moss, 1996; Groth-Marnat, 1997; La Rue, 1992; Lezak, 1995; Spreen & Strauss, 1991) now view higher cognitive function in terms of a small number of major categories or cognitive domains: attention, memory, visual skills, language skills, motor skills, and problem solving and executive functioning.

The psychometric tests most commonly used in aging research are the Wechsler Adult Intelligence Scales (WAIS) and Halstead-Reitan Neuropsychological Battery (HRNB) (Groth-Marnat, 2000). The WAIS (Wechsler, 1955, 1981) are individually administered, composite tests in a battery format. They consist of five verbal subtests and six performance subtests. Lezak (1995) maintains that the aggregate score derived from the sum of the eleven WAIS[1] subtests, while being an excellent predictor of academic achievement, has little use in clinical neuropsychological assessment. She argues that while reduced performance due to brain impairment may be evident on one or two tests, these lower scores may be obscured when averaged with the other subtests which measure capacities not affected by the damage

During the past few decades, many researchers in the field of psychogerontology (eg. Baltes, 1993; Birren, 1959, Labouvie-Vief, 1985, Schaie, 1978 and Woodruff-Pak, 1989) have questioned the ecological validity of using traditional intelligence tests in the assessment of older adults due to the appearance of impairment in normal older adults when their test scores deviate from those observed in children and young adults. However, intelligence tests, such as the WAIS, do allow the neuropsychologist to establish a measure of the older adult's global intellectual functioning and, several of the subtests are related to brain functioning and can be used to evaluate brain and cognitive status thus are useful in aging research (Woodruff-Pak, 1997).

The HRNB battery, which consists of eight standardised and individually administered tests, was specifically designed to measure cerebral functioning rather than IQ. The battery includes measures of motor and sensory perceptual functioning, nonverbal abstract reasoning, auditory attention, psychomotor problem solving, cognitive processing speed and visual scanning, and incidental spatial memory. The emphasis of these tests is on brain lesion detection, localisation, and lateralisation (Groth-Marnat, 1997). Many of the subtests are highly sensitive to aging effects and are widely used in aging studies.

3.1.2 Age effect on intellectual ability

Ideas about the age-intelligence relationship have undergone many revisions during the past 80

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[1]The term WAIS, in this paper, refers to all versions of this test excluding the WAIS III. This is justified on the grounds that the updated WAIS-R (Wechsler, 1981) and (SAWAIS) (1969) retain the same basic format as the original WAIS (Wechsler, 1955). The terms WAIS-R (Wechsler Adult Intelligence Scales-Revised) and SAWAIS (South African Wechsler Adult Intelligence Scales) refer to specific versions of the test battery. The WAIS III is excluded as testing for this study commenced prior to publication of the manual for this latest version.

years. Interest in the assessment of adult intelligence was prompted by the outbreak of World War I in 1917 which required rapid classification, with respect to general intellectual abilities, of a million and a half recruits. Analyses of the army test results, by age level, showed that maximum performance occurred in 18-20 year old men, some decline was noted in the performance of 25 year olds and in the oldest (51-60 years) group, test scores were a whole standard deviation lower than the 18-20 age group. These findings suggested that intelligence declined progressively with increasing age, starting in the mid-twenties (Anastasi & Urbina, 1997).

By the mid-1950's this unidirectional view of adult intelligence was being challenged by researchers such as Birren (1959) on the basis of data obtained from longitudinal studies. Up until the early 1950's, all aging research had been conducted using cross-sectional designs.

The cross-sectional design, compares the performance of different age groups at a particular point in time to determine wether age-related differences exist on certain measures (Cavanaugh & Blanchard-Fields, 2002). The most commonly used version is the bimodal *extreme-age-groups design* which compares a young group, usually university students, with a heterogeneous sample of conveniently sampled older individuals. This design tends to inflate the age differences because of selection effects and the test results suggest that age-related decline is linear in nature (Hertzog 1996). A more informative version of this methodology is the continuous group design.

Continuous group designs, as used in the present study, compare data from adults across the complete age range thus provide more information about the trajectory of decline and also the effects of variables which may covary with age. For example, they allow the researcher to determine wether there are discontinuities in the age-cognition relations corresponding to the occurrence of specific events such as menopause or retirement that are usually restricted to certain ages or wether cognitive decline represents a smooth progression over time (Salthouse, 2000). However both versions of this design are affected by the same limiting factors.

The major problem with cross-sectional designs is that groups differing in age frequently differ in many other factors thus there is confounding of age and generation (birth cohort) effects. Each generation has been exposed to different socio-cultural experiences ranging from wars and financial depressions to changes in the amount of formal education and access to technology to shifting nutritional and exercise patterns. The accumulated impact of all these factors may therefore be as important a determinant of the performance of older groups as intrinsic or biological age changes. (La Rue, 1992).

A common error, resulting from this type of design, occurs when results are interpreted as signifying age *changes* rather than age *differences* between the groups. However, over the last two decades, researchers have come to realise that age differences do not equal age changes (Birren & Schroots, 1996). However, despite the inherent weaknesses and confounds of cross-sectional designs they are the most efficient means of gathering normative data in the adult age range. This data can be used for making social policy decisions based on the proportions of young, middle-aged and old adults in the population and also increases the knowledge base of this relatively new field of research (Woodruff-Pak, 1997).

The longitudinal design does provide information about age changes as the same individuals are tested repeatedly at different points in their lives. This design eliminates inter-individual differences, as a nuisance variable, as the individual is compared with themself at each successive testing (Woodruff-Pak, 1997). However this design also has limitations: (i) due to selective attrition during assessment periods, data may only be representative of an elite group of older people thus the rate of decline may be underestimated (Backman, Small, Wahlin & Larsson, 2000); (ii). there may be practice effects in that participants may show improved performance as a result of being tested over and over again with the same measure and; (iii) it is questionable wether results from a single cohort can be generalised to another cohort (Wilson, Bennett & Swartzendruber, 1997).

To date there are very few published longitudinal studies as this type of research is complex, time-consuming and costly. However this type of design can provide insights into age-related changes that are not possible with cross-sectional designs. For example, because there is no cohort confounding, data from such studies provides more accurate information with regard to inter-individual and intra-individual variability and continuity-discontinuity in intellectual decline (Birren & Schaie, 2001). However, longitudinal studies are also victim to generational effects as many extrinsic factors such as diet, education and health care will have improved over the course of the study and these factors may reduce the apparent amount of age-related decrement (Backman, et al., 2000).

Data from longitudinal studies suggests that declines in intelligence present much later than previously believed (Woodruff-Pak, 1997). To date, there is still some controversy regarding the age at which decline begins, however findings from both cross-sectional and longitudinal studies have demonstrated that intellectual decline is part of the normal aging process. By and large, cross-sectional studies demonstrate an earlier and more pronounced impairment in older adults than do longitudinal studies. The cross-sectional method shows declines of one standard deviation or more beginning around 60, while longitudinal studies report a later onset of around the late 60's. However both methodologies have found a substantial decline in general intellectual functioning beginning in the seventh or eighth decade and becoming more marked in the ninth decade. There is also consensus that age changes are domain-specific: some intellectual abilities remain relatively stable with increasing age, some actually show improvement while others become impaired (Albert, Duffy, & Naeser, 1987; Wilson et al., 1997). This multidirectionality of age related change in intellectual abilities has become apparent during the past half century.

During standardisation of the WAIS (1955), it was noted that different intellectual functions were affected by age in different ways in that some intellectual abilities appeared to 'hold' with age while others showed decline ('no hold'). This pattern of age-related change, which has become known as the "classic aging pattern" (Albert & Kaplan, 1980, p. 403), shows a preservation of verbal abilities and a decline in nonverbal abilities. Several studies (Eisdorfer, Busse, & Cohen, 1959; Horn & Cattell, 1967; Wechsler, 1958) have shown relatively stable scores with increasing age on the Verbal subtests of the WAIS and impaired scores on the Performance subtests which require nonverbal, visuospatial and psychomotor skills. The classic aging pattern has also been found using other measuring instruments, designed to assess general intellectual functioning, such as the Primary Mental Abilities Test (Hochandel & Kaplan, 1984)

Horn and Cattell (1967) suggest that the classic aging pattern can be explained in terms of stable 'crystallized intelligence' which includes cognitive abilities which are dependent on the life-long accumulation of formal and informal educational experiences and, unstable 'fluid intelligence' which reflects the ability to solve novel problems creatively. Crystallized intelligence, which includes familiar, over-learned and well practised skills (e.g. vocabulary and world knowledge), continues to be fully operative and may even show some gains into the 70s and 80s while fluid intelligence (e.g. abstract reasoning), which is dependent on the integrity of the brain and central nervous system (CNS), shows a relatively slow decline in the middle years until the late 50s or early 60s when the decline proceeds at an increasingly rapid rate.

The fluid and crystallised model has been widely adopted by aging researchers and most of the studies conducted during the past few decades use this framework to organise data on abilities which remain stable with age as opposed to those which show decline. However, it is not universally accepted. An alternative hypothesis, to fluid intelligence decline, is the well known fact that older people are simply slower than younger people (Segal, Coolidge & Hersen, 1998) and the WAIS performance subtests mainly require a speeded response. However, although the slowness associated with aging is incontestable, it has been repeatedly demonstrated (Hochandel & Kaplan, 1984; Storandt, 1976) that even after the speed factor is removed, decline is still evident. Salthouse (1991) suggests that the decline in fluid intelligence, as measured by the performance subtests, reflects maturational processes in the central nervous system which results in a slowing of almost all types of information processing.

This view is supported by Cognitive theorists (for example, Chiarello & Hoyer, 1988) who maintain that virtually *all* cognitive performance measures show age-related differences although the differences may be more pronounced on some tests than others. They contend that even abilities like reading, word knowledge and implicit memory, which were previously considered to be impervious to age-related decline, have been shown to be correlated with age. According to Backman et al. (2000) the differential preservation of crystallised abilities in older adults does not generalise to very old age. They maintain that after age 74, the trajectory pattern for multiple intellectual domains, including both fluid and crystallised abilities and practical skills, is one of decrement. Conversely, Schaie (1996) argues that age-associated cognitive decline is not inevitable or irreversible. He claims that high levels of education, a lengthy marriage to an intelligent, well-educated spouse and a stimulating, high status, work environment are high predictors of maintenance of intellectual functioning well into old age.

One explanation for these opposing views is offered by Compton, Bachman and Logan (1997) who highlight the considerable variability in the cognitive performance of older adults: some show only slight changes in cognitive performance whereas others show severe cognitive deficits. According to Cavanaugh and Blanchard- Fields (2002), there are several reasons besides age why performance differences occur. These include cohort differences, personality, health and lifestyle, social variables and educational level. This study, in addition to examining the effects of age on test performance, also considers the effects of education.

3.1.3 Age effect on specific cognitive abilities

Patterns of age-related effects on specific domains of cognitive functioning are collated and reported in several neuropsychological assessment compendiums (for example, Heaton et al., 1991; Lezak, 1983, 1995; Mitrushina, Boone, & D'Elia, 1999; Spreen & Strauss, 1991, 1998). These trends can be summarised as follows:

3.1.3.1 Attention

In general, attention refers to "the distribution and control of limited-capacity mental resources in order to process information" (Green, 2000, p. 44). Research findings show minimal age effects on the performance of sustained attention (concentration) and selective attention tasks but marked age effects on tasks which require attention to be divided or 'switched' between two sets of stimuli (La Rue, 1992; Mitrushina & Satz, 1989). Divided and switched attention tasks require attentional flexibility and many studies have demonstrated that older people are much slower than younger adults on tests measuring this ability (Corrigan & Hinkeldey, 1987; Davies, 1968; Golden, Osmon, Moses & Berg, 1981; Salthouse, 1992). Ponsford (2000) suggests that such tasks place additional demands on the cognitive information processing system which, in older adults, is less efficient thus less able to deal with all the information that should be processed for each task.

3.1.3.2 Memory

Memory involves the capacity to retain information about past events and also to make plans with regard to future events (Robertson-Tchabo & Arenberg, 1989). This cognitive aspect has been more thoroughly studied than any other aspect. Memory consists of multiple processes that can be differentially affected by aging. These processes involve registration, encoding, storage, consolidation and retrieval of information (Tuokko & Hadjistavropoulos, 1998). Moreover, as noted by Reeves and Wedding (1994) these processes operate within a temporal framework involving immediate/sensory memory, recent/primary memory, and remote/secondary memory.

Both sensory memory and primary memory show negligible decline with age, at least up until age 80. However, it has been shown (La Rue, 1992) that older adults need a longer exposure time in order to adequately register a given amount of information for further processing into primary memory and, tasks which make demands on working memory show more age-related decline (Botwinick, 1977; Salthouse, 1991). Huppert (1991) suggests that working memory involves a component of divided attention as attention is divided between retaining information in an active state while carrying out other mental operations. Two tests used in this study, the Digit Symbol SubstitutionTest (DSST) and the Trail MakingTest (TMT)- Part B, while categorized as measures of visuo-perceptual ability, also tap divided attention and working memory abilities.

Numerous studies have reported marked declines in secondary memory, specifically declarative (or explicit) memory which deals with facts directly accessible to conscious recollection (Kramer & Delis, 1998). Craik and Jennings (1992) suggests that older adults engage in less efficient initial processing of new information resulting in degraded memory traces and subsequent difficulty in retrieving information from long-term storage. Studies show that the age effect is less marked on verbal and non-verbal recognition tasks but is very pronounced on new learning and recall tasks. Recognition tasks reduce the demand on retrieval skills and show good performance scores in 65-85 year old groups which indicates that impairments are due to encoding or retrieval difficulties rather than to a reduced storage capacity (Kramer & Delis, 1998; Groth-Marnat, 1997).

Verbal memory is generally tested by list or story learning and recall tasks. Normative data on a variety of such tasks, reported in Groth Marnat (2000), Mitrushina, Boone, and D'Elia (1999) and Tuokko and Hadjistavropoulos (1998), indicates that the recall performance of older adults (60+) is nearly 1 standard deviation below the mean of young adults distribution and decreases further with advancing age. However the older adults, through to age 80 years, show a positive learning curve in that correct responses increase with each learning trial. Female gender is associated with better verbal memory test performance (Tuokko & Hadjistavropoulos, 1998).

Visual (non-verbal) memory is assessed by tests, such as the Rey-Osterrieth Complex Figure (ROCF) or the DSST, which require a visuomotor response such as drawing and includes a copy condition, immediate recall and delayed recall. Several studies reported by Lezak (1995) and Mitrushina et al. (1999) show that copy and recall remains fairly stable until the mid-seventies then shows a marked decline. Normative data on delayed recall, reported in Spreen and Strauss (1998), shows a slow decline beginning in the 30's and increasing slowly through to the 70's when a sharp drop in scores is noted. Some studies show a male superiority on this test (Lezak, 1995).

Salthouse (1991) maintains that most age-related differences in cognition, including memory, can be accounted for by the older adults reduction in perceptual speed. He has demonstrated that age differences in serial recall, free recall and paired associate recall are all significantly attenuated when perceptual speed is statistically controlled.

Marked variations in memory performance of older adults has been noted with healthy, well educated adults in their 60's or 70's performing as well as younger adults on many memory tests. This variability highlights the need for appropriate normative data on older adults (La Rue, 1992).

3.1.3.3 Visual skills

Visual skills, involve the processing and manipulation of nonverbal information and include visuospatial and visuoconstructive abilities. The abilities required for visual skill tasks, range from relatively low-level perceptual processes like attention, scanning and perception, to higher-level abilities such as appreciation of complex visual gestalts and manipulation of visuospatial information during problem solving (Green, 2000).

Simple tasks of visual perception such as the motor free, Judgement of Line Orientation, show that women and older adults perform more poorly (Benton et al., 1981). Greater age effects are observed on more complex perceptual tasks like visual -closure or embedded-figure tests which require identification of a figure from incomplete drawings and the identification of a geometric pattern within a more complex design, respectively (La Rue, 1992). Tasks requiring visual search, for example, cancellation tasks, the DSST or the TMT, also show age effects but these may partially be attributed to the speeded nature of the task (Kaplan & Romans, 1998). Albert (1988) and Lezak (1995) note that the most pronounced age-related declines are observed on measures of visuoconstructive abilities such as Block Design, Object Assembly and Picture Completion and these declines are most evident after age 70 years.

3.1.3.4 Motor Skills

Lezak (1983, 1995) notes that age-related decline is particularly evident on tasks requiring motor speed. Older age is associated with decrements in the planning, control and execution of movements: older adults take longer than younger adults to make similar movements, their coordination is poorer and their ability to maintain continuous movement declines (Rogers & Fisk, 2000).

Tests of manual dexterity, such as the Finger Tapping Test (FTT) used in this study, show prominent slowing from about 50 years, followed by greater decrements in subsequent decades (Heaton et al., 1991). In simple point-to point movement tasks older adults have slower movement times (MT's) than young adults and results reported in Ketcham and Stelmach (2001) show this slowing to be in the region of between 26% and 69%. These studies also report that as task difficulty increases, slowing becomes more pronounced. For example, slowing contributes to the poorer scores of older adults on timed tests such as the DSST and the TMT.

Slowing of simple reaction time begins around age 30 years and by age 60 years may be 20% less than it was in the 20's. Thereafter it continues to decline at roughly the same gradual rate. Conversely, the performance of complex tasks, requiring cognitive processing, shows a rapid rate of slowing from the 60's (Lezak, 1995). Analysis of the performance of complex tasks shows that while some of this slowing is due to age-related musculoskeletal changes and/or to the increased cautiousness that older adults exhibit before responding to the test stimulus, the most important component is slowed cognitive processing (Salthouse, 1991; Van Gorp, Satz & Mitrushina, 1990).

3.1.3.5 Problem solving skills and executive functioning

Problem solving skills include the person's ability to identify rules and concepts, reason logically and abstractly, and apply reasoning skills to finding solutions to problem (La Rue, 1992). Problem solving therefore describes the complex process by which an individual will perform a novel task from its beginning to its completion. Neuropsychologists tend to focus on a related but broader set of abilities, namely executive functions which are described by Wecker, Kramer, Wisniewski, Delis and Kaplan (2000) as 'higher' functions which integrate, organise and maintain other cognitive processes.

It is difficult to summarise age trends in problem solving and executive functioning as a diverse set of tests are used to assess this domain. However, solving novel problems (a fluid intelligence task) requires attentional flexibility, memory acquisition, manipulation of material (working memory), short and long-term memory storage and retrieval abilities, and visual skills all of which, as reported above, are known to decline with age. Thus it is generally accepted that problem solving and executive functioning will deteriorate with age (Wecker et al., 2000).

3.1.3.6 Language skills

Language abilities, like attention and memory, are not a unitary function and research shows different patterns of preservation and decline in specific language skills (La Rue, 1992). However, as language skills are not assessed by the tests used in this study this cognitive domain will not be discussed.

3.1.4 Education effect on intelligence and specific cognitive abilities

The question of wether education can increase a person's intelligence (IQ), and therefore influence test performance, has been one of the most controversial issues in the social sciences in the past few decades. Herrnstein and Murray (1994) reignited this smouldering issue with their publication of *The Bell Curve*. They maintain that there is a relationship between intelligence and social and economic success, and that IQ is the main determinant of such success. They regard intelligence as being primarily genetically determined and argue that formal schooling will have little impact on the individuals later socio-economic success.

Conversely, Ceci (1991), who extensively reviewed literature on the effects of education on intelligence, concludes "that schooling exerts a substantial influence on IQ formation and maintenance" (p. 703). Husen and Tuijnman (1991) also claim that "schooling per se has a substantial effect on IQ test scores" (p. 22) and declare that the intellectual capitol of a nation can be enhanced by formal schooling.

More recently, Winship & Korenman (1997), responding to *The Bell Curve*, report several large scale studies which demonstrate that IQ increases by 2 to 3 points for each year of schooling. Additionally, they cite research which indicates that interruptions in schooling (for example, due to war, school closures or prolonged absenteeism) results in the loss of 3 to 6 points of IQ. Similarly, research by Flynn (1998, cited in Lahey, 2001) shows increases in average intelligence scores, as measured by the WAIS and the Standford-Binet Scales, over successive generations since 1930. For example, tests measuring fluid intelligence show gains of about 20 points per generation (every thirty years). While factors such as improved nutrition and health care during this period have no doubt contributed to the increase in average intelligence, Lahey (2001) points out how each successive generation has received more formal education than the previous one. Moreover, each successive generation has had more educated parents and it is likely that these parents provide a more stimulating home environment which increases the intelligence of their children. Thus, while not denying the effects of genetics on IQ, these findings provide sufficient evidence for regarding educational level as an important variable affecting test performance. However the effect of education may not be equivalent for all cognitive domains

A low level of education has been identified as an important risk factor for both normal age-related cognitive decline and dementia and, conversely, high education appears to have a protective effect against both these conditions. Reviews of WAIS and HRB test performance shows that education often has a greater effect on scores than does age (Heaton et al., 1996) and can have as powerful an effect on performance as can brain damage (Ardila, 1995).

Numerous studies on elderly subjects show that, with the exception of short- term recall (primary memory), performance on all tests show education effects to a greater or lesser degree (for example, Ardila, Ostrosky-Solis, Rosselli and Gomez, 2000; Ardila, Rosselli and Ostrosky-Solis (1992); Compton, Bachman, Brand & Avet, 2000; Huppert, Johnson & Nickson, 2000; Mazaux et al.,1995; Mitrushina, Uchiyama, & Satz, 1995; Portin, Saarijarvi, Joukamaa, & Salokangas, 1995; Steenhuis & Østbye, 1995; Wilson et al., 1999). Furthermore, several of these studies also suggest that level of education influences the rate and magnitude of age-related cognitive decline.

It is well accepted (Christensen et al., 2001; Compton et al., 2000) that highly educated individuals decline from a higher initial level than those with less education and generally take longer to reach the same lower level of performance as those who start the descent from a lower initial level. However, wether high education is associated with a slower or faster level of decline, or with a reduced likelihood of decline, is still controversial. According to Rabbitt (1993) and Compton et al. (1997) both cross-sectional and longitudinal research results indicate that highly educated individuals experience a similar rate of decline as individuals with lower levels of education. However, a high education level and continued intellectual stimulation enhances crystallized intelligence which enables individuals to develop strategies to compensate for age related cognitive changes and these compensatory strategies mask the rate of decline in this group. The ongoing debate on the ameliorating effects of education on age-related cognitive decline provided the motivation for the inclusion of education, as a major influencing variable on test performance, in the present study.

3.2 BRAIN AGING: A BIOLOGICAL PERSPECTIVE

Neuropsychologists are interested in finding correlations between age-related cognitive decline and the brain changes that take place with normal aging (La Rue, 1992).The nature of the brain changes that occur during normal aging have been extensively reported by numerous authors (for example, Albert & Killiany, 2001; Lezak, 1995; Raz, 2000; Scheibel, 1996; Shock, 1985; Walsh, 1994; Willott, 1997; Woodruff-Pak, 1997). The present overview is restricted to a description of the major structural and functional brain changes associated with normal aging.

3.2.1 Gross structural changes

One of the best documented changes is the overall decrease in brain size or volume with age. Brain size has been shown to peak around the early 20's then decline very gradually until the 40's or 50's. After age 50 shrinkage becomes more rapid and, through to age 98, there is a 2% decrease per decade for both women and men (Lezak, 1995). However this amount of loss is relatively small compared with the 9% rate of atrophy, per decade, found in brains of individuals with AD (Albert & Killiany, 2001). The atrophy can be accounted for by progressive neuronal loss in cortical and subcortical structures, progressive atrophy of the convolutions (gyri) of the brain surface with resultant widening of the spaces (sulci) between the convolutions and an accumulation of cerebrospinal fluid in the ventricles (Lezak, 1995; Scheibel, 1996).

Several CT and MRI studies, reported by Albert and Killiany (2001), show that the average individual aged 55 to 65 years has some degree of brain atrophy and longitudinal studies on the same individuals have demonstrated an increase in atrophy with increasing age. Moreover, these authors cite studies which show a negative correlation between brain atrophy and cognitive abilities, that is, as brain atrophy increases, the poorer the cognitive test scores are likely to be. However, while there is a general agreement about age-related changes in brain volume, there is less agreement about which of the two tissue types, grey or white matter, is most susceptible to the effects of aging.

Grey matter consists of neuronal cell bodies in the cortex and subcortical nuclei and the white matter represents tightly packed myelinated axons which connect the cerebral cortex neurons to each other and to other brain regions (Raz, 2000). According to Raz, grey and white matter have different structural, metabolic and neurochemical properties therefore it is plausible that they may be differentially sensitive to the effects of aging. Various studies discussed in Albert and Killiany (2001), Raz (2000) and Scheibel (1996) have shown conflicting findings with some demonstrating only grey matter loss, others only white matter loss and yet others an alteration in the grey/white matter ratio. However, according to these authors, there is some measure of consensus that the loss of cerebral tissue occurs mainly in grey matter until age 50, and thereafter it occurs primarily in white matter. As pointed out by Albert and Killiany (2001) these findings are initially difficult to understand. Conventional knowledge dictates that axonal loss (white matter) would result in cell death thus loss of grey matter. However, evidence from non human primates suggests that the white matter loss represents changes in the myelin sheath rather than axonal loss.

Changes in the myelin sheath have the potential to interfere with communication between neurons, as myelination increases the efficiency and speed of the conduction of nerve impulses among neurons (Willot, 1997). A substantial amount of research (Salthouse, 1996; Scheibel, 1996; Verhaeghen & Salthouse, 1997) has demonstrated that generalized age-related slowing is due to declines in the structural integrity of cerebral white matter. Raz (2000) suggests that the correlation between the state of white matter and cognition is a threshold phenomenon as findings show that cognitive performance in asymptomatic older adults drops dramatically when white matter lesions accumulate above a critical level.

3.2.2 Microscopic changes

Microscopic examination of the brain structure sheds more light on structural changes in the nerve cells, the presence of neurofibrillary tangles and senile plaques, and the dendritic changes found in normal aging brains.

Neural changes. While earlier studies, using hand cell counts, indicated notable amounts of cortical cell loss with age (approximately 100,000 neurons each day), more recent studies of healthy older brains (for example, Griener, Snowdon & Griener, 1999) and more sophisticated cell counting techniques have changed concepts about the amount and nature of neuronal loss with advancing age. Terry and Hansen (1988) have suggested that there may be a size transition in large neurons with advancing age thus the predominant finding may be neuronal shrinkage, due to loss of connective tissue such as axons, dendrites, and synapsis, rather than neuronal loss. Their post mortem study of 51 human brains from subjects aged between 20 and 100 years showed that as age increased there was a corresponding decrease in the number of large neurons which was counter-balanced by an increased number of small, presumably shrunken, neurons. This shrinkage of large neurons was accompanied by a decrease in brain volume and a reduction of cortical thickness in the mid-frontal and superior temporal regions. These authors concluded that while there is some degree of over-all neuron loss associated with age, it is smaller than previously reported. Similar findings are reported by Willott (1997) who maintains that while neuronal loss is found in some aging brains, loss of neurons is not a concomitant feature of aging. However, although there is still some debate on this issue, it does appear that some neuronal loss and/or shrinkage occurs with aging but that the process occurs differentially in terms of rates and parts of the brain and shows diverse effects on different individuals.

Researchers (Raz, 2000; Scheibel, 1996; Walsh, 1994) have identified three brain areas namely, the frontal lobes, hippocampus and cerebral cortex, which seem to be particularly affected by neuronal loss. Cognitive abilities which show age related deterioration have been linked to changes in these areas (Woodruff-Pak, 1997). The frontal lobes are the last cortical area to develop and Walsh (1994) suggests that this 'highest' brain area is the one most likely to be hit earliest and hardest by the aging process. Although a controversial issue for many years, it is now generally accepted that the frontal lobes are the seat of the highest cognitive functions in man, that is, the executive functions (Raz, 2000; Scheibel, 1996; Walsh, 1994). Capacities attributed to the frontal lobes are attention, inductive reasoning, planning and working memory. Hippocampal cell loss, which Lezak (1995) reports is approximately 5% for every decade after the mid-40's, is implicated in age-related deficits in declarative learning and memory. According to Woodruff-Pak (1997), the most direct association between memory impairment and hippocampal atrophy has been demonstrated through the comparison of memory test performance and brain scan data from the same individuals. While the cerebellum does not show significant gross changes with aging, cell loss has been noted in the Purkinji cells in the cerebellar cortex . These cells are thought to be responsible for nondeclarative learning and memory (Scheibel, 1996).

Tangles and plaques. Neurofibrillary tangles develop when fibres in the axon become twisted together to form spiral filaments while senile plaques result from the accumulation of extracellular amyloid fluid (Raz, 2000). While small numbers of both tangles and plaques are commonly found in the neocortex of older adults with normal cognitive functioning large widespread concentrations are associated with cognitive and behavioural abnormalities and are one of the defining characteristics of AD (La Rue, 1992). Tangles and plaques interfere with normal cell functioning.

Dendritic changes. The dendritic systems of neurons are, according to Scheibel (1996) "one of the most significant anatomical yardsticks of neural function, because they are the primary recipients of the arrays of synaptic input impinging on each cell" (p. 116). While early studies demonstrated dendritic regression with advancing age, more recent studies (Geddes & Matus, 1997; Raz, 2000; Scheibel, 1996) show that in the aged brain, dendrites may show stability, regression or proliferation dependent on the brain region. Additionally, there is evidence (Geddes & Matus, 1997: Scheibel, 1996) that between middle age and early old age (65-74) additional dendrites sprout up and may compensate for neuronal loss or shrinkage by creating new connections among nerve cells. However, as pointed out by Flood and Coleman (1988) dendritic regression is the most common finding in the oldest, old and, a possible reason for the absence of dendritic arborization in this group is, according to Schaie (1996), a lack of environmental stimulation. Post mortem examination of the brains of individuals who were still leading an intellectually challenging life style in their late nineties has revealed new cell growth and increases in dendritic branching (Griener et al., 1999). These findings, which support Schaie's hypothesis, indicate that the brain has some degree of plasticity even in very old age, and this offers new possibilities for delaying the onset of, and treatment of, brain diseases such as AD.

3.2.3 Effect of education on normal brain aging

Age and low level of education have been identified as important risk factors for both normal cognitive decline and dementia. However, studies on the effects of education on the brain have been conducted in relation to pathology such as Alzheimer's disease (AD) rather than in relation to normal aging.According to Katzman (1993) higher education and continued education increases synaptic density in the neocortical association cortex thus creating a 'brain reserve' which delays the onset of symptoms, in individuals with AD, by several years. Additionally, research has shown that symptom onset is a threshold phemonemena. For example, Roth (1986) has demonstrated that neuropathology, e.g. disease or injury, must exceed a quantitative threshold before cognitive impairment becomes apparent. Satz (1993) proposes that this threshold is related to the amount of brain reserve.

Satz (1993) suggests that a critical amount of brain tissue is required for normal brain functioning and that cognitive impairment becomes evident when the loss of brain tissue, due to disease or injury, exceeds the threshold. He states that the amount of tissue which can be lost, thus the threshold for the clinical onset of symptoms, differs between individuals. In the brain reserve capacity threshold (BRC) theory, he hypothesises that individual differences in the amount of BRC, raises or lowers the threshold resulting in protection from, or vulnerability to, the onset of cognitive impairment. Since deterioration of cognitive functioning also results from the neural attrition associated with normal brain aging, Jordan (1997) argues that aging itself can be conceptualized as a form of neural impairment or 'disease'. For this reason, in this thesis, the BRC theory will be considered to apply equally to normal brain aging.

While BRC could be operationally defined (and measured) in terms of overall brain size and dendritic branching, Satz (1993) treats it "as a hypothetical construct that is related to adaptive behaviour" (p. 275). He suggests that this construct is represented and measured, albeit indirectly and imprecisely, by two social factors, namely education and general intelligence.

According to Satz (1993), a high BRC, which is related to higher levels of education and intelligence, and associated high socio-economic levels, acts as a protective factor thus decreasing the risk of functional impairment even in the presence of brain damage. Thus, for a highly educated individual, accumulating brain lesions will have no, or minimal effects, on their functioning until the degree of neuropathology reaches the threshold. Conversely, individuals with lower levels of education, and generally low socio-economic levels, start out with less brain reserve capacity (lower threshold) so brain impairment will result in more rapid and extensive cognitive deterioration. Low education therefore acts as a vulnerability factor, increasing the risk of functional impairment. Functional impairment related to neuropathology (or aging) will therefore, present at an earlier stage in individuals with lower levels of education..

According to Satz (1993) several factors, other than education, may lower the brain reserve capacity threshold and increase the vulnerability to symptom onset in individuals with subthreshold neuropathology. The neural attrition associated with normal brain aging may aggregate with neuropathology and increase the risk of functional impairment. Similarly, progressive neural attrition, associated with advancing age, will have the same aggregation effect.

Functional impairment is, therefore, more likely to be revealed on performance of cognitive tasks which are age sensitive. High challenge tasks that is, complex tasks which stress the cognitive system, may alter the BRC threshold. Satz suggests that symptoms of cognitive impairment may remain undetected until a sufficiently high challenge assessment measure is presented. While he does not specifically discuss gender as a risk factor for reduced BRC, he does make reference to studies which show an increased prevalence of dementia in women, particularly those with limited education. Conversely, other research (Miller and Gustavson, 2000) has demonstrated that some brain structures, such as the cerebral cortex, shrink more rapidly in men, than in women, with advancing age which suggests that male gender may be a BRC lowering factor.

In terms of Satz's theory, factors which alter the brain reserve capacity threshold, particularly education level, will influence the performance on cognitive tests.

CHAPTER 4: ISSUES RELATING TO THE NEUROPSYCHOLOGICAL ASSESSMENT OF OLDER ADULTS

The main purpose of neuropsychological assessment (Groth-Marnat, 2000; Heaton et al., 1996; Lezak, 1995) is to determine wether the individual's test results are indicative of brain pathology, particularly when there is no clear anatomical evidence of alterations. In addition to contributing to the diagnostic process, neuropsychological assessment can also be used to detect persons at risk for some specified condition or those who require a fuller diagnostic work up. This 'screening' aspect includes identifying which older patients, presenting with memory loss, need to be fully investigated for dementia. Although neuropsychological assessment can identify normal functioning, it is primarily aimed at detecting and measuring deficits.

The concept of behavioural deficit assumes some normal level of functioning which can provide a standard against which the patient's present performance can be measured. Test scores, in and of themselves, are simply numbers (Cimino, 1994) and meaningful interpretation can only be generated through some comparison standard. The most frequently used method of assessing deficits is by comparing the individual's test scores with normative data (Heaton et al., 1996).

4.1 NORMATIVE DATA AND THE IMPORTANCE OF AGE AND EDUCATION

Normative data provide an empirical frame of reference (Mitrushina et al., 1999) and "represent the range of performance on a particular test of a group of medically/neurologically healthy individuals with relatively homogeneous demographic characteristics" (p. 35).

When an individual's test scores are compared with some normative standard, the extent to which these scores deviate from the norms, or mean scores, provides the clinician with information regarding which cognitive abilities are impaired or spared. However, as Lezak (1995) points out, the validity of normative data is heavily dependent on the degree to which the individual being assessed is similar to the demographic features of the normative sample. This is of particular importance in the assessment of older adults in South Africa as data derived from American standardisation samples may not be appropriate to this local population and result in misclassification. As Tuokko and Woodword (1996) point out, the degree of similarity increases the likelihood that identified deficits are true deficits and not measurement errors. Measurement errors can results from extraneous variables which affect test performance. While numerous factors can impact on test performance, Heaton et al. (1996) and Lezak (1995) have noted a particularly strong relationship between the performance on most neuropsychological tests and the subject's age and education.

Numerous texts (Groth-Marnat, 1997; Heaton et al., 1986, 1991, 1996; Lezak, 1995: Podell & Lovell, 2000) have shown that when normative scores, derived from the test performance of young adults, are used to evaluate the older adult's performance on cognitive tests, a high percentage of non-clinical individuals are misclassified as impaired. For example, Heaton et al.(1986) administered a comprehensive test battery to 553 normal individuals, divided into sub-groups at three age levels (<40 years, 40-59 years, 60+ years), and found that the rate of misclassification increased with each older age group when only a single set of norms was used. However, although the influence of age on neuropsychological test performance has been taken into account for many years there is still a paucity of normative data for the older adult, particularly for the oldest, old.

For some measures, the effect of education on test performance may be even greater than that of age. For example, Ardila & Rosselli (1989) administered a basic neuropsychological battery to 346 normal adults, age range 55-76+ and education range 0-12 years of schooling and found that 28 of the 29 tests showed an education effect while only 23 tests showed age effects. However, despite such evidence, the effects of education on test performance have only recently been systematically introduced into norm development (Axelrod & Goldman, 1996).

The use of norms which have not been stratified for education runs the risk of misclassification when the individual being assessed differs, in terms of level of education, from the normative sample. For example, in terms of the BRC theory a highly educated person with brain impairment may be judged as intact because they function at the same level as a normal person with lower level of education. Additionally, while education may influence the test performance of people of all ages, in older adults, the effect of this variable may interact with the age effect on many tests.

4.2 CONSIDERATIONS IN THE INTERPRETATION OF NORMATIVE DATA

Traditionally, aging research data has been presented as mean scores and standard deviation scores across different age groups. The mean scores, which reflect the average performance of each age group, are used as global normative comparison standards, while the standard deviations, which reflect the dispersion of individual scores around the mean, have generally been disregarded as unavoidable error-variance (Diamantopoulos & Schlegelmilch, 1997). Jordan (1997) however, argues that the variability phenomenon needs "to be studied rather than dismissed as error" (p.2). She points out that the focus on the mean score obscures the inter-individual variability within adult age groups which results in a distorted picture of the aging process and gives rise to negative stereotypes about older people. The variability data, however, illustrates the diversity of cognitive performance in older adults and creates a more positive, optimistic picture of the aging process. Jordan supports Shock's (1985) classic dictum that aging is a highly individualised process and states that *"Normative data across the adult age spectrum should never be considered in isolation without reference to the variability data"* (Jordan, 1997, p. 430, her italics). Rabbitt (1993) goes even further by suggesting that more information, on age-related cognitive changes, may be gained by analysing changes in variability across age groups than by examining changes in average performance.

Literature on aging, published during the past two decades, (for example, Benton et al., 1981; Christensen et al.1999; Dannefer, 1988; Morse, 1993; Rabbitt, 1993; Rowe & Khan, 1987; Schaie, 1996) reflects an increasing recognition that the study of mean change with age does not fully account for cognitive change across the life span. These authors have found that there is a greater range of responses at older ages, that certain intellectual domains are more susceptible than others to aging effects and that variables, other than age (e.g. health, psychological functioning and social factors), affect cognitive performance.

Research findings also show increasing differentiation, or inter-individual differences, on test performance of older adults as compared with younger adults. For example, Morse (1993) conducted a meta analysis of four years of published studies which compared functional trends of young and older adults. She found that variability was greater among older people, as compared with a group of younger people, on measures of fluid intelligence (speed and memory) but not for crystallized intelligence. A more recent study by Christensen et al. (1999), on a sample of 426 elderly community dwellers, age range 70 to 85+ years, demonstrated increased variability with increasing age for measures of memory, spatial functioning and speed, but not for crystallized intelligence.

Nelson and Dannefer (1992) contend that if individual variability increases with age then mean changes in cognitive performance are likely to be "less meaningful" and "less typical" (p.17) as a summary of cognitive change. However, although there is considerable evidence to support a systematic pattern of increasing interindividual variability with age, this phenomenon has not been well researched (Christensen et al., 1999). While numerous journal articles and texts.(e.g. Handbooks on Aging) make reference to the differential aspect of the aging process, the focus on normative trends predominates, and variability is not discussed as a topic in its own right. The only major study on this topic (known to this author) is that of Jordan (1997).

Jordan (1997) conducted a meta-analysis of multiple data sets available in the aging literature to investigate the nature of inter-individual variability on cognitive task performance in normal adults. She identified a number of regularly occurring patterns and used these to develop a model of variability (the shuttle model) which is explained in terms of Satz's (1993) brain reserve capacity (BRC) theory (see Section 3.2.3) and situated within a neuropsychological framework.

Jordan's analysis shows that variability in the performance of cognitive tasks, regardless of functional modality, increases with advancing age then decreases in older, old age. The greatest level of within-group variability (referred to as the shuttle bulge) is reached in middle to late adulthood and "reflects the presence of a significant number of individuals with disproportionately low and/or high scores who are not well- represented by the central trend" (p. 160). According to Jordan, the increase in variability, which is associated with a concurrent decline in group mean performance, reflects the diverse effects of age-associated neural attrition on individual group members. The subsequent decrease in variability, with advancing age, demonstrates a more pronounced neural attrition for all group members. Additionally, individual differences in brain reserve capacity influence the onset of functional decline.

Jordan suggests, in accordance with Satz's theory, that the age of onset of the initial increase in variability is related to several factors which serve to heighten, or lower, the brain reserve capacity threshold. Specifically, the differential influences of education/IQ, age sensitivity of tasks (as measured by mean performance analysis), task challenge and gender, cause the bulge to shift backwards and forwards along the adult age axis. For example, an earlier age onset of the bulge (defined by Jordan, as a left shuttle shift effect) is associated with low education, tasks that are sensitivity to age effects, high challenge tasks and being of male gender. A later emergence of the bulge, defined as a right shuttle shift effect, is conversely, associated with high education, tasks which have low age sensitivity, low challenge tasks and female gender.

The results of Jordan's (1997) research shows that *"when neural aging starts to take effect, it does so in a manner which is distinctly uneven across individuals"* (p. 424, her italics) and she concludes that there is a need "for a differential perspective on aging, as a complement to the prevailing normative tradition" (p. iii).

4.3 SELECTING TESTS FOR USE WITH OLDER ADULTS

Although neuropsychological assessment has gained increasing value as a clinical tool for assessing the cognitive status of the expanding elderly population (Schmitt & Ranseen, 1989) assessing older adults presents additional challenges. One such challenge relates to the use of tests batteries.

The most common approach to assessment involves the use of a fixed, comprehensive test battery such as the previously mentioned WAIS-R and the HRNB. There are several advantages to using this approach: the subtests are extensively researched so there is an extensive body of validation data and test manuals provide carefully standardised instructions for administration and interpretation. Disadvantages include time and labour intensiveness and the risk that the breadth of the assessment, and the resulting composite score, may not detect subtle deficits in performance (Groth-Marnat, 2000). Moreover, and perhaps more important, fixed batteries are not suitable for the assessment of many older adults because they are too lengthy and often require stamina beyond the capabilities of the individual (Albert, 1981). As Green (2000) points out, older adults, particularly those with cognitive impairment, are likely to become frustrated or tired quickly so will not perform optimally

Schmitt and Ranseen (1989) suggest that in addition to fixed batteries, there is a need for short screening batteries for the initial evaluation of older adults. Such batteries, which would include tests that are highly sensitive to the impact of dementia on cognitive performance, could be used to identify the need for more extensive neuropsychological evaluation. They note that several subtests from the WAIS-R and HRB have demonstrated utility in differentiating between normal age-related cognitive decline and dementia so are very suitable for inclusion in a dementia screening battery. For this reason, and because such subtests have the advantages discussed in relation to fixed batteries, one WAIS-R and two HRB subtests were used in this study. All three tests, reported on in this study, can be completed in a maximum of 15 minutes which represents a saving in time, and distress, for the elderly individual and are less labour intensive for the clinician. These tests are discussed in Chapter 5.

CHAPTER 5: COGNITIVE TESTS USED IN THIS STUDY

The tests chosen for this study are: The Finger Tapping Test, the Digit Symbol Substitution Test, the Digit Symbol Incidental Recall (Immediate and Delayed) Tests, and the Trail Making Test. These tests were selected since literature (for example, Groth-Marnat, 1997; Lezak, 1995) reports that they are sensitive to age and education. Although test administration of the tests is fully described under Methodology (Chapter 6), for clarity, a brief description of the administration and scoring procedures is included in this chapter. An effort has been made to avoid unnecessary repetition of material.

5.1 FINGER TAPPING TEST (FTT)

5.1.1 Historical background

The Finger Tapping Test, previously referred to as the Finger Oscillation Test, is one of the original tests introduced by Halstead in 1947 to test motor speed and motor control. In the original version finger tapping speed was only measured for the dominant hand but in 1955, Reitan modified the test administration to include the performance of both hands. The test is now an essential part of the Halstead-Reitan Neuropsychological Test Battery (HRNB) and one of the most widely used tests of manual dexterity (Groth-Marnat, 1997; Lezak, 1995).

5.1.2 Functions measured by test

The FTT, while requiring some degree of coordination, is primarily a test of simple motor speed and lateralisation (Groth-Marnat, 1997). Any motor performance task, that allows a comparison of the two sides of the body, permits inferences about functional efficiency of the two brain hemispheres (Henninger, 1992). The FTT should, therefore, reflect Central Nervous System (CNS) dysfunction contralateral to the hand with slower tapping speed. However, if the impairment is in the posterior cortex, the lateralised damage may not be reflected in the score (Reitan & Wolfson, 1993).

The general guideline (Groth-Marnat, 1997; Henninger, 1992) for normal performance, is that dominant hand speed will be 10% faster than non-dominant hand speed although considerable variability has been shown (Satz, Achenbach, & Fennell, 1967) in the normal population. A faster non-dominant hand performance is a strong indication of damage to the dominant hemisphere and differences of 20% or more between hands suggests brain lesions contralateral to the side of the slowing. However, differences between dominant and non-dominant hands must be treated with caution as several studies (Satz et al., 1967; Thompson, Heaton, Matthews, & Grant, 1987) have reported larger intermanual difference for right-handers than for left-handers as the non-dominant hand of left-handers is faster than the non-dominant hand of right-handers. For example, Satz et al. (1967) found a mean difference between hands of 6.0 taps for right-handers and 2.8 taps for left-handers. This suggests that when the 20% difference is used in left-handers, impaired individuals may be classified as normal. However localisation and lateralisation need to be treated cautiously (Groth-Marnat, 1997) as a variety of cerebral locations can produce right-left motor discrepancies. For example, the FTT requires executive function activities such as planning and initiation of behaviour which would be impaired with anterior frontal or subcortical damage, and damage in the motor strip or the cerebellum could cause a coordination dysfunction.

5.1.3 Method of administration and scoring

According to Lezak (1995) the order in which tests in a battery are presented has no influence on performance. The single exception to this rule concerns the FTT which shows slight slowing when administered at the latter end of a test battery. For this reason, the FTT should be administered early in the battery as was done in the present study.

Performance on this test is generally measured by a manual recording instrument and scored according to the HRB manual (Reitan, 1979). Denckla (1973) however, administers the test without using a measuring instrument. Her method requires the individual to tap each finger in succession, from index finger through to little finger, against the thumb as quickly as possible until told to stop. The test requires each tap to be a discrete entity and any 'dragging' of the thumb across the finger tips is corrected and the test restarted. Mistakes involving coordination are allowed as long as the five sets of taps are completed. The score is the time taken for 20 taps.

Denkla uses this version for the assessment of children with suspected minimal brain damage. She reports a high retest reliability of r = .78 for dominant hand and r = .81 for the non-dominant hand on normal children three weeks after initial testing.

Denkla's method was used in this study for several reasons: (i) it is used routinely as part of the neuropsychological assessment battery in the Department of Neurology and Neurosurgery at Groote Schuur Hospital, Cape Town (Balarin, 1992); (ii) it has been used extensively in South African studies conducted by Ann Shuttleworth-Edwards, Rhodes University, both to generate normative data and to screen for mild closed head injuries in rugby players and; (iii) normative data for a high education population is available for comparison with the low education data generated in this study.

5.1.4 Age sensitivity

An age-related decrement on FTT performance has been demonstrated in numerous studies (Bornstein, 1985; Fromm-Auch & Yeudall, 1983; Heaton et al., 1991; Nagasaki, Itoh, Maruyama, & Hashizume, 1988; Ruff & Parker, 1993; Shimoyama, Ninchoji, & Uemura, 1990; York & Biederman, 1990). Most of these studies indicate that performance peaks in the 30+ to 40 age group then declines notably from 40+ years in both men and women. Lezak (1995) suggests that age-related slowing becomes prominent from about the 5th decade and becomes increasingly marked with each subsequent decade.

However, contrary to the above findings, a study by Ruff and Parker's (1993), stratified for education, showed that while women's performances decreased with increasing age, men experienced no significant age-related decrements on performance. The authors offer no explanation for this finding which contradicts all previous ones.

5.1.5 Education sensitivity

Many studies (Bornstein, 1985; Finlayson, Johnson & Reitan 1977; Fromm-Auch & Yeudall, 1983; Heaton et al., 1991) have found significant education effects with more highly educated individuals demonstrating faster tapping rates than less educationally advantaged individuals. Additionally, Thompson et al. (1987) found that improvement in scores, after practice, was greater for those with higher levels of education. Conversely, a few studies (Ruff & Parker, 1993; Mc Curry et al., 2001) found no significant education effects. Despite these findings, the consensus is that the FTT is sensitive to education effects (Groth-Marnat, 1997; Lezak, 1983, 1995). However, the education effects are less than the age effects. For example, Heaton et al.'s (1991) study found that only 6% of the score variance, for dominant hand performance, was attributed to education while 9% was attributed to age. No age by education interaction was reported in any of the aforementioned studies.

5.1.6 Gender sensitivity

Although gender is not a variable of interest in this study, it has been shown to have a significant effect on FTT test performance with men consistently out performing women on each hand (Bornstein, 1985; Filskov & Cantonese; Fromm-Auch & Yeudall, 1983; Heaton et al., 1986; Morrison, Gregory & Paul, 1979; Ruff & Parker, 1993). In the Heaton et al. (1991) study, 19% of the score variance, for dominant hand performance, was accounted for by gender. This finding is supported by Ruff & Parker who reported that gender differences accounted for 18% of the score variance of non-dominant hand performance and 19.5 % of variance of dominant-hand performance. They further noted, that for both dominant and non-dominant hand performance, male performance in the 55-70 age group (M= 53.4 and 48.3, respectively) was greater than the best female performance in the 16-24 age group (M = 49.5 and 45.6, respectively). According to Dodrill (1979) the better male performance can be accounted for by the larger hand size in males. His study demonstrated a correlation between hand-span and FTT performance: the greater the hand span, the faster the tapping speed. A later informal study showed that when male and female subjects had the same hand size, no performance differences were noted.

5.1.7 Utility in differentiating between age effects and dementia

Podell and Lovell (2000) note that tests of impairment in fine and complex motor skills have almost the same sensitivity as other cognitive tests in differentiating between healthy older adult and those with mild, early dementia. The FTT, in particular, has been described by several prominent neuropsychologists (Groth-Marnat, 1997; Lezak, 1995; Mitrushina et al., 1999) as one of the most sensitive tests in the HRB for determining brain impairment. Furthermore, this test, which is equally sensitive to aging effects can effectively differentiate between normal aging and dementia. For example, Muller, Weisbrod, and Klingberg (1991) found that individuals in the early stages of Alzheimer's Disease (AD) performed significantly slower relative to intact older subjects.

Muller et al's (1991) findings are supported by a South African study (Aronson, 1994) which compared FTT performance of mild AD, moderate AD and normal control subjects. Results showed that for both mild and moderate AD patients, performance on the FTT was significantly slower than that of the control groups. Patients with mild AD showed slowing in both hands but more markedly on the non-dominant hand. Slowing was equally marked in both hands of patients with moderate AD. These results demonstrate the test's ability to differentiate between normal and demented subjects, and between mild and moderate stages of AD.

5.1.8 Normative data

Shuttleworth-Jordan and Bode (1996), provide (unpublished) normative data on Denkla's version of the Finger Tapping Test for a South African, high education population: mean education level 14.93 years, range 10-22 years. The data is tabulated as means, standard deviations and ranges across five age groupings. Results indicate a linear increment in mean scores (poorer performance), for both preferred and non-preferred hand tests, with each successive age group. For preferred hand performance, the 70-79 age group shows the highest standard deviation which suggests that variability is highest within this group however non preferred-hand performance shows the greatest variability (highest SD) in the 80-89 group. These norms are the only ones available, for adults, on this version of the test.

The results of this study will provide additional preliminary normative data for a relatively low education population and a comparison will be made between this data set and that of Shuttleworth-Jordan and Bode.

5.2 DIGIT SYMBOL SUBSTITUTION TEST (DSST)

The Digit Symbol Immediate and Delayed Incidental Recall tests are recent extensions of the Digit Symbol Substitution Test (WAIS-R). To date there is meagre published literature on these extensions. For this reason, and to avoid repetition of material, all three will be discussed under the main heading of Digit Symbol Substitution Test.

5.2.1 Historical background

The DSST is one of the eleven subtests in the Wechsler Adult Intelligence Scales (WAIS). It was incorporated into the initial Wechsler-Bellevue Intelligence Scales (W-B), which were first published in 1939, from the Army Group Examinations (Army Beta). The W-B was revised to form the WAIS in 1955, the WAIS-R in 1981, and the WAIS 111[2] in 1997 (Groth-Marnat, 1997). The South African Wechsler Adult Intelligence Scales (SAWAIS) is based on the W-B but, as the instruction manual was only published in 1969, many psychologists mistakenly believe it to be a local version of the 1955, WAIS (Nel, 1994) . The SAWAIS, DSST was used in this study.

5.2.2 Functions measured by test

The test was originally designed to measure associational learning, yet research suggests that psychomotor speed is a more important determinant of performance than is the incidental learning which takes place during performance of the task (Joy, Fein & Kaplan, 1992). There is, in fact, still a lot of controversy regarding what DSST actually measures. The key issue is wether performance is most affected by memory or motor skills.

Test performance involves the appropriate combining of the newly learned memory of the digit with the symbol, as well as spatial-motor coordination followed by the executive action of drawing the symbol. It requires the ability to learn an unfamiliar task, accurate eye-hand coordination, short term memory, attentional skills and the ability to work under the pressure of

[2] The Digit Symbol format has been altered in the WAIS 111 and as testing for this study commenced prior to publication of the WAIS 111 manual, the newer version is not discussed.

performance being timed. Difficulties in performing this task may be the result of deficits in any of these skill areas or an interaction between several skill deficits (Groth-Marnat, 1997). The DSST is therefore a multifactorial test which is sensitive to dysfunction anywhere in the central nervous system. However, as scores are depressed regardless of the location of the damage, the test can not identifying which specific functions are impaired and which are intact. This limits the use of the standard test to screening for cognitive defects. However, the DSST is reported to be very sensitive to age effects so is a suitable measure for assessing the cognitive status of older adults (Lezak, 1995).

Despite being very sensitive to age effects and to brain damage, the DSST does not specifically test memory which is also very sensitive to age and brain damage effects. Joy, Fein and Kaplan (1992) have remedied this deficit by extending the WAIS-R version of the test to include two measures of incidental learning (immediate recall and free recall) which assess non-verbal, short-term memory. Incidental memory, or recall, differs from intentional memory in that no instruction is given to memorize the material. Lezak (1995) notes that "when the declarative memory is intact, much information is also acquired without directed effort, by means of incidental learning" (p.30).. These extensions enhance the screening potential of the WAIS-R (and WAIS III) as they are the only direct measure of visual recent memory in the batteries.

In addition to an immediate recall test, Lezak (1995) also administers a delayed recall test as a measure of remote memory which is even more sensitive to differentiating different types of cerebral pathology. She argues that tests of memory must consider both immediate memory and retention, and points out that immediate recall trials do not test retention, learning, or the efficiency of the memory system. A delayed trial is necessary to show what information has been stored in more than a temporary form. Secondly, interference such as the administration of other tests, during the delay period prevents rehearsal of new information and the delayed recall results can then be considered as a measure of learned material. Lezak notes that patients with retentional problems show a lower delayed recall score, compared with the immediate recall score-sometimes being only one or even none. Additionally, some testees show improvement on delayed recall as opposed to immediate recall which Lezak suggest may indicate a problem with processing speed.

5.2.3 Method of administration and scoring

5.2.3.1 Digit Symbol Substitution Test (SAWAIS)

The DSST test involves copying abstract symbols associated with numbers according to a printed key at the top of the test sheet. The score is the number of correct matches achieved in 90 seconds (Lezak, 1995).

The SAWAIS version of the test is identical to that of the WAIS-R (1981) except that it has been shortened by one line. This effectively means that the abbreviated format has 67 instead of 93 test blocks and three lines rather than four. However, as Shuttleworth-Jordan and Bode (1995) point out, the elimination of one line has minimal, if any, effect on the test scores as very few individuals, including young people, achieve more than 68 pairs on the standard administration of the test.

5.2.3.2 Incidental Recall Test: Immediate (Shuttleworth-Jordan and Bode, 1995 version)

A short form of the incidental recall test, using the SAWAIS Digit Symbol test, has been developed by Shuttleworth-Jordan and Bode (1995) and this version was used in this study. On completion of the standard administration, testees who have not completed the second row are instructed to continue filling in the blank spaces until the end of this row. The key and completed rows are then hidden and testees are asked to fill in the third row from memory The score is the number of correct pairs remembered.

Completion to the end of the second last row allows for 42 digit/symbol pairings as opposed to 68 pairs completed in the Joy et al. (1992) WAIS-R version so testees have one whole line less of practice prior to the recall test. While highly functioning individuals are likely to complete more than 42 pairs on the standard WAIS-R test, older adults will complete fewer. Mayo's Older American Normative Scores (MOANS) (Ivnik et al., 1992) provide scores of 38-42 pairs and 28-31 pairs for highly educated individuals in the 65-75 and 83 + age groups respectively. However, above average intelligence individuals in the 20-34 age group average between 60 and 70 pairs (WAIS-R Manual, 1981). Clearly the abbreviated version runs the risk of a ceiling effect with young adults but this is compensated for by reduction of the variation in amount of practice across the age groups. This is an important factor as older adults take much longer to complete substitution tasks. The completion of 42 blocks ensures that all participants will match all nine pairs at least once (Shuttleworth-Edwards, Border & Reid, 2000; Shuttleworth-Jordan & Bode, 1995). Free recall is not measured in this version of the test.

The rationale (Shuttleworth-Jordan & Bode, 1995) for the abbreviated version is that a shorter test will reduce fatigue and stress experienced by elderly subjects in test situations and facilitate optimal performance. A comparison of the shorter and longer versions of this test has shown no significant difference with respect to the number of symbols recalled thus Shuttleworth-Jordan and Bode have recommended that, for clinical practice, the shorter version is more user friendly and economical. It is therefore likely that this version of the test will continue to be used in South African aging studies despite the introduction of the WAIS III Digit Symbol Substitution test which is even longer than the WAIS-R version of this test.

5.2.3.3 Incidental Recall Test: Delayed

Lezak's (1995) delayed recall measure is administered approximately 30 minutes after the immediate recall and the score is the number of correct pairs recalled.

5.2.4 Age sensitivity

Digit symbol is one of the performance tests of the WAIS thought to measure 'fluid intelligence' which is believed to decline with age (Lezak, 1995). According to Botwinick (1967), of all eleven WAIS subtests, Digit Symbol ranks first in differentiating between the performances of young and old people. However, although this age related difference has been demonstrated in numerous studies, the reason for the poorer performance of older adults on this measure have not yet been fully determined. Several hypothesis have been proposed in recent years.

The peripheral motor speed hypothesis, proposes a reduction of speed in manual movements such as in writing symbols. Several studies (Erber, 1976; Erber, Botwinick & Storandt, !981; Salthouse, 1978; Storandt, 1976) have been conducted to test this hypothesis. For example, Storandt (1976) attempted to establish which dimension, speed or cognition, was responsible for the poorer performance in older adults. In order to measure copy speed she asked young (20-30 years) and old (65-75 years) subjects to copy the symbols as quickly as possible; thus there was no coding or digit symbol substitution aspect involved. Her results showed that copying speed (perceptual motor speed) accounted for 50% of the total Digit Symbol time and coding (cognitive component) for the other 50%. The ratios for the copying speed to the standard measure were almost identical, that is (.50) for young adults and (.53) for old adults. Her results, supported by the other above mentioned studies, indicated that both dimensions contributed equally to age-related performance. Although Storandt's findings failed to support the peripheral motor speed hypothesis, more recent research on 177 healthy older adults (Joy et al., 2000) demonstrates that the age-related decline in symbol copy speed ($r = -.58$), is almost as steep as the decline in Digit Symbol performance ($r = -.64$).

The second hypothesis invokes memory limitations as the critical factor and this proposal has directed several studies. Erber (1976) suggested that age-related decline is due to a reduction in learning and memory capacity thus older individuals have to consult the code key more frequently which increases performance time. She found that young adults achieved greater incidental learning of the digit-symbol pairings after 10 practice trials while older adults' performance did not improve. Erber's (1976) study was repeated by Grant, Storandt and Botwinick (1978) and Beres and Baron (1981) who allowed subjects 20 and 100 repetitions, respectively, of the task. The increased practice (rehearsal of digit pairs) should have enabled both young and older adults to commit the Digit-Symbol pairs to memory and reduced the difference between the young and older adults performance. However, results showed that while the performance of both groups improved, there was no change in the magnitude of the difference in performance between the young and older adults.

Salthouse (1978) disagreed with Erber's hypothesis that older individuals have to consult the key more frequently and proposed that both young and old subjects perform the DSST with functionally equivalent memory capacities. His conclusions were based on several studies which examined the effect of the number and frequency of Digit Symbol pairs presented. For example, he demonstrated that age related differences were still present after the memory load was minimized by reducing the number of digit-symbol pairings from 9 to 6 to 3 to 1. Salthouse had reasoned, that if the age difference in performance was due to memory capacity then older adults would benefit by the reduction in pairings as less time would be spent on scanning the key. However it was shown that both groups devoted approximately the same proportion of time to this scanning activity and, even when the number of Digit Symbol pairs was reduced, the age difference remained unchanged.

To date, the limited memory capacity hypothesis has not been proven. In fact, two recent studies conducted by Joy et al. (2000) and Kreiner and Ryan (2001) demonstrated that incidental learning accounted for only 1-3% of the variance in DS scores when entered into a multiple regression with the speeded Symbol Copy test. In the Joy et al. study, the decline in incidental recall was modest (r = .26) compared with that of the Symbol Copy (r = -.58). Kreiner and Ryan's findings are consistent with those of Joy et al., thus both studies demonstrate that motor speed is substantially more important than memory in explaining differences in Digit Symbol performance.

The third hypothesis (Salthouse, 1992) suggests that age related performance deficits may be the consequence of a rather global slowing of many perceptual, motor and cognitive processes rather than being accounted for by any one specific process. Studies conducted by Salthouse (1992) show that age trends are produced by a gradual shift in the entire distribution of scores which suggests that age related decline is typical, or normative, for most adults. Moreover, the differences between mean scores for younger and older adults are not associated with an increased variance in the distribution which indicates that the older group scores are not reflecting a tendency for some older individuals to have very low scores while others are relatively high performing. Salthouse suggests that age differences in performance of DSST reflects a slower rate of processing information rather than deficits in memory or in the efficiency of specific processes such as motor speed. He also proposes that the speed at which the central nervous system (CNS) processes information may influence memory performance and this may explain the failure of rehearsals in the aforementioned studies to improve performance of elderly subjects. However, other studies (e.g. Shuttleworth-Jordan & Bode, 1995; Smith, 1997) have demonstrated an increasing variance in scores of older adults relative to younger adults which contradicts this hypothesis.

5.2.5 Education sensitivity

According to Heaton et al. (1986) all WAIS subtests, including Digit Symbol, show an association between better test performance and educational attainment. On Digit Symbol specifically, 25% of the test variance is accounted for by education. Several other studies (Kaufman, McLean & Reynolds, 1988; Mazaux et al., 1995; Mortensen & Gade, 1993; Portin et al., 1995) have demonstrated significant effects for education. Thus it is currently held that high education level is associated with better Digit Symbol performance and, a possible reason (Mazaux et al., 1995), is that individuals with high educational attainment are more accustomed to abstract tasks such as psychometric tests. None of the above mentioned studies found a significant age by education effect.

5.2.6 Utility in differentiating between age effects and dementia

The DSST is regarded as the most sensitive of all the WAIS-R subtests to the effects of aging and the effects of brain damage.(Albert, 1981; Glosser, Butters & Kaplan, 1977; Groth-Marnat, 1997; Joy et al., 1992; Lezak, 1995). Lezak states that even with minimal brain damage, Digit Symbol will be the lowest subtest overall. While depressed DSST scores are associated with a wide variety of central nervous system dysfunctions and with normal age-related decline research has shown that the test can effectively differentiate between these two conditions (Groth-Marnat, 1997; Joy et al.1992; Lezak, 1995). For example, Fleischmann (1991) used a wide variety of cognitive tests to determine their sensitivity to Alzheimer's Disease. His research sample consisted of two groups (N = 41 each) both with a mean age of 78.10 years (range 62-89). Group 1 consisted of subjects diagnosed with Alzheimer's-type dementia while Group 2 comprised age-matched subjects with no evidence of organic dementia. Results showed that compared with other psychometrical memory tests, Digit Symbol had a superior test performance to discriminate between patients with AD and normal age-matched subjects.

It has been suggested (Glosser et al., 1977) that the factors which influence test performance may be different for brain-damaged individuals and non-brain damaged individual. For example, psychomotor speed is thought to be the major determinant of performance in intact normal subjects, but other visual processing variables may have a major influence on performance of patients with brain damage. To test this theory, Glosser et al. conducted research with four groups: (I) alcoholic Korsakoff patients, (ii) right hemisphere brain damage patients, (iii) alcoholics in rehabilitated centres and (iv) normal subject. All groups (N=10 each) were evenly matched for age and education. Results showed that Digit Symbol not only differentiated between normal and brain damaged subjects but also demonstrated that the task measures different functions in these distinct groups. While psychomotor speed was the main determinant of performance in normal subjects, visuoperceptive processes such as visual scanning, contour formation and organization were also involved in the performance of brain-damaged subjects.

The Digit Symbol Incidental Recall test has been shown (Hart, Kwentus, Wade & Hamer, 1987) to effectively differentiate between normal control subjects, depressed patients and mildly demented (AD) patients even when the standard test failed to differentiate between the two patient groups. While DSST performance was equivalent for the depressed and mild dementia patients, incidental learning performance was superior for the depressed patients. Similarly, the normal subjects showed better performance on both DSST and Recall than the depressed patients however the difference in recall performance between these two groups was less marked than that between the two patient groups.

5.2.7 Normative data

5.2.7.1 Digit Symbol Substitution Test

The SAWAIS manual (1969) provides age-graded conversions of raw scores to normalised scores for all the individual subtests. However scores are only given up to age 59 which, according to Lezak (1983) is precisely the point at which age-graded scores become of utmost importance, since age-related effects, particularly on timed tests, become marked from the onset of the sixth decade. Additionally, a comparison of Digit Symbol raw data converted to WAIS-R and SAWAIS shows higher SAWAIS scaled scores relative to those of WAIS-R which indicates that SAWAIS scores are too lenient to allow for valid conclusions about 'normality' and deficit in present day, better educated and more test-wise, South Africans (Nel, 1994; Shuttleworth-Jordan, 1995). Nel (1994) argues that the almost 40 years old SAWAIS norms do not reflect the ongoing educational development of the age cohorts in the target population. Furthermore, these outdated norms are likely to inflate ability so that 'average' results may be obtained even in the presence of significant cognitive impairment. This highlights the need for accessible, updated South African normative data.

In contrast to the SAWAIS, the WAIS-R manual (1981) presents scores for the ages 16-74 and Ryan, Paolo and Brungardt (1992) have expanded the WAIS-R norms by providing age-corrected subtest scores for individuals over 75 years with a mean educational level of 9.54 years (Lezak, 1995). Additionally, Ivnik et al. (1992) have supplied norms for WAIS-R on an older adult sample (N= 512, age = 56-97 years). However 84% of their subjects had an education level of over 12 years so these norms were developed on a better educated sample than the WAIS-R normative samples and the Ryan et al. older sample (Lezak, 1995). Normative data, highly comparable with those of Ivnik et al., have been reported by Joy et al. (1992) on subjects aged 50-90 years (mean education = 13.58 years) and Shuttleworth-Jordan and Bode (1995) on subjects aged 20-89 (mean education = 14.93 years). All three studies have shown decreased performance with increasing age. However, with regard to these normative studies, only Shuttleworth-Jordan and Bode have drawn a comparison between young and older adults, and no comparison has been made, in any of these studies, between different education levels despite evidence of the effect of education on Digit Symbol performance. Mitrushina et al., (1999) have not included the Digit Symbol test, or any variation, in their Handbook of Normative Data.

5.2.7.2 DSST: Immediate Recall Test

To date there is little normative data on immediate incidental recall. Lezak (1995) suggests, as a general guideline, six correct pairs as the lower end of the normal range, but the only published normative data stratified for age, and which were derived from relatively high education samples, are those of Joy et al., (1992) and Shuttleworth-Jordan and Bode (1995). Joy et al. provide mean scores from a sample of older adults divided into four age groups: 50-59 (M = 5.41), 60-69 (M = 5.20), 70-79 (M = 4.62) and 80-89 (M = 3.76) while Shuttleworth-Jordan and Bode present means of 7, 5, 6, 3.5 and 3 for the age groups 20-39 59, 60-69, 70-79 and 80-89 respectively. Both studies show a consistent decrement in performance with age although the decade to decade decline is smaller, and more gradual, in the Joy et al. study: Shuttleworth-Jordan and Bode report a dramatic decline in the 70-79 age group. The Shuttleworth-Jordan and Bode score for young and middle-aged adults (20-69 years, mean = 6) concurs with Lezak's recommendation of six pairs as the lower limit of normal, however the participants in their two oldest age groups and all of Joy et al.'s participants would be diagnosed as impaired if this 'norm' were applied.

Joy et al. (2000) provide norms on a relatively low education sample (≤ 12 years) with the same age groupings as their 1992 high education sample: 50-59 (M = 5.00), 60-69 (M = 5.18), 70-79 (M = 4.52) and 80-89 (M = 2.07). As evidenced from Joy et al's samples (1992 & 2000) performance is poorer (marginally) in the low education group, compared with the high education group, particularly in very old age. A similar education effect is expected in the present study and, owing to the larger age range in this study, compared with that of Joy et al., it is possible that an earlier onset of decline may be detected.

South African Normative Data

Shuttleworth-Jordan and Bode (1995) provide means, standard deviations and ranges across five age groupings (same sample as for FTT). Their findings showed that increasing age is associated with poorer Digit Symbol performance as reflected by the number of correct digit/symbol pairings. The Digit Symbol Incidental Recall test likewise, shows that recall of correct pairing decreases with increasing age. Data from this study will be compared with the Shuttleworth-Jordan and Bode (1995) data.

5.2.7.3 DSST: Delayed Recall Test

Lezak (1995) does not suggest any normative standard for this test. However, her reported findings on the Symbol Digit Modalities test indicate that most testees recall the same, or almost the same number of symbol-digit pairs for delayed recall as for immediate recall. Joy et al. (1992) and Shuttleworth-Jordan and Bode (1995) have not included a delayed recall aspect in their Digit Symbol recall measurements nor has it been included in the WAIS-111 manual (1997) hence there are no available norms for this test.

5.3 THE TRAIL MAKING TEST (TMT)

5.3.1 Historical background

The historical background of the TMT has been fully described by Brown, Casey, Fisch and Neuringer (1958) thus will not be repeated here. The test was incorporated into the Halstead Battery by Reitan in 1944 and is presently part of the Halstead-Reitan Neuropsychological test battery.

5.3.2 Functions measured by test

Lezak (1995) lists the TMT under tests which require orientation and attention both of which involve a series of related skills such as complex scanning and visuomotor tracking, focussed attention, mental flexibility, speed of information processing, planning and coordination, motor speed, and letter and number fluency. Effective performance therefore requires an integration of all these different abilities (Armitage, 1946; Corrigan & Hinkeldey, 1987; Reitan, 1958; Schear & Sato, 1989; Stuss, Stethem & Poirier, 1989).

While both parts A and B of the TMT provide information regarding attention, visual scanning, and speed of eye-hand coordination and information processing (Lezak, 1995), Part B, which is a more complex task, also assesses the ability to alternate between sets of stimuli, which is an executive function (Mitrushina et al., 1999). Consistent with this is that Part B has been shown (Larrabee & Curtis, 1995) to be more closely associated with spatial intelligence than with attention, immediate memory and information processing.

Research suggests that the two parts of the TMT may be differentially sensitive to impairment in the dominant and non-dominant brain hemispheres. Understanding and correct sequencing of numbers and letters draws on left hemisphere abilities while right hemisphere abilities are tapped for the visual scanning of the page (Groth -Marnat, 1997). Reitan & Tarshes, (1959) have hypothesised that patients with right hemisphere damage will show performance deficits on both parts of the test as their visual scanning abilities will be impaired. Left hemisphere damage will be evidenced by poor performance on Part B which requires processing of complex symbolic material. However, several studies reviewed by Lezak (1983) have failed to support this laterality and Groth-Marnat cautions that decisions about lateralisation should not be based on TMT scores as test performance more accurately measures overall integrity of brain functioning.

Despite the lack of empirical support for the TMT's ability to lateralise functions it is accepted that Part B requires additional cognitive abilities and further, that this accounts for the longer time taken for completion (Groth-Marnat, 1997; Lezak, 1995). Gaudina, Geisler and Squires (1995) have also drawn attention to other differences which make Part B harder to perform than Part A, namely, the distance between targets and the complexity of visual search in each part. They report that Part B has an additional, between target, difference of 2.4 cm which results in Part B being 56.9 cm longer than Part A. Additionally the amount of visual interference is greater for part B which has, in total, 28 items within 3 cm of the path between each target whereas Part A has only 11 items. They conclude that Part B is more complex than Part A *on many levels* and caution that poor performance on Part B may overestimate cognitive deficits when a direct comparison is made between performances on Parts A and B.

5.3.3 Method of administration and scoring

The TMT, Part A requires participants to draw a connecting line between randomly scattered circled numbers from 1 through to 25, and in Part B they have to draw a line connecting alternate numbers and letters (e.g., 1-A-2-B-3, etc.) ending at 13. Parts A and B are scored separately.

The method of administration and scoring has undergone many changes since the test's inception. The Army Individual Test manual (U.S War Department, 1944) provided a 10 point scale for converting raw scores, with 1 as the worst and 10 as the best score. The raw score was the time taken for an errorless performance (Brown et al., 1958). Armitage (1946) modified the administration by allowing subjects to complete the test but awarding a score of zero for uncorrected errors. An errorless performance within 20 seconds received the maximum score of 10 while slower performances were awarded partial credits depending on the time taken for completion. The emphasis in this administration was on speed and accuracy. Reitan (1955) changed the administration procedure further by having the examiner point out errors to the subject who was then required to correct it before proceeding. With this procedure, the test was always completed but errors had the effect of increasing the completion time and the type of error was not analysed: scoring was based exclusively on time. This method of administration and scoring was included in the Reitan (1956) manual and has become standardised over the years.

Lezak (1983, 1995) argues that reliability of the TMT is reduced by this simplified method of administration and scoring since the time taken for error correction depends as much on the examiner's speed of response, as it does on the testees' ability to comprehend and correct the error. However this criticism is not supported by research. A study instituted by Lezak (1983) found that reliability, as measured by the coefficient of concordance, remained constant (.78 for Part A and . 67 on Part B) over three administrations at six and twelve month intervals. Snow, Tarn, Zorzitto, Fisher, and Reid (1989) also reported a one-year retest reliability of .64 for Part A and .72 on Part B for 67 year old normal subjects. Moreover, in 1992, Fals-Stewart conducted an interrater reliability study using four experienced psychometrists to administer and score TMT performances. Results showed high interrater reliability on both parts of the test (Part A $\underline{r}$ = .94, and Part B $\underline{r}$ = .90), with no significant differences in the average number of milliseconds required by each examiner to correct errors. This suggests that experienced examiners are unlikely to introduce substantial variance to the test scores and that TMT can be considered a reliable measure.

5.3.4 Age sensitivity

The relationship between age and TMT performance is well documented. Normative data presented in Lezak (1983, 1995), Mitrushina et al. (1999) and Spreen and Strauss (1991) shows that performance times increase significantly with each succeeding decade. The majority of the studies, reported in these texts, show a greater age effect for Part B than for Part A

In one of the earliest publications on TMT performance, Brown et al. (1958) highlighted the necessity of accounting for age when interpreting test results. Later, Reed and Reitan (1963) reported that normal older adults showed impaired performances similar to those found in younger, more highly educated, brain-damaged subjects.

Many of the early studies on TMT performance investigated the effectiveness of the cutting scores developed by Reitan (undated) to interpret test performance of both brain-damaged and older subjects. Reitan used a single cutoff score to differentiate between normal and brain damaged subjects (Chavez, Trautt, Brandon & Steyaert, 1983). Two, frequently quoted studies, conducted by Davies (1968) examined the effects of age on TMT performance. The first study sample consisted of 540 normal subjects aged 20 to 79. Results showed that, when Reitan's cutoff points were used, misclassification rates increased through each successive decade age group from 30% in 20 year old subjects to 90% for 70 year old subjects. The second study based on individually matched normal and clinically diagnosed brain-damaged subjects demonstrated that correct classification of brain-damaged subjects required different cutoff points for 'young' and for 'middle-aged' groups. Davies' concluded that while Reitan's cutoff criteria were suitable for young adults, normal adults were at risk of being misclassified as brain-damaged as age increased.

Similar findings were reported by Goul and Brown (1970) who administered the TMT to 93 brain-damaged and 103 control subjects with an age range of 20 to 72 years. Results showed an overall false positive classification rate of 48.1% when using Reitan's cutoff points for Parts A+ B, with specific rates of 23.1 % in the youngest group (20-29 years) and 93.3 % in the 60-72 age group. However, Davies' (1968) age-corrected cutoff points also produced a high (63.2%) overall, false positive rate. When cutoff points were adjusted for each age decade (Goul & Brown, 1970) misclassification was reduced to an overall 19.8%. Goul and Brown emphasised the need for age corrected norms but also cautioned that such norms might not cross-validate to other settings thus local norms may need to be developed.

Boll and Reitan (1973) attempted to replicate the Gould and Brown findings with a similar, but substantially larger sample. However, their results showed no significant correlation between age and TMT performance for the control, or the brain-damaged subjects thus they concluded that the Reitan's cutoff scores did *not* result in an increasing number of either false positives or false negatives. They reported that the poorest percentages of correct classifications for both groups occurred in the youngest (15-19 years) and oldest (60-64 years) age groups but their general conclusions were that TMT performance was independent of age. Similarly, Yeudall, Reddon, Gill and Stefanyk (1987) reported no relationship between TMT performance and age which would seem to support Boll and Reitan's results. However, this is an erroneous assumption as the upper age limit in the Yeudall et al. sample was 40 years and other data sets, according to Mitrushina et al. (1999), show that age related declines only become apparent after 40 years of age. Mitrushina et al. also suggest that the Boll and Reitan study did in fact show an age related decline in that the oldest age group (60 to 64 years) scores were significantly poorer than all of the younger age group scores. Thus it is generally held that age does significantly affect TMT performance. However, it has been suggested that the poorer performance of older adults may be due, at least in part, to age-related sensory deficits.

Schear and Sato (1989) investigated the contribution of visuomotor speed and near visual acuity to performance of tests, such as the TMT (and the DSST), which tap these functions. Their results showed a correlation between performance on Part B of the TMT and finger tapping speed (-.42, $p=.001$) and visual acuity (-.27, $p=.05$). Conversly, Wahlin , Backman, Wahlin and Winblad' s (1996) study, while reporting an age-related slowing on TMT performance on older subjects with normal visual acuity, found no age-related differences in performance of tests measuring hand motor functions. These latter findings suggest that psychomotor slowing is cognitive in origin and part of the normal aging process rather than being of perceptual-motor origin. However, other research (Lezak, 1983) has show that while TMT- Part A is primarily a measure of psychomotor speed, Part B requires the ability to shift conceptually between sequential numbers and letters. This suggests that the observed age-related slowing is due to both cognitive and perceptual-motor factors. This slowing must therefore be taken into account when interpreting TMT performance scores to avoid misclassification of normal older adults as impaired.

5.3.5 Education sensitivity

The original version of the TMT, then named the Pathways, was found to have a high correlation with the Standford-Binet Intelligence test, and Reitan (1958) later found a similarly high correlation between the TMT and the Wechsler-Bellvue Scales for both normal and brain-damaged subjects. Other studies (Boll & Reitan, 1973; Goul & Brown, 1970; Kennedy, 1981) have confirmed this strong association between TMT performance and full IQ score.

The relationship between intellectual abilities and level of education is well known (Matarazzo, 1972, showed a .70 correlation) and numerous studies have reported a significant correlation between higher education and better TMT performance (Anthony, Heaton & Lehman, 1980; Bornstein, 1985; Bornstein & Suga, 1988; Finlayson et al., 1977; Gordon, 1972; Heaton et al., 1986, 1991; Kennedy, 1981; Parsons, Maslow, Morris, & Denny, 1964; Portin et al., 1995; Stanton, Jenkins, Savageau, & Zyzanski, 1984; Stuss et al., 1987).

Stanton et al. (1984), for example, found a significant education effect which was most marked for subjects with less than nine years of formal education. The percentage of their sample classified as impaired, when the cut-off scores suggested by Russell, Neuringer and Goldstein (1970) were used, ranged from 16.3% on Part A and 7.0% on Part B, in the most highly educated group to 50 % on both parts of the test in the least educated group. When this sample was stratified into three age decade groups (40's, 50's and 60's) a statistically significant difference was found between the 40's and 60's groups: performance in the older group was poorer. As the age by education interaction was not investigated, it is possible that a portion of the misclassifications can be accounted for by age effects.

Some studies (Bornstein, 1985; Ernst, 1987; Stuss et al., 1987) indicate that education effects are more pronounced on Part B than Part A. For example, Bornstein (1985) reported education correlates of .19 for Part A and .33 for Part B, after age effects had been partialed out. However, a few reported studies (Ivnik et al., 1992; Wahlin et al., 1996; Yeudall et al., 1987) found no significant education effect on TMT performance.

Age by education effect

Heaton et al. (1986) report a significant age by education interaction on Part B of the test. Their study showed that for individuals under 60 years, low levels of education resulted in greater age-related impairment while for subjects over 60 years the effect of education level was less marked.

However these findings have been challenged by Richardson and Marotoli (1996- cited in Mitrushina et al., 1999) who report that while mean performance of normal elderly subjects with less than 12 years education remained stable across the 76-80, and 81-90 age groups, it was notably poorer than the same age, better educated subjects and, well below the Heaton et al.(1991) age-stratified normative data. Only two published studies (Ivnik et al., 1996; Yeudall et al, 1987) have reported no significant age by education interaction.

The effect of education and the age x education effect on TMT performance has received limited attention. The Mayo's Older American Normative Studies (MOANS) provide the only published norms for the oldest old (80+ years) age group but their data has not been stratified for education (Ivnik et al. 1992). Bornstein & Suga (1988) point out that normal individuals with low levels of education may require more time to complete the test but risk being diagnosed as impaired when compared with the existing normative data. This highlights the need for normative data stratified for age and education.

5.3.6 Utility in differentiating between age effects and dementia

The TMT is a sensitive measure of executive functioning which makes it a very effective tool for detecting cerebral dysfunction in the differential diagnosis of dementia and in mild traumatic head injury (Mitrushina et al., 1999). TMT scores correlate more highly, than any other measure, with the overall impairment index from the HRNB (Heaton et al., 1986). While equally sensitive to the effects of aging, there are numerous studies which confirm the ability of the test to differentiate between normal and brain-damaged subjects (Armitage, 1946; Bornstein, Paniak, & O' Brien, 1987; Davies, 1968; Parsons et al., 1964; Reitan, 1955, 1958). For example, in one of these studies, Reitan (1955, 1958) administered the TMT to groups of matched brain-damaged and control subjects and found highly significant (6.26 points) intergroup mean differences.

While both Parts A and B have proved effective in detecting the early stages of dementia and tracking the progressive decline as the disorder advances (Botwinick, Storandt, Berg, & Boland, 1988; Greenlief et al., 1985), Part A alone has been shown (Botwinick et al., 1988) to effectively differentiate between control subjects and patients with dementia. Furthermore, the TMT has proven ability in detecting cognitive impairment before clinical onset. Chen et al., (2002) compared sixteen cognitive tests to identify the most accurate measures in discriminating between individuals with presymptomatic AD and individuals who remained nondemented over a 10-year follow-up period. Their results showed that the TMT had a higher discriminating ability than the Mini- Mental State Examination which is the most commonly used measure for detecting dementia.

5.3.7 Normative data

Reitan (1955, 1956, 1958) initially recommended use of the scaling method described in the Manual for the Army Individual Test and suggested, cutoffs for impaired performance based on the scaled scores. Later Reitan (1959- cited in Ernst, 1987) provided cut-off scores in terms of raw scores. However several studies (Bak & Greene, 1980; Bornstein et al., 1987; Ernst, 1987; Davies, 1968, Goul & Brown, 1970; Kennedy, 1981) have demonstrated an unacceptably high rate of misclassification, mainly false positives, for normal subjects, particularly older subjects, when cutoff scores are used. For this reason, according to Spreen and Strauss (1991), the use of cutoff scores has been abandoned by most clinicians and TMT performance scores are now compared with normative data. Mitrushina et al. (1999) state quite emphatically that the use of a single cut off score is not appropriate considering the significant association between TMT performance and variables such as age, IQ, and education.

During the past three decades many studies have been conducted to generate normative data on TMT performance and the most widely accepted norms are presented in Mitrushina et al.'s (1999) Handbook of Normative Data. Many of these studies provide means and standard deviations of raw scores stratified for age (Bornstein, 1985; Fromm-Auch & Yeudall, 1983; Kennedy, 1981; Van Gorp et al., 1990). Other studies present age corrected scaled scores (Ivnik et al., 1996), age-corrected cutoff points (Davies, 1968; Goul & Brown, 1970), age x education x gender corrected T scores (Heaton et al., 1991) or percentile scores (Davies, 1968).

Heaton et al. (1991) provide one of the most comprehensive normative data sets derived from 486 subjects assigned to 10 age groupings (age range 15-81 years) by six educational groupings.

However, with the exception of Ivnik et al. (1996), none of the aforementioned studies have provided normative data for the oldest old (80+) age group and the Ivnik et al. sample (age range 56-94 years.) does not allow for a comparison between young and older adults.

South African Normative Data

Cornfield and Shuttleworth-Jordan (1996) provide normative data on TMT performance in three older age groups: 60-69, 70-79 and 80-89 years, statistically equivalent for education level (M = 15 years). Their results show that time (seconds) taken for performance of both Parts A an B increased with each older age group. Jordan (1997) further reports a significant increase in variability for the 80-89 year old age group on Part A and an earlier onset (from the 70's) of increased variability for Part B. Data from the present study will be compared with those of Cornfield and Shuttleworth-Jordan (1996).

CHAPTER 6: METHODOLOGY

6.1 AIMS OF THE RESEARCH

This study is part of an ongoing normative data collection process, initiated by Professor Ann Edwards, of the Rhodes University Psychology Clinic, to study normal cognitive aging in a South African population. Data was collected between 1997 and 1999 by the present author and three co-researchers. Preliminary data on the Digit Symbol Substitution Test and the Digit Span Test was reported by Smith (1997) at an early stage of the process and results, based on a larger data set, were presented by Botha (1998) (Word Fluency and Digit Span Tests) and Nicolson (1999) (Mini Mental State Examination). The present study presents findings on the Finger Tapping Test (Preferred and Non-Preferred hands), the Digit Symbol Substitution Test, the Digit Symbol Incidental Immediate and Delayed Recall Tests and the Trail Making Test (Parts A and B).

The aim of this research is threefold: (i) to generate age-related normative data for a South African white population of relatively low education with respect to the Finger Tapping Test, the Digit Symbol Subtest, Digit Symbol Incidental Recall (immediate and delayed) and the Trail Making Test; (ii) to examine the data statistically for age effects with respect to central trends (means) and variability (standard deviation); and (iii) to examine education effects on mean performance and variability through a comparison of these data with existing normative data on these tests for a relatively high education.

The research hypotheses are: (i) for all tests, declining mean performance will be associated with increasing age and this decline will occur earlier for groups in the present low education sample as compared with groups from a high education sample; and (ii) for all tests, the highest level of variability will be evident at an earlier point along the age axis for the present low education sample as compared with the high education sample.

6.2 SAMPLING METHOD AND PARTICIPANTS

A process of convenience and snowball sampling was used to access participants. Young adults

(20-59 years) were recruited from work places such as shops, hospitals and municipal service departments while older adults (60+ years) were referred by friends, local health workers or were resident in retirement villages and homes. The aim of the study was explained to potential participants who were informed that the results would be used for Honours and Masters thesis projects and publication purposes. They were told that the assessment would involve a brief interview and a variety of cognitive tests which were not harmful in anyway and were usually enjoyed by testees. The general procedure and required time were explained, carefully and respectfully, to candidates and appointments made with those who agreed to participate. In some instances, relatives of older participants and retirement centre managers were consulted to gain access to, and to confirm cognitive soundness of potential recruits.

An attempt was made to balance for gender but this proved extremely difficult particularly with the older age groups, which reflected population demographics of a majority of female survivors, thus the final sample consisted of 54 males and 109 females. With regard to the younger group, several males between the ages 40-59, employed in government departments, were approached as potential participants. However, despite being reassured that the results would be confidential, they refused to participate on the grounds that it might jeopardize their jobs. The disproportionate number of females in this study was not considered problematic since gender was not a variable of interest in this study. Moreover, gender has not been shown to significantly affect performance on the DSST (Pietrzak, 1972; Yeudall et al. 1987) or the TMT (Chavez et al.1983; Kennedy, 1981) and reports on gender effects on the FTT are inconsistent (see section 5.1.2).

6.2.1 Inclusion criteria

The participants needed to fulfil the following criteria: they were required to be of Caucasian origin, fluent in English, working class, aged between 20 and 89 years and have an education level of between 8 and 12 years. Participants with less than 8 years of education were excluded since these levels might include individuals in the borderline retarded, or retarded intellectual range. The choice of Caucasian, English speaking participants was intentional to make this sample comparable with previous studies on Caucasian, professional populations with a relatively high education. However, it also had the advantage of controlling for cultural differences which are known (Ardila et al., 1992) to affect test performance. In South Africa, these differences are quite vast as a result of historical, socio-political stratification which limited access to formal education for non-white population groups. Many individuals in the present 50 to 90 year old age group had little, if any, schooling so would have been unsuitable for inclusion in this study.

The level of education (range = 8-12 years, mean = 10.35) in this study is considered 'low' relative to the Cornfield and Shuttleworth-Jordan (1996), and Shuttleworth-Jordan and Bode (1995, 1996) studies in relatively 'high' education populations (range = 10-27 years, mean = 14. 97, and range = 10-22 years, mean = 14.93, respectively). Although there is some overlap between this sample and the above mentioned samples, an education range of 8 to 10 years would have been too restrictive in terms of participant recruitment for this study.

Since the aim of this study was to generate normative data for a non-clinical population an important consideration was to identify and exclude individuals who might have some cognitive impairment.This was achieved through a pre-testing interview for all participants and administration of the Mini Mental State Examination (MMSE) to all participants aged 60 and above.

6.2.2 Sample composition

The overall sample consisted of 163 participants with a relatively low level of education, from a White, South African population. The sample was composed of 30 participants in each of the following age categories: 20-39, 40-59, 60-69, 70-79 and 80-89. These age categories are the same as Shuttleworth-Jordan and Bode's (1995, 1996) high education sample while the last three categories are also the same as Cornfield and Shuttleworth-Jordan's (1996) high education sample (See Table 16). In addition to these five groups, 13 participants in their 90's were tested and it was decided to include them as a sixth group despite their small number as there is minimal normative data on the 90+ age group. With the exception of five individuals (90+ group) from a senior citizens' home, all of the older subjects, were living active, independent lives either in their own homes, or in a retirement village.

6.3 PROCEDURE AND INSTRUMENTS

6.3.1 Procedure

Participants were given a fuller description of the aims of the study and the testing procedure and were assured that individual results would remain totally confidential and anonymous. Informed written consent (see Appendix 1) was obtained prior to commencement of interviews and testing. Participants were tested individually, by the author and three co-researchers, on a wide battery of tests. All the researchers, including those who participated in the earlier high education group studies, were trained in test administration and scoring by Professor Ann Edwards from the Rhodes University Psychology Clinic, thus ensuring optimal interrater reliability.

The test battery of the overall study was administered in the following order:

(I) The Sequential Finger Tapping Test

(ii) The SAWAIS Digit Symbol Substitution Test

(iii) The Digit Symbol Incidental Recall- Immediate

(iv) The Trail Making Test - Parts A and B

(v) The Word Fluency Test

(vi) The SAWAIS Digit Span tests (Digits Forwards and Digits Backwards)

(vii) The Digit Symbol Incidental Recall- Delayed

Most participants were tested in their own homes but a few, for their convenience, were tested in their workplace. Care was taken to ensure that the testing environment was comfortable, had good lighting and minimal distractions such as high noise levels or interruptions. Particular care was taken with older participants as literature suggest they are more likely to experience test anxiety than younger participants and high anxiety may compromise reliability of test results (Albert, 1981; Green, 2000; Hertzog & Schear, 1989; Holden, 1988). As Hunt (1989) points out, older persons are far removed from school-associated experiences that involve tests and their anxiety is related to concerns about how well they will understand the test and how well they will perform. Schaie (1996) notes that the older person's expectation of doing poorly may become a self-fulfilling prophecy thus additional praise and reassurance is required to counteract this expectation.

The following measures, as recommended by Green (2000), were taken to promote the respondents motivation, reduce performance anxiety and increase test confidence: (i) implicit instructions were given in a clear voice with adequate volume; (ii) respondents were told that it was not unusual to make some mistakes and, (iii) efforts were praised and reassurance given that performance was normal.

6.3.2 Pre-data collection assessment measures

Interview questionnaire

The interview questionnaire, which is attached in Appendix 2, had two sections. Section one elicited biographical details of the participants such as gender, age, years of education, reasons for discontinuing education, occupation, and source of fluency in English (for example, home language, education medium, or work medium). Section two comprised a brief health history which served to reveal medical, psychiatric or neurological conditions (including prior head injury), substance abuse, motor disabilities and uncorrected visual or hearing deficits which would necessitate exclusion of participant from the study.

Tuokko and Hadjistavropoulos (1998) describe how changes in sensory processes such as vision and hearing are common with increasing age and may impact on the performance of cognitive tests. Most people over 60 years experience some visual impairment while those in the 70-80 age range have some hearing loss. Participants who were compromised in either of these areas were encouraged to wear reading glasses or hearing aids during the testing. These authors also point out, that older persons have an increased prevalence of a variety of chronic conditions which could influence performance. Forty-six of the participants, aged 60 years and above, reported a history of at least one chronic medical condition: hypertension (24), age onset diabetes (3), asthma (7), hypothyroidism (3) anaemia (1), arthritis in knees, hips or back (6) and angina (2). All of the aforementioned conditions, treated with medication, were of minor severity, and participants reported feeling actively healthy. Three elderly women reported occasional bouts of dysphoric mood but denied any mood disturbance at the time of testing. Twelve participants who used sedative medication (sleeping pills) were retained in the study but testing was carried out at least 12 hours after the most recent intake of medication.

Mini-Mental State Examination (MMSE)

The Mini-Mental State Examination (MMSE) (see Appendix 2) was administered to all participants aged 60 and above. The MMSE, devised by Folstein, Folstein, and McHugh (1975), is a widely used, brief test of overall cognitive functioning. The test measures orientation, registration, attention and calculation, recall, language and visuo-constructional ability It consists of nineteen questions and has a score range of 0-30. Research by Anthony, Le Resche, Niaz, Van Korff and Folstein (1982) found that, with a cut-off score of 23/24, this device has a 87% sensitivity and 82 % specificity, for detecting dementia. Later findings by Bleeker, Bolla-Wilson, Kowas and Agnew (1988) demonstrated that MMSE scores, in a healthy population, decreased significantly with age and they suggested age-specific cut-off scores of 28, 28 and 26 for ages 60+, 70+ and 80+ respectively. Cornfield and Shuttleworth-Jordan (1996) use a cut-off score of 26 for all subjects above 60 to ensure an adequate level of cognitive functioning and this is the cut -off score used in the present study. Several studies (Butler, Ashford, & Snowdon, 1996; Crum, Anthony, Basset & Folstein, 1993; Liu et al., 1994) have shown that lower MMSE scores are obtained by participants with less education. However, a comparison of data (Nicolson, 1999) from the sample in the present study with that of the aforementioned 'relatively' high education sample, showed no significant differences.

These initial steps (interview questionnaire and MMSE) resulted in the exclusion of five potential participants. Four (two in the 80's and two in the 90's groups) had MMSE scores below the cut-off point of 26 and the fifth, diagnosed as having Bipolar Disorder, was heavily medicated.

6.3.3 Data collection for selected cognitive tests

For this study, data was collected for the following tests: Finger Tapping Test (Preferred and Non-Preferred hand); Digit Symbol Substitution Test (DSST); DSST Immediate and Delayed Recall Tests; Trail Making Test Parts A and B. A copy of the tests, and the test instructions, is included as Appendix 3.

The Sequential Finger Tapping Test: (Denkla, 1973)

Prior to administration of the test participants were questioned about their hand dominance. They were then asked to place both their elbows on the table and using their preferred hand (right/left) only, touch each finger to their thumb in turn, starting with their index finger. The procedure was demonstrated by the examiner and participants were allowed a few practice trials to ensure that the instructions had been understood. They were then instructed to do this as fast as possible from the time the examiner said go, until they were told to stop. They were reminded to touch each finger to the thumb and not to go backwards. Timing only commenced with the initial thumb-index finger tap which eliminated reaction time to the word "go" being included in the score. The score was the number of seconds taken to complete 20 taps (5 x 4 taps) with the dominant hand and the procedure was then repeated, and scored, for the non-dominant hand

The Digit Symbol Substitution test (SAWAIS)

This test consists of three rows of 67, randomly assigned, digits with an open block below each digit. Above these rows is a printed key which pairs each number, from 1 to 9, with a different symbol. Participants were asked to fill in the open blocks with the appropriate symbol as per the key. The examiner demonstrated how this was done by completing a sample (8 blocks) at the beginning of the first row. The participant was asked to point out the matching symbol for each number in the sample and this was filled in by the examiner. The participant was then asked to fill in the remaining open spaces as quickly as possible without leaving out any symbols or pausing to make corrections. The number of blocks completed in 90 seconds was noted as the score but testees were allowed to complete the second row (42 pairs) to ensure adequate exposure to all nine symbols prior to the next phase of test. Administration and scoring of test was according to the SAWAIS Manual (1969)

Digit Symbol Incidental Recall : Immediate (Shuttleworth-Jordan & Bode, 1995)

The completed Digit Symbol Substitution Test was put out of view and respondents were given a recall sheet on which the numbers 1 to 9 were printed above blank spaces. They were asked to write down as many of the matching symbols as they could remember. Participants who were initially unsure of the number/symbol match were allowed to write down, below the grid, as many symbols as they remembered and then make the correct match. The test was not timed and the score was the number of correctly matched symbols.

Administration and scoring of this test differed slightly from that described by Joy, Fein and Kaplan (1992). In their study subjects were allowed to complete three rows of the WAIS-R (68 pairs). The paper was then folded over to conceal those rows and the key, and subjects were asked to fill in the fourth row from memory. The Shuttleworth-Jordan & Bode (1995) shorter version follows this pattern except that subjects only complete 42 pairs in the Digit Symbol subtest. In the present study, the shorter version of the test was used, but a separate form was used for the Incidental Recall test and the numbers were presented in sequence from 1 to 9 as opposed to the random assignment of numbers on the Shuttleworth-Jordan and Bode version. It is unlikely that these small variations in format would make any difference to the task performance (Professor Ann Edwards- personal communication, 1998).

Digit Symbol Incidental Recall (Delayed)

On completion of all the other tests in the battery, participants were presented with a second recall sheet and asked to fill in as many of the symbols, correctly paired with digits, as they could remember. The score was the number of correctly paired numbers and symbols. The time between completion of the immediate recall test and presentation of the delayed recall test varied between 20 and 35 minutes. Lezak (1995) allows for a 30 minute delay for this test. The time variations in this study resulted from the longer time taken by older subjects to complete the intervening tests. However as the purpose of the delayed recall test is to screen for memory impairment in the older adult, this study, in terms of time delay between presentations, concurs with that of Lezak.

5) The Trail Making Test - Parts A and B

The trail making test consists of two parts, Part A and Part B. Each part has a practice sample sheet and a test sheet.

The test sheet for Part A consists of 25 randomly placed, circled numbers. Participants were asked to draw a line connecting all the numbers sequentially, as quickly as possible, and without lifting the pencil from the paper. The sample, an abbreviated version of the test containing 8 numbers, was used for a pre-test practice. Where necessary, during the practice phase, mistakes were pointed out and task requirements re-explained. In the test proper, mistakes were immediately brought to the participants attention for correction. Timing included the time taken to correct errors.

The test sheet for Part B has a similar structure to Part A except that the 25 circles contain 12 letters and 13 numbers. The pre-test sample contains 4 circled letters and 4 circled numbers. After completion of the practice sample participants were asked to connect consecutive numbers and letters alternatively (that is, 1-A-2-B-3-C and so on) on the test proper.

Both parts of the test were administered to participants in accordance with Reitan's (1979) administration instructions. The test was scored according to the number of minutes taken to complete each part.

6.4 DATA ANALYSIS

6.4.1 Data cleansing

A preliminary examination of the analysed data identified two gross outliers in the 40-59 age group on FTT (both hands) and on TMT Part-B. One, a male aged 43 with an educational level of 12 years had a TMT-B score of 163.91 seconds which was 6.20, standard deviations (SD's) beyond the mean. Two, a 58 year old female with 9 years of education, had a TMT-B score of 199.57 seconds which was 8.65, SD's beyond the mean. Their raw scores were compared with the mean of the 40-59 age group, after their scores had been excluded, and with the same age and educational level means from Ernst (1987) and Dodrill (1979) studies. La Rue (1992) and Cimino (1994) suggests that scores which are 1.5 to 2 standard deviations beyond the mean of appropriate norms are suggestive of impaired performance. Examination of both test protocols revealed no history of neurological impairment, or other reason for exclusion, however the male's handwriting was very shaky on both parts of the TMT and the female had made multiple errors on Part B. As the aim of this study is to generate normative data, the author concluded that there was sufficient evidence to completely exclude both of these participants from the study. Participants in this group were therefore reduced to 28.

A few mild outliers were noted in the two oldest age groups. Re-examination of the interview data, MMSE scores and test protocols of these participants showed no reason why they should be excluded. They were therefore retained in the study in order to preserve the integrity of the sample as representative of all variants of the normal aging population.

6.4.2 Statistical data analysis

Demographic characteristics: Means, standard deviations, and ranges were computed for each of the six age groups to determine subject characteristics by age and years of education. Additionally, each group was stratified for gender.

Age effects: For all the tests, descriptive statistical procedures were used to determine the normative data, tabulated as means, standard deviations, and minimum and maximum values, for each age group. These data, generated for a non-clinical sample, will be valuable for diagnostic purposes in the practice of clinical neuropsychology, and will have implications about the normal aging process.

Data from the Digit Symbol Substitution Test, the Immediate Recall Test, the Delayed Recall Test and the Trail Making Test, Part B, met the assumptions of normality of distribution and homogeneity of variances, required for parametric tests, so an analysis of variance (ANOVA) was conducted to determine if there were significant differences between the group means.

Data from the FingerTappingTest (Preferred and Non-Preferred Hands) and the Trail Making Test Part A violated the assumptions of normality and homogeneity (Levene's test result: $p = < 0.05$), so the data was log transformed to yield homogenous variances. Frequently, this transformation, which is conducted to meet one assumption, also brings the data closer to the other assumption (Howell, 1987). However, the transformed values still failed to meet the assumptions of normality (Kolmogorov-Smirnov test result: $p = <0.05$) so the results were checked against the non-parametric equivalent test (Kruskal-Wallis (KS) ANOVA) which confirmed that there was a significant difference between groups.

It is common practice, when a significant result is obtained on transformed data, to report and discuss the means in the units of the unlogged data as these original units (e.g. seconds taken to complete test) are generally more informative and meaningful (Howell, 1987), so the unlogged data are reported in the results section.

The failure of these data to meet the assumptions of homogeneity of variances and normality of distribution was not unexpected. Lezak and Gray (1984) point out how, in many instances, the variable of interest in neuropsychological research is not normally distributed in the brain-damaged population and often, even less so, in the normal control sample. One variable known to affect the distribution of scores is age. It has been noted previously (see section 3.2.1) that progressive brain atrophy is associated with normal aging and that cognitive test performance declines as this atrophy increases. However, as these brain changes and the effects they have on cognitive functioning vary considerable from one individual to another, some group members may show only minimal decline in test performance while others show marked decline. The age-associated decrease in mean scores will therefore be accompanied by an increase in variability. Extreme high or low scores, or both, within a group will result in a skewed distribution not amenable to parametric procedures.

Where age effects resulted in significant F ratios at $p < 0.05$, Scheffe's, *post hoc,* multiple comparison test was run, to show where the differences between groups lay.

Education effects: Two way t-tests and Levene's F-tests were used to compare the group means and standard deviations, respectively, for the present (low education) age groups with those of: (i) Shuttleworth-Jordan and Bode's (1995, 1996) equivalent (high education) age groups on the Finger Tapping Test, Preferred and Non-Preferred Hands, the Digit Symbol Test and the Digit Symbol Immediate Recall Test and, (ii) Cornfield and Shuttleworth-Jordan's (1996) equivalent (high education) age groups on the Trail Making Test, Parts A and B. No normative data for the 90+ age was available for comparison from either of the aforementioned studies.

CHAPTER 7: RESULTS

7.1 DEMOGRAPHICS

The demographic data of the six groups appears in Table 1 below.

Table 1. Participants stratified according to gender, age and level of education

Age Group	N	Gender		Age			Years of Education		
Total		M	F	M	SD	Range Min/ Max	M	SD	Range Min/ Max
20-39	30	16	14	28.03	6.20	20-38	11.30	1.06	8-12
40-59	28	10	18	51.00	5.48	40-59	10.43	1.41	8-12
60-69	30	10	20	64.80	3.13	60-69	10.23	1.59	8-12
70-79	30	6	24	73.97	2.66	70-79	10.23	1.61	8-12
80-89	30	7	23	83.73	3.05	80-89	10.47	1.46	8-12
90+	13	4	9	91.00	1.87	90-95	9.46	1.39	8-12
Total	161	54	109	62.75	20.87	20-95	10.45	1.49	8-12

It can be noted that the first two age groups span two decades rather than one. This is consistent with Shuttleworth-Jordan and Bode's (1995) original grouping which was justified on the grounds that age effects on cognitive test performance are rare before age 60.

7.2 AGE EFFECTS ON TEST PERFORMANCE

In this section, the means, standard deviations and ranges (minimum and maximum values) of all tests performances for the six age groups are presented. In all instances, ranges have been rounded off to the nearest integer. The tabulated descriptive statistics, for each test, are followed by the Scheffe, *post hoc*, multiple comparison test results. To facilitate easy reading of results, the scoring method for each test is noted below the descriptive statistics table.

7.2.1 Finger Tapping Test: Preferred Hand

Table 2: Finger Tapping Test: Preferred Hand (descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	5.97	6.55	7.08	8.92	10.52	10.52
SD	1.48	1.17	0.87	2.37	4.89	2.28
Range	3-10	4-10	6-9	6-17	5-28	6-13

Score: seconds taken to complete to complete 20 taps

Table 3: FTT-PH : Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity		
[1]	20-39	5.97	***		
[2]	40-59	6.55	***		
[3]	60-69	7.08	***	***	
[4]	70-79	8.92		***	***
[5]	80-89	10.52			***
[6]	90-95	10.52			***

Mean performance: As can be seen in Table 2, the mean scores show a trend of decreasing performance (higher means) with increasing age. However, the decrements are small until the 70's and thereafter become more marked. No difference is noted between the mean performance of the 80-89 and the 90-95 age groups. The analysis of variance showed a highly significant age effect across age groups ($F (5,155) = 22.961$, $p = 0.0000$).

The multiple comparison of mean scores (presented in Table 3) indicates no significant difference between the 20- 39, 40-59 and 60-69 age groups, or between the 60-69 and 70-79 age groups, or between the 70-79, 80-89 and 90-95 age groups. However there is a significant difference between the 70-79 age group and the 20-39 and 40-59 age groups and, the 80-89 and 90-95 groups are significantly different from the 20-39, 40-59 and 60-69 age groups. Significant drop-off in performance is therefore noted in the 70's age group and again in the 80's age group

Variability: Levene's test for homogeneity of variance showed a significant difference between age groups ($F = 2.9638$, $p = 0.0139$). Table 2 shows that the standard deviation (SD) increases notably from the 60-69 age group, reaches its highest level in the 80-89 age group then decreases in the 90-95 age group. In both the 70's and 80's age groups, the SD is double that of the preceding age group which indicates increasing diversity in performance with advancing age. The higher SD in both the 20-39 and 40-59 age groups, compared with the 60-69 age group, may be sampling artifact produced by the two decade age span of the two younger groups compared with the one decade span of all the older age groups.

The minimum range score in the 60-69 age group (6 points) is double that of the 20-39 year group (3 points) which indicates that from the age of 60 years all individuals experience some decline in performance. However, there is no further increase in minimum scores for the three oldest age groups (70-95 inclusive). Maximum scores, which are similar for the three youngest groups, increase by 8 score points in the 70's age group, a further 11 points in the 80's age group and then decrease by 15 points in the 90's age group. Clearly the oldest age groups (70-95 inclusive) have some individuals who continue to perform as well as 60 year olds while others show marked decline.

7.2.2 Finger Tapping Test: Non-Preferred Hand

Table 4: Finger Tapping Test: Non-Preferred Hand (descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	6.10	6.95	7.28	8.85	10.58	10.43
SD	1.31	1.39	0.99	2.23	2.99	2.41
Range	3-9	5-12	5-9	6-18	6-21	8-15

Score: seconds taken to complete to complete 20 taps

Table 5: FTT-NPH: Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity			
[1]	20-39	6.10	***			
[2]	40-59	6.95	***	***		
[3]	60-69	7.28		***	***	
[4]	70-79	8.85			***	***
[5]	80-89	10.58				***
[6]	90-95	10.43				***

Mean performance: Table 4 shows a trend of decreasing performance with increasing age, similar to that seen for the Preferred Hand test. However, for this test the 90-95 age group have a marginally smaller mean than the 80-89 age group. The analysis of variance on the effect of age revealed was highly significant ($F(5,155) = 27.981$, $p = 0.0000$).

The multiple comparison of mean scores (presented in Table 5) shows that the 70-79, 80-89 and 90-95 age groups are significantly different from the three youngest age groups and that the 60-69 age group differs from the 20-39 age group. A significant decline in performance is noted in the 60-69 age group which indicates an earlier onset of decline for this test, compared with the Preferred Hand test.

Variability: Levene's test of homogeneity of variance showed a significant difference between age groups ($F = 2.3159$, $p = 0.0462$). As for the FTT-PH, the standard deviation (SD) is lowest in the 60-69 group (see Table 4) and thereafter increases steadily until the 90's age group where it decreases. However, although variability is highest in the 80-89 age group for both PH and NPH, the SD is far larger (4.89) for the former, than the latter (2.99) which suggests a greater fall off in performance for all individuals for the NPH test.

Minimum range scores show a gradual increase across the age groups. The 2 score point increase in the 40-59 age group indicates an earlier onset of decline in performance than that noted for the PH. In the 90-95 group both the minimum and maximum scores are 2 score points higher than that noted for the PH test which indicates greater fall-off in performance, for this group, on this test. It is also interesting to note that the *minimum* score for the 90's group is similar to the *maximum* score in the youngest age group. Maximum scores, in the 70-79 group are double those of the 60-69 group, increase further in the 80-89 group then decrease in the 90's group.

7.2.3 Digit Symbol SubstitutionTest

Table 6: Digit Symbol Substitution Test (descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	45.75	39.11	33.70	29.93	24.23	18.88
SD	8.16	9.44	6.43	7.59	8.96	6.56
Range	28-62	24-56	18-45	14-43	5-41	4-30

Score: number of correct digit/symbol pairings in 90 seconds

Table 7: Digit Symbol: Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity				
[1]	20-39	45.75	***				
[2]	40-59	39.11	***	***			
[3]	60-69	33.70		***	***		
[4]	70-79	29.93			***	***	
[5]	80-89	24.23				***	***
[6]	90-95	18.88					***

Mean performance: Table 6 show a consistent pattern of decline in performance (lower scores) with increasing age. The analysis of variance showed a highly significant age effect across age groups ($F(5,155) = 34.242$, $p = 0.0000$).

The multiple comparison of mean scores (presented in Table 7) indicates significant differences between the 20-39 age group and the 4 older age groups (60-95 years), between the 40-59 age group and the 3 older age groups (70-95 years), and between the 70-79 age group and the 2 oldest age groups (80-95). Significant incremental decline is therefore evident from 60 years.

Variability: Levene's test of homogeneity of variance demonstrated no significant difference between age groups ($F = 1.1475$, $p = 0.3378$). However, as noted for the FTT, the standard deviation (SD) for Digit Symbol (see Table 6) is lower for the 60-69 age group compared with the two younger groups. From the 60's age group, onwards, there is a trend of increasing variability with age with the highest SD occurring in the 80-89 age group followed by a substantial decrease in 90-95 age group.

Both minimum and maximum range scores show a steady decrease with increasing age across all the age groups. The decline in performance is quite gradual until the 80's when there is a marked drop in the minimum score (from 14 to 5). The 90's age group show an even lower minimum score, than the 80-89 age group, plus a markedly decreased maximum score. However, while a decline in performance is evident for some individuals from age 40-59 years, some individuals in the 60-89 age range retain a high level of performance.

7.2.4 DSST: Immediate Recall Test

Table 8: DSST: Immediate Recall Test (descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	6.63	4.96	4.83	4.07	3.50	3.00
SD	1.77	2.20	2.20	2.06	2.01	2.24
Range	3-9	1-9	1-9	0-8	0-7	0-7

Score: number of correct digit/symbol pairing recalled immediately after standard test

Table 9: Immediate Recall: Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity	
[1]	20-39	6.63	***	
[2]	40-59	4.96	***	***
[3]	60-69	4.83		***
[4]	70-79	4.07		***
[5]	80-89	3.50		***
[6]	90-95	3.00		***

Mean performance: Table 8 show a consistent trend of poorer performance (lower scores) with increasing age. The decrements are small (approximately 0.5 score point) between successive age groups with the exception of the 40-59 age group which is 1.67 mean score points less than the 20-39 age group. The analysis of variance revealed a highly significant age effect across age groups (F (5,155) = 9.689, p = 0.0000).

The multiple comparison of mean scores (presented in Table 9) reveals that the 20-30 age group is significantly different from the 60-69, 70-79, 80-89 and 90-95 age groups which are all homogenous. The 40-59 age group is not significantly different from the 20-39 age group despite the mean score point difference. Significant age effects are therefore only present from the 60's.

Variability: Levene's test of homogeneity of variance showed no significant difference between age groups (F = 0.3973, p = 0.8501). However, as can be gleaned from Table 8, standard deviations (SD) show a trend of decreasing variability from the 70's followed by an increase, to the highest level, in the 90-95 age group. It is possible that the two decade age span of the first two groups is obscuring an increase in variability from the 60's, or even earlier, as suggested by the ranges.

Minimum scores decrease from 3 in the 20-39 age group to 1 in the 40-59 and 60-69 age groups, then fall off completely to 0 in the three older age groups. The 2 score point drop in the 40-59 age group demonstrates a substantial decline in performance for some individuals in this age group. Maximum scores are maintained at 9 in the first three age groups (20-69), decrease to 8 in the 70's and to 7 in the 80's and 90's. As 9 is the maximum score, a ceiling effect in the youngest group may be obscuring the true onset point of age related decline.

7.2.5 DSST: Delayed Recall Test

Table 10: DSST: Delayed Recall Test (Descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	6.43	5.30	4.53	3.71	3.05	2.85
SD	1.60	2.20	1.90	1.99	1.82	2.41
Range	4-9	0-9	1-9	0-8	0-7	0-7

Score: number of correct digit/symbol pairing recalled 20-30 minutes after standard test

Table 11: Delayed Recall: Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity		
[1]	20-39	6.43	***		
[2]	40-59	5.30	***	***	
[3]	60-69	4.53		***	***
[4]	70-79	3.71		***	***
[5]	80-89	3.05			***
[6]	90-95	2.85			***

Mean performance: Table 10 shows a consistent decline in performance (lower means) with increasing age with the mean for the oldest group being less than half that of the youngest group mean. The analysis of variance showed a highly significant age effect across age groups ($F(5,155) = 12.961$, $p = 0.0000$).

The multiple comparison of mean scores (presented in Table 11) shows that the 20-39 age group are significantly different from the 4 oldest age groups which are homogenous and that the 40-59 age group differs from the two oldest age groups. Significant decline is therefore evident from the 60's and becomes more marked from the 80's. While the comparison of means for the Immediate Recall test showed no significant difference between the four oldest groups, results for this test demonstrate a further drop-off in performance from the 80's.

Variability: Levene's test of homogeneity of variance revealed no significant difference between age groups (F = 0.5972, p = 0.7021). There is no consistent trend of variability across the age groups (see Table 10). The lowest standard deviations (SD) is present in the 20-39 age groups and the highest in the 90-95 age groups. However, it can be noted that the SD in the 40-59 group is similar to that seen in the oldest group. This could be attributed to the larger age span of the younger group compared with the four older groups however the range suggests this is not the case.

Minimum scores decline from 4 in the 20-39 age group to 0 in all other age groups except the 60-69 group which had a score of 1. Marked decline in performance of some individuals is therefore evident from the 40-59 years onwards. Maximum scores hold at 9 (ceiling score) for the first three age groups (20-69) then fall off to 8 in the 70's and to 7 in the 80' and 90's. From the 60-69 year group onwards, the ranges are identical to those found for the Immediate Recall test

7.2.6 Trail Making Test: Part A

Table 12: Trail Making Test (Part A) (Descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	25.41	30.27	36.35	52.95	62.02	95.05
SD	5.86	7.05	7.86	23.54	27.82	40.60
Range	17-43	21-54	22-59	24-136	32-180	50-172

Score: seconds taken to complete test

Table 13: Trail Making Test (Part A): Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity			
[1]	20-39	25.41	***			
[2]	40-59	30.27	***	***		
[3]	60-69	36.35		***		
[4]	70-79	52.95			***	
[5]	80-89	62.02			***	
[6]	90-95	95.05				***

Mean performance: Table 12 shows a gradual increase in mean scores (poorer performance) across the first three age groups (20-69 inclusive) followed by a sharp increase in the 70-79 age group, a further increase in the 80-89 age group and a major increase (65%) in the 90-95 age group. The analysis of variance revealed a highly significant age effect across age groups ($F_{(5,155)} = 51.591$, $p = 0.0000$).

The multiple comparison of mean scores shows that the 90-95 group is significantly different from all the other age groups (presented in Table 13). The 20-39 age group differs significantly from the 60-69, 70-79 and 80-89 age groups while the 60-69 age group is significantly different from the 3 older age groups (70-95 inclusive). Incremental decline in performance is therefore evident from the 60's

Variability: Levene's test of homogeneity of variance showed a significant difference between age groups ($F = 4.3059$, $p = 0.0011$). Table 12 shows a consistent trend of greater variability with increasing age. The increase in standard deviations (SD) are fairly small for the first three age groups (20-69 years inclusive), then shows a marked increase (15.86 points) for the 70-79 age group and a further sharp increase (12.78 points), from the 80's level, in the 90-95 age group which has the highest SD.

Minimum range scores show fairly small increases across ages 20-79 followed by a sharp increase in the 80-89 age group and an even larger increase in the 90-95 age group. Maximum scores follow a similar pattern except that a marked increase is noted from the 70's. The range therefore demonstrates that, while some individuals show marked decline from the 70's, others maintain a reasonably good level of performance through the 80's.

7.2.7 Trail Making Test: Part B

Table 14: Trail Making Test (Part B) (Descriptive statistics)

Age Group	20-39 (N=30)	40-59 (N=28)	60-69 (N=30)	70-79 (N=30)	80-89 (N=30)	90-95 (N=13)
Mean	55.81	72.60	85.31	109.38	140.32	232.28
SD	15.16	14.68	21.35	42.61	62.54	66.19
Range	29-92	48-104	50-139	55-239	73-334	136-354

Score: seconds taken to complete test

Table 15: Trail Making Test (Part B): Scheffe's multiple comparison test by age group (alpha= 0.05), with alignment of asterisks denoting homogenous groups.

Group	Age	Mean	Homogeneity				
[1]	20-39	55.81	***				
[2]	40-59	72.60		***			
[3]	60-69	85.31		***	***		
[4]	70-79	109.38			***	***	
[5]	80-89	140.32				***	
[6]	90-95	232.28					***

Mean performance: Table 14 demonstrates a gradual decline in performance (larger mean scores) across the first three age groups (20-69 inclusive), a more marked decline in the 70-79 and 80-89 age groups, then a major decline in the 90-95 age group.The analysis of variance showed a highly significant age effect across age groups ($F(5,155) = 56.278$, $p = 0.0000$).

The fall off in performance between the 20-39 and the 40-59 age groups is more marked than that between the 40-59 and 60-69 age groups. This finding may be a result of an education effect in that 63% of participants of the 20-39 age group had 12 years of education compared with only 32% of the 40-59 age group. In other words, the performance of the 20-39 group may have been superior to that which would have been found in the same aged group with a lower mean education level. This difference between groups I and 2 was not found for TMT Part A.

The multiple comparison of mean scores (presented in Table 15), indicates that both the 20-39 and the 90-95 age groups are significantly different from all the other age groups including each other. The 40-59 means are significantly different from the three older groups (70-95) and the 60-69 age group differs significantly from the 80-89 age group. Significant, incremental decline is therefore evident after age 40 years.

Variability: Levene's test of homogeneity of variance revealed no significant differences between age groups ($F = 2.2384$, $p = 0.0532$). However, Table 14 shows a trend of greater variability with increasing age with the exception of the 40-59 age group which has a slightly lower standard deviation (SD) than the 20-39 age group. Differences in standard deviations between the 60's and 70's age groups and between the 70's and 80's age groups are quite large (20 score points each) and small (3 score points) between the 80's and 90's age groups. As for Part A, the greatest amount of variability in Part B is found in the 90-95 age group.

Minimum range scores increase notably between the 20-39 and 40-59 age groups followed by minor increases in the 60's and 70's age groups. A marked increase is present in the 80's age group and an even greater increase in the 90's age group (double the score of 80's group). Maximum scores show a steady increase over the first 3 age groups (20-69), a marked increase in the 70's and again in the 80's, followed by a small increase in the 90's group. Lower range scores demonstrate that some individuals, in the 60 and 70's age groups are still performing at a fairly high level while others show notable drop-off, particularly in the 70's age group.

7.3 EDUCATION EFFECTS

In this section, data from the present study are compared with existing data from two high education samples to examine education effects on mean performance and variability trends. Comparative data, including mean scores, standard deviations, ranges, t statistics, f statistics and significant differences (p values), between the present sample and the available high education norms are presented separately for each test. Score ranges for the groups in both samples have been included in the comparison tables to provide extra information, where required, on the within and between group variability.

The Finger Tapping test, Digit Symbol test and the Digit Symbol Immediate Recall test are compared with data from the Shuttleworth-Jordan and Bode (1995) sample which had a mean education level of 14.94 years compared with 10.53 years for the present sample. No high education data is available for comparison with the Digit Symbol Delayed Recall test. The Trail Making test, Parts A and B are compared with data from the Cornfield and Shuttleworth-Jordan (1996) sample which had a mean educational level of 15 years compared with 10.31 years for the present sample. Subject characteristics for both high education samples are provided in Table 16.

Table 16: Subject characteristics: gender, age and education for comparative groups Shuttleworth-Jordan and Bode (1995)

Age Group	20-39	40-59	60-69	70-79	80-89
N	23	21	28	31	28
Gender (M: F)	8:15	6:15	4:24	10:21	10:18
Education mean	15.91	15.10	14.07	14.97	14.82
Standard deviation	1.90	2. 79	2.26	2.82	2.68
Range	12-19	12-22	10-18	10-22	10-21

Cornfield and Shutleworth-Jordan (1996)

Age Group	60-69	70-79	80-89
N	33	38	34
Gender (M: F)	7:26	14:24	14:20
Education mean	14.6	15.3	15.0
Standard deviation	3.0	2.8	2.6
Range	10-27	10-22	10-21

In the following tables, **the data from the two high education samples are bolded** to differentiate them from the unbolded data from the present sample. Additionally the comparison data are, hereafter, referred to as HE (high education) norms or groups while data from the present study are referred to as LE (low education).

7.3.1 Finger Tapping Test: Preferred Hand

Table 17: FTT-PH: Comparison Between High and Low Education Groups

FTT-PH				Min-Max	Means		Variance	
Age	N	Mean	SD	Range	t value	p value	f ratio	p value
20-39	**22**	**5.17**	**0.68**	**4-9**				
	30	5.97	1.48	3-10	2.36	<0.025	4.74	<0.01
40-59	**21**	**5.66**	**1.07**	**4-9**				
	28	6.55	1.17	5-10	2.73	<0.0088	1.28	ns
60-69	**28**	**5.89**	**1.29**	**3-9**				
	30	7.08	0.87	6-9	4.14	<0.0001	2.20	<0.025
70-79	**26**	**6.49**	**1.40**	**3-8**				
	30	8.92	2.37	6-17	4.58	<0.001	2.87	<0.01
80-89	**26**	**6.71**	**1.32**	**4-9**				
	30	10.52	4.89	5-28	3.85	<0.0001	13.72	<0.01

Mean performance: Compared with the HE norms, the present sample showed poorer performances (higher means) across all age groups. The 20-39 and 40-59 age groups showed the least differences ($\underline{t}$ = 2.36, $\underline{t}$ = 2.73 respectively) while the greatest differences were present in the 60-69 and 70-79 groups ($\underline{t}$ = 4.14 and $\underline{t}$ = 4.58, respectively). In the 80-89 age groups, the mean differences ($\underline{t}$ =3.85) showed a slight decrease from the previous group level. The education effect on performance is therefore evident for all age groups but is most marked in the 60-69 and 70-79 age groups and then decreases in the 80-89 age group.

Variability: The LE groups, with the exception of the 60-69 age group, demonstrated greater variability than the HE groups. While the 60-69 age groups were significantly different ($\underline{f}$ = 2.20), examination of the standard deviations shows less variability in the LE group compared with the HE group. Additionally, in the 40-59 age groups, while the standard deviation of the LE group is higher than the comparable HE group, the difference does not reach statistical significance. There is a significant difference in variability between the 20-39 age groups ($\underline{f}$ = 4.74) and a smaller, but significant, difference between the 70-79 age groups ($\underline{f}$ = 2.87). The greatest between groups difference is found in the 80-89 years age group ($\underline{f}$ = 13.72) which shows a substantially larger SD for the LE group (4.89) than for the HE group (1.32). The highest variability for the HE sample occurs in the 70-79 age group followed by a decrease in the 80-89 age group. In the LE sample, the highest level of variability is present in the 80-89 age group then, as noted in Table 2, variability decreases in the 90-95 age group.

7.3.2 Finger Tapping Test: Non-Preferred Hand

Table 18: FTT-NPH : Comparison Between High and Low Education Groups

FTT-NPH				Min-Max	Means		Variance	
Age	N	Mean	SD	(Range)	t value	p value	f ratio	p value
20-39	**22**	**5.19**	**0.70**	**4-7**				
	30	6.10	1.31	3-9	2.96	<0.0001	3.50	<0.01
40-59	**21**	**5.45**	**0.92**	**4-7**				
	28	6.95	1.39	5-11	4.23	<0.0001	2.28	<0.025
60-69	**28**	**5.91**	**1.27**	**3-8**				
	30	7.28	0.99	5-9	4.60	<0.0001	1.65	ns
70-79	**26**	**6.62**	**1.35**	**3-9**				
	30	8.85	2.23	6-18	4.44	<0.0001	2.73	<0.01
80-89	**26**	**6.88**	**1.46**	**4-10**				
	30	10.58	2.99	6-21	5.74	<0.0001	4.19	<0.01

Mean performance: Means of the present sample are higher than those of the HE means across all age groups which indicates poorer performance for all the low education groups. The smallest difference (t = 2.96) is present between the 20-39 year groups. Larger, but similar, difference are present between the means of the 40-59, 60-69 and 70-79 age groups (t = 4.23, 4.60 and 4.44 respectively). The greatest difference between the two sample means is in the 80-89 age groups (t = 5.74) which differs from the FTT-PH test which showed a decrease in mean differences between these LE and HE groups.

Variability: The pattern of variability differences is similar to that shown in the FTT-PH with the 60-69 age group in the present sample showing a lower standard deviation, thus less variability, than the HE group. However, while this difference was significant for the FTT-PH, it is not statistically significant for this test. All other age groups in the present study show higher standard deviations (SD) than the HE groups. There is a notable difference in variability between the 20-39 age groups (f =3.50) and smaller differences between the 40- 59 and the 70-79 age groups (f = 2.28, f = 2.73 respectively). The greatest difference, as in the FTT-PH, is present between the 80-89 age groups (f = 4.19). However, for the present test the difference in variability in this age group is much smaller than that seen in the PH test (f = 13.72). This finding is accounted for by less variability in the LE group, for this test, compared with that found for the FTT-PH and a small increase in variability, from the 70's age group level, for the HE group which indicates a lesser education effect on test performance in this age group.

7.3.3. Digit Symbol SubstitutionTest

Table 19: Digit Symbol Test : Comparison Between High and Low Education Groups

Digit Symbol Test				Min-Max	Means		Variance	
Age	N	Mean	SD	Ranges	t value	p value	f ratio	p value
20-39	**23**	**58.24**	**8.62**	**33-67**				
	30	45.75	8.16	28-62	-5.33	<0.0001	1.17	ns
40-59	**21**	**51.95**	**8.02**	**39-67**				
	28	39.11	9.44	24-56	-4.99	<0.0001	1.39	ns
60-69	**28**	**43.55**	**10.96**	**29-67**				
	30	33.70	6.43	18-45	-4.21	<0.0001	2.91	<0.01
70-79	**31**	**35.92**	**9.80**	**20-58**				
	30	29.93	7.59	14-43	-2.66	<0.005	1.67	ns
80-89	**28**	**31.36**	**5.98**	**20-46**				
	30	24.23	8.96	5-41	-3.55	<0.0001	2.24	<0.025

Mean Performance: The means of the present sample are smaller than the HE means across all age groups which indicates poorer performance in the low education groups. The difference between mean performances is greatest in the 20-39, 40-59 and 60-69 age groups ($\underline{t}$ = -5.33, -4.99 and -4.21 respectively) and smallest ($\underline{t}$ = -2.66) in the 70-79 age group. The decrease in between means differences, in the 70-79 age groups, is due to a greater magnitude of decline, for the HE group compared with the LE group. In the 80-89 age groups, the LE group shows a greater amount of decline than the HE group which results in a small increase in the between means difference ($\underline{t}$ = -3.55) from the 70-79 age groups level. The education effect is therefore more pronounced before 70 years and thereafter declines.

Variability: Standard deviations for the present sample are lower (less variability) in the 20-29, 60-69 and 70-79 age groups and higher in the 40-59 and 80-89 age groups compared with the HE norms. However the $\underline{f}$ ratio is not significant for the 20-39, 40-59 and 70-79 age groups. Significant differences in variability are therefore only noted in the 60-69 and 80-89 age groups ($\underline{f}$=2.91 and $\underline{f}$=2.24 respectively). It is interesting to note, that for the HE sample, the greatest variability is found in the 60-69 age group (SD = 10.96) whereas, for the LE sample, it presents in the 40-59 age group (SD = 8.69). However, while variability peaks in the 60's age group for the HE sample then decreases with increasing age, the LE sample peaks in the 40-59 age group followed by a decrease in the 60-69 group and then variability increases in the 70-79 group and again in the 80-89 age group. As noted in Table 6, variability then decreases in the LE 90-95 age group. The appearance of the highest variability in the 40-49 LE group may be an anomaly produced by the two decade age span as compared with the one decade age span in all the older age groups. It is therefore possible that the true peak is that found in the 80-89 age group.

The range for the LE samples show a trend of decreasing minimum and maximum scores across the age groups while the HE sample maintains a ceiling maximum score (67 points) and fluctuating minimum scores across the first three age groups. From the 60's, the HE sample show a trend of decreasing minimum and maximum scores. In the LE sample, the largest range (36 score points) is present in the 80-89 age group which supports the proposition that the highest variability occurs in this age group.

7.3.4 Digit Symbol: Immediate Recall Test

Table 20: Immediate Recall Test: Comparison Between High and Low Education Groups

DSST: Immediate Recall				Min-Max	Means		Variance	
Age	N	Mean	SD	Range	t value	p value	f ratio	p value
20-39	**23**	**7.30**	**1.54**	**3-9**				
	30	6.63	1.77	3-9	-1.44	ns	1.32	ns
40-59	**21**	**5.48**	**1.98**	**2-9**				
	28	4.96	2.20	1-9	0.84	ns	1.23	ns
60-69	**28**	**6.16**	**2.15**	**2-9**				
	30	4.83	2.20	1-9	-2.33	<0.025	1.05	ns
70-79	**31**	**3.50**	**1.48**	**1-6**				
	30	4.07	2.06	0-8	1.24	ns	1.94	<0.05
80-89	**28**	**3.11**	**2.14**	**0-8**				
	30	3.50	2.01	0-7	0.72	ns	1.13	ns

Mean Performance: Compared with the HE means, the present sample shows marginally poorer performance (< than 1 score point lower) for the 20-39, 40-59 and 60-69 age groups but slightly better performance for the 70-79 and 80-89 age groups. However, the only statistically significant difference between means is that for the 60-69 age groups (t = -2.33). This difference is accounted for by a very small decrease in the LE means, from the 40-59 age group level and an *increase* (better performance) for the HE group (6.16) from the 40-59 age group (5.48). This is possibly due to a sampling effect in the HE 60's age group. Overall, there is minimal education effects for this test.

Variability: The difference in variablity between the 70 -79 age (f = 1.94, p = <0.05) barely reaches statistical significance and there is no significant difference between any of the other age groups. However, compared with the HE norms, standard deviations are slightly higher for all groups in the present LE sample except for the 80-89 age group which has a lower SD than the HE group. Variability is highest in the 60-69 HE group followed by decreases in the subsequent older age groups. In the LE sample, the highest variability is noted in both the 40-59 and 60-69 age groups. As noted for the Digit Symbol test, the greater age span of the 40-59 group, may be obscuring a more gradual increase in variability with increasing age and the 60-69 age group may represent the highest variability.

With regards to range scores, both samples maintain a maximum ceiling score (9 points) across the three youngest groups while minimum scores decrease across all age groups. From the 60's, the LE sample show a 1 score point decrease in minimum score per decade while the HE sample demonstrate a 3 score point drop-off in the 70-79 age group followed by a 2 score point increase in the 80-89 age group.

7.3.5 Trail MakingTest- Part A

Table 21: TMT-Part A: Comparison Between High and Low Education Groups

TMT: Part A				Min-Max	Means		Variance	
Age	N	Mean	SD	Range	t value	p value	f ratio	p value
60-69	**33**	**28.70**	**7.78**	**17-43**				
	30	36.35	7.86	22-59	3.88	<0.0001	1.02	ns
70-79	**38**	**35.64**	**7.63**	**23-56**				
	30	52.95	23.54	24-136	4.27	<0.0001	9.52	<0.01
80-89	**34**	**47.85**	**13.15**	**29-80**				
	30	62.02	27.82	32-180	2.65	<0.01	4.48	<0.01

Mean Performance: Means of the present sample are higher for all three age groups compared with the HE group means which indicates poorer performance in the LE sample. The most notable differences are present in the 60-69 and 70-79 age groups (t = 3.88, and 4.27 respectively) while the smallest difference occurs in the 80-89 age groups (t = 2.65). The largest statistical difference, which is found between the 70-79 age groups, reflects a drop in mean scores, from the 60's level, of 6.94 score points for the HE group and 16.6 score points for the LE group. However, the decline is less for the LE 80-89 group (9.07 score points) than for the HE group (12.21 score points) which indicates that after age 80 years the effects of education, on TMT-Part A performance, are less pronounced.

Variability: Standard deviations (SD) for all three LE groups are greater than those of the comparable HE groups, however the difference in variability between the 60-69 age groups is not statistically significant. A highly significant difference is present between the 70-79 age groups (f = 9.52) and a lower, but still notably significant difference in the 80-89 age groups (f = 4.48). While the SD of the HE 70-79 age group (7.63) is similar to that of the HE 60-69 age group (7.78), the LE 70-79 age group shows a 15.68 score points increase in SD from the 60-69 age group. While the minimum range scores for both groups (70-79 years) are very similar, the maximum range score for the LE group (136) greatly exceeds that of the HE group (56). This demonstrates a greater decline in performance for some individuals in the LE group. A similar pattern is seen in the 80-89 age groups. For both samples, the highest variability is present in the 80-89 age group.

7.3.6 Trail MakingTest- Part B

Table 22: TMT-Part B: Comparison Between High and Low Education Groups

TMT: Part B				Min-Max	Means		Variance	
Age	N	Mean	SD	Range	t value	p value	f ratio	p value
60-69	**33**	**69.32**	**20.90**	**38-123**				
	30	85.31	21.35	50-139	3.00	<0.005	1.04	ns
70-79	**38**	**85.00**	**38.71**	**45-179**				
	30	109.38	42.61	55-239	2.47	<0.025	1.21	ns
80-89	**34**	**131.03**	**43.73**	**81-270**				
	30	140.32	62.54	73-334	0.70	ns	2.05	<0.05

Mean Performance: The means of the present sample are higher (poorer performance) than those of the HE sample across all three age groups but the difference is not significant in the 80-89 age groups. The greatest difference (t = 3.00) is found between the 60-69 age groups and a slightly smaller difference (t = 2.47) between the 70-79 age groups. It can be seen that the differences between means becomes smaller with increasing age which suggest that the effects of education, across all three age groups, is less marked for this test than for Part A.

Variability: Standard deviations are greater for the present sample, as compared with the HE sample, across all age groups but the differences are not significant in the 60-69 and 70-79 age groups. A significant difference (f = 2.05) is present at the 80-89 age level. The variabiltiy pattern differs from that seen for TMT- Part A which showed significant differences in variability between the 70-79 and 80-89 age groups. This supports the conclusion, derived from the comparison of means, that education has less effect on the performance of TMT-Part B

CHAPTER 8: DISCUSSION

The present study was concerned with investigating the effects of age and education on selected cognitive tests. The research hypotheses were that: (i) increasing age would be associated with declining performance on all tests; (ii) decline would become evident at an earlier age for the low education sample as compared with the high education sample; and (iii) the highest level of within group variability would occur at an earlier age for the low education sample as compared with the high education sample.

These hypotheses were based on the findings in literature namely: (i) brain atrophy, due to neural attrition, occurs gradually from the late 20's to the 40's or 50's and after that proceeds more rapidly through to age 98 (Lezak, 1995; Scheibel, 1996), (ii) motor speed peaks around the late 30's and then declines from 40 years onwards, (iii) 'fluid intelligence' shows a relatively slow decline from the middle years through to the late 50's or early 60's when the decline proceeds at an increasingly rapid rate (Horn & Cattell, 1967) and, (iv) higher levels of education have a protective effect against the functional impairment which results from age-associated cognitive decline (Satz, 1993) so impairment will become evident at an earlier age in individuals with lower levels of education.

In the discussion each test will be discussed in terms of: (i) the age effects on mean performance and variability for the present sample and, (ii) the education effects, in terms of mean performance and variability, demonstrated by a comparison of the present low education (LE) data with the high education (HE) data. Due to the large amount of data which has already been presented, in both tabular and text form, in the results section, only the t and f statistics will be reiterated, where necessary for emphasis, in the discussion section.

Before commencing the discussion of the age and education effects on test performance, several possible sampling effects need to be highlighted as they may have influenced results, particularly for the Finger Tapping Tests, the Digit Symbol Substitution Test and the Digit Symbol, Immediate and Delayed Recall tests which were conducted on participants ranging in age from 20-95 years. A brief mention of these effects, at this point, will prevent unnecessary repetition in the discussion of each individual test.

While an attempt was made to control for education effects, it was difficult to find participants in the 20-39 age range with less than 12 years of education thus the education mean of this group (M = 11.30 years) was significantly higher than any other age group. As notable age effects are not expected before 60 years, the possibility of an education effect in the youngest group, while relevant, is not expected to have much bearing on the discussion of mean age effects across the age groups. However, a possible education effect will be considered if an exaggerated mean difference is noted in the subsequent age group for any of the tests.

Second, results for the aforementioned tests showed that variability decreased significantly in the 60-69 age group compared with the 20-39 and 40-59 age groups with the exception of the Digit Symbol Immediate Recall test which had an equivalent standard deviation to that of the 40-59 age group. The greater variability in the two younger groups was most likely due to the two decade age range of these groups compared with the one decade age range of all of the older groups. The larger age range of the two younger groups could have artificially inflated the variability relative to the older groups. This sampling artifact is expected to be more problematic, than the education one, as it may obscure the true onset of increasing variability. Since the variability findings will be discussed in terms of Jordan's (1997) shuttle model, correct identification of the 'shuttle bulge' is of critical importance. However, since the model shows that the onset of increased variability occurs concurrently with a drop-off in mean performance, this identification should prove possible.

A further possible sampling effect, concerning all the measures, is the gender imbalance in all groups except for the 20-39 age group. The predominance of females increases across successive age groups, is most marked in the 70-79 and 80-89 age groups and then decreases in the 90-95 age group. However, this is not considered problematic as reports on gender effects on test performance (Groth-Marnat, 1997; Lezak, 1995; Mitrushina et al. 1999) indicate that the only test, used in this study, which is likely to show this effect is the FTT. Gender effects will be considered if any unusual results are found for this test. Of note, a similar sampling effect is present in the high education sample (see Table 16). Finally, the 90-95 age group consisted of only 13 participants, compared with 28 to 30 in all the other age groups, so results have to be treated with caution.

8.1 THE FINGER TAPPING TEST: PREFERRED HAND

The Finger Tapping test (FTT) is primarily a measure of simple motor speed although performance also requires some degree of coordination (Groth-Marnat, 1997).

8.1.1 Age effects

It is well documented that age-related decline is particularly evident on tasks requiring motor speed (Groth-Marnat, 1997; Lezak, 1983, 1995). Older adults generally take longer than younger adults to execute movements and their coordination is poorer (Rogers & Fisk, 2000). These age effects were evident in this study.

Results showed a consistent trend of decrement in performance (higher mean scores) with each successive age group. Furthermore, the higher mean score and higher minimum range score noted for the 40-59 age group, compared with those of the 20-39 age group, was consistent with most of the well-known studies on the FTT, which report a decrease in performance from 40+ years (Bornstein, 1985; Fromm-Auch & Yeudall, 1983; Heaton e tal., 1991; Nagasaki et al., 1988; Ruff & Parker, 1993; Shimoyama et al., 1990; York & Biederman, 1990).

The results do not, however, support Lezak's (1995) report that *prominent* slowing is evident from about the fifth decade. Although the mean scores of the 20-39, 40-59 and 60-69 age groups demonstrated small decrements in performance with increasing age, statistically there was no significant difference between these groups. Examination of the raw data showed that 71% of the individuals in the 40-59 age group were 50+ years so prominent slowing from around 50 years would have resulted in a notably higher mean for this age group, compared with the 20-39 age group mean.

The possibility of a gender effect operating in the 40-59 age group was considered since 64% of participants were female. Numerous studies have shown gender to have a significant effect on FTT performance with men consistently out performing women (Bornstein, 1985; Filskov & Cantonese; Fromm-Auch & Yeudall, 1983; Heaton et al., 1991; Morrison et al., 1979; Ruff & Parker, 1993). In light of these studies, a gender effect would have resulted in notably poorer performance (higher mean score) which was not the case. It can therefore be concluded that, in the present study, prominent slowing is not evident around 50 years.

The results did show a substantial decline in performance from the seventh decade which concurs with results from both longitudinal and cross-sectional studies (Bengtson & Schaie, 1999; Birren & Schaie, 1990; 1996; Boller & Grafman, 1991; Craik & Salthouse, 1992; Heaton et al., 1986; Lezak, 1983; 1995). The 70-79 age group, which showed the greatest overall amount of decline, was significantly different from the two youngest groups. This finding is consistent with Ketcham & Stelmach's (2001) report of slower movement times in older adults, compared with young adults. In this study, the 70-79 and 80-89 age groups scores were, respectively, 49% and 76% greater (slower performance) than the 20-39 age group score.

With reference to variability, there was a notable increase in the 70-79 age group (SD = 2.37) but the greatest amount presented in the 80-89 age group (SD = 4.89). The increased variability in the 80-89 age group is accounted for by both lower minimum and higher maximum range scores than those found for the 70-79 age group. Clearly, many of the 80-89 year old participants are still functioning at a high level while others are showing notable cognitive decline. This finding is consistent with Willot's (1997) assertion that both neural attrition associated with aging, and the effect it has on cognitive abilities, varies considerably from one individual to another. The substantial decrease in variability in the 90-95 age group (SD = 2.28), demonstrates that the effects of age, on test performance, are fairly equal for all participants. Further evidence for this claim can be gleaned from the score range (6-13) which was notably less than that of the 80-89 age group (5-28).

8.1.2 Education effects

Compared with the equivalent age HE groups, all age groups in this study showed slower tapping rates (higher means). This result is consistent with the findings of most published studies which demonstrate faster tapping speeds for individuals with higher levels of education (Bornstein, 1985; Finlayson et al., 1977; Fromm-Auch & Yeudall, 1983; Heaton et al., 1991).

The between means differences for the low and high education, 20-39 and 40-59 age groups, while statistically significant (t = 2.36 and 2.73 respectively), were small. However, the between group differences increased notably in the 60-69 age groups, even more so in the 70-79 age groups and then decreased slightly in the 80-89 age groups (t = 4.14, 4.58, 3.85 respectively). The magnitude of these differences are accounted for by a larger, incremental decline in performance for the 3 oldest LE age groups, compared with the HE groups which show minimal decline across these age groups. These findings demonstrate that: (i) education level affects performance across the entire age span (20-89 years) and, (ii) educationally advantaged older individuals show a lesser amount of cognitive decline than individuals with lower levels of education.

Although the average older adult has some degree of brain atrophy due to neural attrition by age 55-65 years (Albert & Killiany, 2001) and this atrophy increases with increasing age, the greater 'brain reserve capacity' of educationally advantaged individuals delays the onset of observable cognitive decline (Satz, 1993). Conversely, the individuals with lower levels of education have less BRC so minimal neural attrition results in an earlier onset of decline. Education level also affects the magnitude of decline as evidenced in for this test. A comparison of both HE and LE 80-89 age group means, with the same sample 70-79 age group means, shows minimal decline (0.22 score points) for the HE group, and marked decline (1.6 score points) for LE groups.

A comparison of variability trends for the high and low education samples showed small increases for the HE sample across the age groups with the highest standard deviation (SD) occurring in the 70-79 age group followed by a small (0.08 score points) decrease in the 80-89 group. The LE group demonstrated a more marked increases in variability from the 60's with the highest SD presenting in the 80-89 age group followed by marked decrease in the 90-95 age group. This suggests that individuals in the high education sample become more compatible, in terms of decline, at an earlier age than do individuals in the low education sample.

Jordan (1997) refers to the greatest level of within-group variability as the 'shuttle bulge' and proposes that this is reached in middle to late adulthood. However the point along the age axis at which the bulge presents is related to several factors. An early presentation (left shuttle shift effect) is associated with low level of education, tasks which are highly sensitive to age effects, high challenge tasks and male gender. A later presentation (right shuttle shift effect) is influenced primarily by high levels of education and to a lesser extent by tasks which are less age-sensitive, low challenge tasks and being of female gender. In terms of the factors influencing the onset of increased variability, the age sensitivity and task challenge of the FTT, and the preponderance of female participants across the age groups, is the same for both groups so the only factor which differs is that of education level. Thus, the LE group should demonstrate an earlier onset of increased variability. The finding of a 'bulge' in the 70-79 high education group (left shuttle shift effect) and in the 80-89 low education group (right shuttle shift effect) is, therefore, inconsistent with Jordan's model.

Examination of the range scores in the HE sample showed that both the minimum and maximum range scores for the 70-79 age group were 1 point lower (better performance) than those of all the younger age groups and, of the 80-89 age group, which indicates superior performance from at least one participant in the 70's group. It is possible that the results in the 70-79 group are an anomaly and that the Shuttleworth-Jordan and Bode (1995) study 'missed' the shuttle bulge (a right shuttle shift effect) by not including a 90+ age group. However without the raw data for the high education group this remains mere speculation.

8.2 THE FINGER TAPPING TEST: NON- PREFERRED HAND

8.2.1 Age effects

Results showed a steady decrease in performance across all age groups with the means being slightly higher than those for the FTT-PH. This is consistent with other findings which showed a slower non-dominant hand speed compared with dominant hand speed (Groth-Marnat, 1997; Henninger, 1992; Satz et al., 1967).

Compared with the FTT- PH, this test showed a slight decline in performance for the 90+ group compared with the 80-89 age group. The comparison of means showed a notable drop-off in performance from the 60's which indicates an earlier onset of impaired performance than that found for the PH test (70 years). As individuals are less familiar with doing tasks with their NPH, the task challenge is greater than that of the PH test, and may exceed the threshold of the brain reserve capacity (Satz, 1993) at an earlier age.

Most of the normative data studies published in Mitrushina et al. (1999) and Spreen and Strauss (1991) do not report scores for groups over 70 years yet multiple range analysis conducted on the present sample revealed a significantly poorer performance on FTT, both PH and NPH, for the 70-79 age group compared with the 20-39 and 40-49 age groups. Additionally the two oldest groups (80-95) were significantly different from the three youngest groups (20-69). Numerous authors have pointed out that a high percentage of non-clinical individuals are misclassified as impaired when normative scores, derived from the test performance of young adults, are used to evaluate the older adult's performance on cognitive tests (Groth-Marnat, 1997; Heaton et al., 1996; Lezak, 1995: Podell & Lovell, 2000). The findings in this study support this position and highlight the need for normative data on older adults.

With reference to variability, the pattern for the NPH was the same as that noted for the PH except that the increase in variability for the 80-89 age group, from the 70-79 age group level, was much smaller (SD = 0.76) for this test, compared with that for the PH test (SD = 2.52). A probable explanation for this finding is the aforementioned greater task demand of this test which rendered individuals in the group more compatible in terms of observed decline.

8.2.2 Education effects

Education effects were evident across all age groups with the high education group consistently outperforming the low education groups. This education effect is consistent with most other reported findings (see Section 5.1.5). While the between means difference for the two 20-39 groups ($\underline{t}$ = 2.96) was similar to that found for the FTT-PH, the marked increase in between group differences ($\underline{t}$ = 4.23), presented at an earlier age (40-59 years) for this test. Larger differences were found between the 60-69 and 70-79 groups followed by an exaggerated difference between the 80-89 groups which contrasts with the decrease in mean differences in the PH test for the 80-89 group.

Comparison of the means of the youngest and oldest groups in each sample showed a difference of 1.69 mean score points for the HE sample compared with 4.48 score points for the LE sample. So, although the means scores indicate some degree of age-related decline in the HE group, the comparison of mean scores shows that the LE sample, lacking the protective effects of education (Satz, 1993) demonstrated an earlier onset of impaired performance and a much faster rate of decline with increasing age.

With reference to variance, there were significant differences in variability between all age groups, except for the 60-69 age groups which were not significantly different from each other. The between group differences become marked from the 70-79 age groups and are reflecting a far greater increase in variability for the LE groups compared with the HE groups. The highest variability (shuttle bulge) is found in both 80-89 age groups however the magnitude differs. While the HE group have a SD of 1.46 score points and a score range of 4-10, the LE group SD is almost double (2.99 score points) and the range (6-21) is far larger. The protective effects of education clearly extend well into old age.

8.2.3 Comparison of present data with data from Dementia Study

An interesting comparison can be made between the present data and data from Aronson's (1994) South African study on the test performance of high education groups, clinically diagnosed as mild or moderate dementia. However, it must be noted that Aronson's small sample size, compared with the present sample size, may influence the results.

Table 24: Comparison of Aronson's and Stewart's results

Mild Dementia	N	Age	Education (years)	FTT-PH (SD)	FTT- NPH (SD)
Aronson (1994)	3	70-79	14.97	8.67 (1.53)	10.00 (2.00)
Stewart (2002)	30	70-79	10.23	8.92 (2.37)	8.85 (2.23)

Moderate Dementia	N	Age	Education (years)	FTT-PH (SD)	FTT- NPH (SD)
Aronson (1994)	9	80-89	14.82	10.11 (3.55)	10.89 (3.37)
Stewart (2002)	30	80-89	10.47	10.52 (4.89)	10.58 (2.99)

The present low education, 70-79 age group showed slightly poorer performance, than the high education group with mild dementia on FTT-PH but not on NPH performance. Likewise, in the 80-89 groups, the present sample had a slightly higher mean (poorer performance) on the FTT-PH, and a marginally lower means on the NPH, than the moderate dementia group. In terms of these findings many LE participants in both the 70-79 and 80-89 age groups, who were classified as 'normal' according to their reported medical/neurological status and MMSE scores, would be diagnosed with dementia if compared with norms from the higher educational sample. These findings support Ardila's (1995) contention that educational level can have as powerful an effect on test scores as can brain damage. As pointed out by Axelrod and Goldman (1996), norms which are not stratified for educational level run the risk of misclassifying normal individuals as impaired.

8.3 THE DIGIT SYMBOL SUBSTITUTION TEST

The Digit Symbol Substitution test (DSST) is a multifactorial test which taps a wide range of abilities such as motor speed, attention, new learning and memory, visual skills, and accurate eye-hand coordination (Groth-Marnat, 1997)

8.3.1 Age effects

Results in this study showed that Digit Symbol test performance decreased steadily with increasing age. This finding is consistent with literature (Erber, 1976; Erber et al., 1981; Lezak, 1995; Salthouse, 1988; Storandt, 1976) which describes the Digit Symbol test as a measure of 'fluid intelligence' which is known to decline with age. The 'classic aging pattern' (Hochandel & Kaplan, 1984; Horn & Cattell, 1967) shows that decline of 'fluid intelligence' is relatively slow during the middle years then proceeds rapidly from the late 50's or early 60's.

The findings in this study were initially inconsistent with this pattern. Although, the 20-39 and the 40-59 age groups were statistically homogenous, the mean score for the latter group was 6.64

points lower than that of the younger group. The magnitude of decline in the 40-59 age group was greater than that found between any subsequent age groups. These results suggested that decline was most prominent in the 40-59 age group, as opposed to the early 60's, and more gradual for all the other later age groups.

A possible explanation for this contradictory finding was the higher mean education level (11.30 years) in the 20-39 age group compared with the 40-59 age group (10.43 years). In a *post hoc* control for education in the 20-39 age group, which excluded the 19 individuals with 12 years of education, the mean score for the remaining 11 individuals was 42.8 which effectively reduced the mean difference between this group and the 40-59 age group to 3.69 score points. After the education effect had been controlled, it became evident that marked decline in performance was present from the 60's.

Although numerous studies have reported age effects for this test, the reason for the poorer performance of older adults have not yet been established. Some of the abilities tapped by this test are sustained attention, which generally shows minimal age effects (La Rue, 1992), and visual search, working memory and divided attention which show marked age-related decline (Huppert, 1991).

It has also been hypothesised that the age-related decline in performance is due to the slower peripheral motor speed of older adults (Erber, 1976; Erber et al., 1981; Salthouse, 1988; Storandt, 1976). As noted earlier, numerous studies including the present one (see FTT results in Sections 7.2.1 and 7.2.7) have shown that motor speed declines with age so it is quite plausible that older adults will take longer to copy the symbols. However, the aforementioned studies failed to support this hypothesis: the observed copying speed for young and old adults was almost identical. Despite these findings, the fact that significant decline, with advancing age is present for both the FTT-PH and the DSST suggests that motor speed is a major influencing factor in DSST performance of older adults. However, it can be noted that significant decline occurs earlier for the DSST (60-69 years) than for the FTT-PH (70-79 years) due, most likely, to the higher cognitive demand of this test. Lezak's (1995) has reported that the performance of complex tasks, requiring cognitive processing, shows a rapid rate of slowing from the 60's.

According to Kelmach and Stelmach (2001), motor slowing becomes more pronounced as task difficulty increases and requires more cognitive processing. While some of the motor slowing of older adults is due to age-related musculoskeletal changes, Van Gorp et al. (1990) maintain that the most important component in the performance of complex tasks such as the DSST, is slowed cognitive processing.

It has also been suggested (Erber, 1976) that memory limitations are the major influencing factor on performance of older adults. Memory involves the capacity to learn and retain new information (Robertson-Tchabo & Arenberg, 1989) which, for this test, would be the correct digit/symbol pairing. Erber hypothesised that older adults would need to consult the key more frequently than younger adults and this would result in an increases performance time. This proposal has merit since research has shown that older adults require longer exposure time, than younger adults, in order to adequately register material for further processing into primary memory (La Rue, 1992). While each exposure to a specific digit/symbol pair should allow for summation of memory traces which would produce a stronger memory trace and subsequently better memory performance, the less efficient initial processing of information by older adults results in degraded memory traces and subsequent difficulty in learning and retaining new information (Craik & Jennings, 1992). This age effect is marked on visual memory tasks such as the DSST.

Lezak (1995) and Mitrushina et al. (1999) report that visual memory remains fairly stable until the mid-seventies then shows notable decline. Since the results of this study showed a significant decline in performance from the 60's, it seems unlikely that visual memory is the major influencing factor on DSST performance. In fact, two recent studies by Joy et al. (2000) and Kreiner and Ryan (2001), have provided evidence that memory accounts for only 1-3% of the variance in DS scores. It would appear, from both these studies and from the present one, that motor speed is the most important determinant of Digit Symbol performance.

Salthouse (1992) suggests that the poorer performance in older adults can be attributed to a global slowing of many perceptual, motor and cognitive processes rather than to a decline in any one specific process. Various studies conducted by Salthouse show that while mean performance declines with age, there is no accompanying increase in variability. However, other studies (for example, Shuttleworth-Jordan & Bode, 1995; Smith, 1997) and the present one, do not support this argument. The drop in mean scores noted in the older age groups, compared with the younger ones, is accompanied by an increase in variability.

Variability increases from the 60's, reaches its highest level in the 80-89 age group then decreases notably in the 90-95 age group thus a right shuttle shift pattern of variability (Jordan, 1997) is evident. Minimum range scores show a marked incremental drop off in performance for many individuals from the 60's however the maximum scores demonstrate that many individuals in the 70's and 80's groups are still performing at the same fairly high level as the best scorers in the 60's group.

It could be argued that many of the older participants in the present, low education sample have a high innate intellectual ability despite being denied, for whatever reason, the opportunities for tertiary education. However, while the effect of genetics on intellectual ability are undeniable (Herrnstein & Murray, 1994) there is also sufficient evidence (see Section 3.1.4) that the number of years of schooling per se has a substantial effect on test performance. The evident diversity in performance is most likely due to differential psychological and socio-cultural components of aging which compensate for many of the biological deficits (Baltes & Graf, 1996)

8.3.2 Education effects

Education effects were apparent across all the age groups with the LE sample demonstrating inferior performances compared to the HE sample. These findings are consistent with published studies (Heaton et al., 1986; Kaufman et al., 1988; Mazaux et al., 1995; Mortensen & Gade, 1993; Portin et al., 1995) which show an association between educational attainment and DSST performance. Heaton et al. (1986) report that 25% of the test variance is accounted for by education. According to Mazaux et al. (1995) a possible reason for the education effect is that individuals with higher levels of education are more familiar with abstract tasks such as the DSST.

The education effect was most marked between the 20-39, 40-59 and 60-69 age groups although the magnitude of the between group difference became smaller with each successive age group

($\underline{t}$ = -5.33, -4.99, - 4.21 respectively). Moreover, the smallest between means difference was present in the 70-79 age groups ($\underline{t}$ = -2.66), followed by an increased means difference between the 80-89 age groups ($\underline{t}$ = 3.55). These finding question the protective effects of education. Higher education clearly results in better performance across the age groups but examination of the mean differences between successive age groups shows that for the 60's and 70's age groups the magnitude of decline is greater for the HE group than for the LE group. A slightly greater amount of decline is evident in the LE, 80-89 age group, compared with the equivalent age HE group, however this observed decline may be due to the marked impairment in the performance of this test by one individual (score = 5). Although all the older participants were carefully screened for cognitive impairments, cross-sectional studies may inadvertently include participants with terminal drop (Berg, 1996) which can exaggerate the perceived extent of age-related decline (Ferraro, 1997). Examination of the raw data reveals that this 88 year old female had a MMSE score of 29 and her best scores were on the two recall tests, the only non-speeded tests. These findings contradict the idea of terminal decline but demonstrate marked decline in motor speed.

Rabbit (1993) and Compton et al. (1997) have indicated that both cross-sectional and longitudinal research results show that the rate of decline, in tests of 'fluid intelligence', is similar for both high and low education individuals. However, results of this study show an increased rate of decline for the more highly educated groups. This finding suggests that education does not delay the onset of decline but rather that, as pointed out by Christensen et al. (2001), the more highly educated individual declines from an initial higher level so takes longer to reach the same lower level of performance as the less well educated individual.

In terms of the BRC theory (Satz, 1993) there is a risk of a false negative result if the test scores of a highly educated person are compared with normative data derived from individuals with lower levels of education. The highly educated person with brain impairment may be functioning at the same level, or even a higher level, than the non-impaired low education normative group.

With reference to variability, comparison of the two samples showed that statistically significant difference were present only between the high and low education 60-69 and 80-89 age groups. The difference between the 60-69 age groups can be accounted for by the greater variability (SD

= 10.96) in the HE group compared with that of the LE group (SD = 6.43). This high variability in the HE group is accompanied by the highest, between successive age groups, drop off in mean score (8.4 points). The range scores for this HE, 60-69 age group show that while some individuals continued to perform optimally (maximum score = 67), a fall-off in performance for some individuals is evidenced by the minimum range score of 29 which is 10 score points less than that of the previous age group.

It is interesting to note that the HE 60-69 age group had the lowest education level (M = 14.07, SD = 2.26, Range = 10-18) of the entire sample. It is therefore likely that many individuals in this group did not start from an 'initial higher level' but were in fact performing at the same level as many of the individuals in the LE group. With regards to the LE 60-69 age group both lower minimum and maximum range scores decreased from those of the 40-59 age group which indicates that all of the individuals in this group were showing cognitive decline although variations in the amount of decline is evident.

Further examination of the minimum and maximum range scores for both samples show that the HE group maintain an upper range score of 67, in the first three age groups (20-39, 40-59 and 60-69) while the minimum range scores, for each successive group, decreased. As 67 is the highest possible score in the SAWAIS Digit Symbol test, it is possible that a ceiling effect occurred for some of the participants in the two youngest groups resulting in lower mean scores than would have been found on the WAIS-R version of this test. The WAIS-R manual (1981) indicates that above average intelligence individuals in the 20-34 age group average between 60 and 70 correct digit-symbol pairs. Furthermore, Ivnik et al. (1992) provide scores of 38-42 pairs for highly educated 65-75 year olds so one can assume a certain amount of decline between the ages of 34- 65. In terms of these normative scores a maximum range score of 67 in the HE 60-69 age group is very surprising. It is possible that this score reflects the superior performance of one individual and this outlier has inflated the variability noted for this group. However, without the raw data, this remains pure speculation.

In the two 80-89 age groups, the picture is opposite to that seen for the 60-69 age groups. The HE group shows notably less variability (SD = 5.98) than the LE group (SD = 8.98). Upper range scores for both groups are similar (46 and 41, respectively) which demonstrates that the effects of age are similar for many individuals and not mediated much by educational level. However, even at this late age, some of the HE individuals have not declined to the same level as the LE individuals as demonstrated by the respective minimum range score (20 and 5, respectively).

The comparison of variability trends between the low and high education groups shows that variability peaks in the HE 60-69 group then decreases in subsequent age groups while, for the LE group, variability peaks in the 80-89 group followed by a decrease in the 90-95 age group. This finding is inconsistent with Jordan's (1997) shuttle model of variability. The HE group show an earlier onset of increased variability (left shuttle shift effect) while the LE group show a later onset (right shuttle shift effect). In terms of the model, the increase in variability should have occurred at an earlier point along the age axis for the present sample as the left shuttle shift effect is associated, primarily, with low education level.

8.4 THE DIGIT SYMBOL INCIDENTAL RECALL TEST: IMMEDIATE

The Digit Symbol immediate, incidental recall is a test of short-term memory

8.4.1 Age effects.

It is generally held that primary memory shows minimal decline with age, at least up until age 80 (Lezak, 1995), although as mentioned earlier, older adults need a longer exposure time in order to adequately register information (La Rue, 1992). Reported studies on immediate, visual (non-verbal) recall (Lezak, 1995; Mitrushina et al., 1999) show that performance remains fairly stable until the mid-seventies after which the decline becomes more notable. The present study however, demonstrates a significant decline in performance from age 60 years. Additionally, while the difference between the 20-39 and 40-49 age groups did not reach statistical significance, the mean score for the latter group (4.96) is notably lower than the mean of the 20-39 age group (6.63). This indicates a trend of decreasing performance with increasing age. This trend continues across the four older age groups although they are not statistically different from each other.

Available knowledge on age-related brain changes sheds light on the results for this test. The three brain areas, identified by researchers as being particularly affected by age-associated neuronal loss, are the frontal lobes, hippocampus and cerebral cortex (Raz, 2000; Scheibel, 1996; Walsh, 1994). Memory functioning is related to the first two of these areas. According to Lezak (1995) the hippocampus loses approximately 5% of its neurons for each decade after the mid-forties and Woodruff-Pak (1997) reports a direct association between immediate memory impairment and hippocampal neuronal loss. Brain atrophy becomes more rapid after age 50 (Lezak, 1995) and the frontal lobes have been identified as one of the areas sustaining the highest neurol loss. Therefore, both of the brain areas related to memory show a marked increase in neuronal loss around 50 years and the trend of increasing decline in memory performance, from the 40-59 age group onwards, is consistent with age -related brain changes.

With regards to variability, while there was no statistically significant difference between the groups, the standard deviation (SD) of the 80-89 age group is lower than the 70-79 age group SD, which in turn is lower than the 60-69 age group SD which is the same as the 40-59 age group. The pattern of decreasing variability with increasing age is reversed in the 90-95 age group which shows the highest SD (2.24) and also the lowest mean score. In terms of the shuttle model, the 'bulge' would appear to present in the oldest group. However, considering the pattern of decreasing variability from the 60 through to the 80's, this finding is questionable and requires further investigation.

The range scores for both the 80-89 and 90-95 groups are identical (0-7) so it is possible that the observed increase in variability for the latter group is the result of a sampling artifact. The 90-95 age group consisted of 13 participants while the 80-89 age group had 30 participants. Furthermore, it is likely that the aforementioned sampling artifact in the 20-39 and 40-59 age groups may have inflated the observed variability in those groups so that the highest level of within group variability occurs in the 60-69 age group, followed by decreases in the two later groups.

It can also be noted that the range score for the 40-59 and 60-69 age groups is the same (1-9), although the younger group has a higher mean score, which indicates that some individuals in both groups show notable decline while other show no decline. However, since 9 is the maximum possible score, a ceiling effect in the younger group may be obscuring evidence of some decline in the apparently superior individuals in the later group. Overall, it seems likely that a left shuttle shift (Jordan, 1997) is present for this test.

8.4.2 Education effects

Numerous research studies (see Section 3.1.4) have demonstrate that short-term recall is not influenced by education level and the results of this study concurs with these findings. The mean differences between the HE and LE groups were not statistically significant except for the 60-69 age groups and this difference may be due to a sampling error in the HE group. Both samples showed a gradual decline in performance from the 20-39 age groups through to the 80-89 age groups with the exception of the HE 60-69 group which had a higher mean score (6.16) than the HE, 40-59 age group (5.48). As a result the observed decline between the HE 60' s and 70's groups was greater than that seen between any other two successive groups in either sample.

Although not statistically significant, (except for the 60-69 age group) the mean scores for the HE 20-39, 40-59 and 60-69 age groups are slightly higher (better performance) than the mean scores of the equivalent LE age groups. This finding is consistent with the observation that more highly educated individuals are generally more familiar with abstract tasks (Lezak, 1995) rather than showing any protective effects of education. Interestingly, the means of the two oldest groups show a slightly superior performance for the LE sample.

Overall there was minimal difference between the performance of both samples and the means of the present LE 60-69 and 70-79 groups are similar to those reported by Joy et al. (2000) on a low education sample. However, the present 80-89 age group demonstrated a better performance (> I score point) than Joy et al's equivalent age group. These findings suggest that there is no need for normative data stratified for education. However, compared with Lezak's (1995) recommendation of six pairs as the lower limit of normal, 81% of the present LE sample would be diagnosed as impaired.

With reference to variability, no difference is evident between the low and high education groups except for the 70-79 age groups where the difference barely reaches statistical significance ($f = 1.94$, $p = 0.05$). Considering the small, gradual age effects and lack of education effects on this test, this finding is not surprising. Standard deviations are slightly higher for all the LE groups except for the 80's group which has a marginally lower SD than the equivalent HE group. These higher SD's reflect a greater variation in performance in the LE sample as evidenced by the range scores.

While maximum range scores for both 20-39, 40-59 and 60-69 age groups are the same (9 score points) the minimum scores drop by 1 score point in the HE 40-59 and 60-69 age groups and by 2 score points in the equivalent LE groups. The minimum score drops to 0 score points for the LE, 70-79 and 80-89 age groups while this only occurs in the 80-89 HE group. Contrary to earlier conclusions, examination of the range scores suggests that education may have some, albeit minimal, protective effects for some individuals. This finding supports Jordan's (1997) contention that mean scores should never be considered in isolation without reference to the variability data.

The HE group show their highest standard deviation (shuttle bulge) in the 60-69 age group (2.15), followed by a decrease in SD in the 70-79 age group (1.48). Since the LE sample also demonstrated the shuttle bulge in the 60-69 age group it would seem that both high and low education groups show a left shuttle shift pattern of variability. As this test shows minimal, if any, education effects this finding is not inconsistent with the shuttle model (Jordan, 1997). However, it can be noted that the HE 80-89 age group has a SD (2.14) similar to the 60-69 age group and it is possible that had a 90+ group been tested they would have demonstrated a subsequent decrease in variability. This suggests that a right shuttle shift effect may be present in this group which would indicate that there was an education effect. The probable sampling error in the HE 60-69 age group has undoubtable affected the variability pattern but without the raw data it is not possible to determine how it was affected.

8.5 THE DIGIT SYMBOL INCIDENTAL RECALL TEST: DELAYED

The Digit Symbol delayed, incidental recall is a test of long-term memory. Lezak (1995) points out that immediate memory tasks do not test learning and retention and so delayed recall tasks are necessary to show what information has been transferred to long-term memory.

8.5.1 Age effects

Normative data (Lezak, 1995; Mitrushina et al., 1999) shows minimal decline on immediate visual recall until the 70's, and a gradual decline from the 30's, followed by a marked increase in decline from the 70's, for delayed visual recall. However, in this study significant decline for both immediate and delayed recall is evident from 60 years and, for delayed recall, decline is more pronounced from the 8th decade. Additionally, while the difference between the two youngest groups is not statistically significant, there is a 1.13 mean score points drop in means for the 40-59 age group, from the 20-39 age group level, which suggests a gradual decline in performance from at least 40 years. Overall, these findings are not consistent with other normative data.

With reference to variability, there was no statistically significant difference between age groups. The standard deviations (SD) fluctuate across the age groups with the lowest SD present in the 20-39 age group and the highest in the 90-95 age group. However the largest range score (0-9) is present in the 40-59 age group which is also the group which shows the highest drop off in mean score compared with a preceding group. The standard deviation in this group (2.20) is larger than that of the 20-39 age group and is followed by lower SD's in the 60's, 70's and 80's groups. However, given the aforementioned sampling artifact in the two youngest groups (see Section 8), the identification of the shuttle bulge in the 40-59 age group and therefore a left shuttle shift pattern of variability (Jordan, 1997) for this sample must be treated with caution.

No high education data was available, for comparison purposes, on this test. However, according to Lezak (1995), more highly educated individuals show a later onset of decline on delayed recall tests.

8.6 THE TRAIL MAKING TEST: PART- A

The TMT-Part A taps visual scanning, speed of eye-hand coordination, attentional and cognitive processing abilities (Lezak, 1995).

8.6.1 Age effects

The effects of age on the TMT are well documented (see Section 5.3.4): performance declines with each successive age decade. The present findings are consistent with other normative studies in that decrements in performance (higher mean scores) were demonstrated across the age groups.

The mean scores show a trend of gradual decline until the 70's when there is a major fall-off in performance followed by a very dramatic decline in the 90-95 age group. However, the comparison of means scores reveals a statistically significant difference between the 60-69 age group and the 20-39 age group which shows that pronounced decline is evident at an earlier age than that suggested by the mean score trend. A finding of significant decline from the 60's is consistent with results reported by Goul and Brown (1970) which showed that when Reitan's cut-off scores, for Part A, were used, 93.3 % of the 60-72 age group were falsely classified as impaired, compared with only 23.1 % of the 20' s age group. Moreover, while the Boll and Reitan (1973) study did not report an age effect, their results showed that the oldest age group (60-64 years) had a significantly lower mean score than all of the younger age groups.

These age effects can be accounted for by a decline in the various abilities tapped by this test. As noted for the DSST, motor slowing becomes more pronounced as task complexity increases. In this study a strongly positive correlation, $r = 0.67$, was found between the FTT-PH and TMT-Part A performance for the whole sample. Since the FTT is primarily a test of motor speed, this correlation highlights the influence of speed on TMT performance.

The visual skills required for Part A include relatively low level perceptual processes such as attention, scanning and perception. Tasks requiring these abilities show poorer performance in older adults and, women generally perform more poorly than do men (Benton et al., 1981). However, with regards to a possible gender effect, numerous studies on the TMT have shown no significant difference between the mean scores of males and females (Chavez et al., 1983; Davies, 1968; Dodrill, 1979; Kennedy, 1981; Stanton et al., 1984). It seems likely therefore that visuomotor speed is the main determinant of performance for TMT-Part A.

Variability increases gradually across the three youngest age groups then the standard deviation triples in the 70-79 age group, from that of the 60-69 age group. A further small increase is seen in the 80-89 age group followed by a substantial increase in the 90-95 age group which has the highest standard deviation. The marked increase in variability in the 70's age group shows that some individuals are experiencing marked cognitive decline however the minimum range score (55) show that some individuals are still performing at a high level. Of interest, the minimum score in the 90-95 group is marginally smaller than the maximum score of the 40-59 age group which highlights the diversity of performance across the age groups.

It is possible that an education effect is operating on this test due to the sample education range (8-12 years) since Stanton et al. (1984) reported a significant education effect for individuals with less than nine years of education.

8.6.2 Education effects

Several studies (for example, Bornstein, 1985, Ernst, 1987; Stanton et al., 1984; Stuss et al., 1987) have demonstrated an education effect on TMT performance however these effects have been more pronounced on Part B than on Part A. Bornstein has reported education correlates of .19 for Part A and .33 for Part B. Stanton et al. also report that, when the cut-off scores suggested by Russel et al. (1970) were used, the percent of their sample classified as impaired, ranged from 16.3 % on Part A and 7% on Part B in the most highly educated group to 50% on both A and B for the least educated group. However, a few studies (Ivnik et al., 1996; Wahlin et al., 1996; Yeudall et al., 1987) have not found an education effect. In this study an education effect was evident.

Examination of the means of both samples show that the HE 60' 70's and 80's age groups are performing at a higher level than the equivalent LE groups. The between means difference is greatest for the 70-79 age groups ($t = 4.27$) and least for the 80-89 age groups ($t = 2.65$). While both samples show age effects, decline in the LE 70's age group, compared with the 60-69 age group mean performance, is more than double that of the HE group. However the pattern of decline is reversed in the 80-89 age groups with the HE group showing a greater magnitude of decline (12.21 score points) than the LE group (9.07 score points). This suggests that the protective effects of education become less potent in very old age.

Comparison of variability supports the above conclusion regarding education effects. While there is no statistically significant difference in variability between the two 60-69 age groups, a highly significant difference occurs for the 70-79 age groups ($f = 9.52$) and a significant, but smaller difference, is evident between the 80-89 age groups ($f = 4.48$). As noted above, the standard deviation (SD) in the LE 70-79 age group is triple that of the LE 60-69 age group while there is no significant difference in SD between the HE 60-69 and 70-79 age groups. While minimum range scores increase gradually across successive age groups in both samples, maximum range scores show small incremental increases for the HE sample but substantial increases for the LE sample.

Despite the obvious education effect, the highest level of variability, for both groups is evident in the 80-89 group. As noted in section 6.1.1 variability decreases in the LE 90-95 age group so the shuttle bulge (right shuttle shift effect) is evident in the 80-89 age group. It is possible that the inclusion of two older age groups (9th and 10th decades) in the HE sample may have demonstrated a later onset of the bulge.

8.7 THE TRAIL MAKING TEST: PART- B

Part B is a more complex task than Part A as it also requires the ability to alternate between two sets of stimuli which is an executive function (Mitrushina et al., 1999)

8.7.1 Age effects

Part B demonstrates a trend of declining performance across successive age groups. The comparison of mean scores shows a statistically significant difference between the 40-59 age and the 20-39 age group which suggests an early onset of decline than that found for Part A. The performance of the 40-59 age group is notably poorer than that of the 20-39 age group (16.67 score points higher).

An education effect could be inflating the mean score of the 20-39 age group since 63% of the participants have 12 years education compared with only 32% in the 40-59 age group. A *post hoc* control for education, in which the 19 participants with 12 years of education were removed, showed a mean score of 58.72 for the remaining 11 participants thus better performance (2.91 score points lower) than for the whole group. It can be concluded that no education effect is present and that the onset of significant decline is present from 40-59 years which is earlier than that found for Part A. This finding is consistent with normative data (see Lezak, 1983, 1995; Mitrushina et al., 1999; Spreen & Strauss, 1991) which shows that age effects are more pronounced for Part B than for Part A.

Part B is a more difficult task than Part A on many levels. The two parts of the TMT are not structurally equivalent: the between target difference of 2.4 cm results in part B being 56.9 cm longer than Part A thus requiring a longer time for completion. Visual interference is greater for Part B which has, in total, 28 items within 3 cm of the path between each target while Part A has only 11 items Gaudina et al. (1995). Research has shown that older adults demonstrate poorer visual search, when distracters are present, than younger adults (Woodruff-Pak, 1997). Tipper and Cranston (1985) suggest that older adults are less able to ignore the distracters because inhibitory processes may be especially vulnerable to aging effects.

Part B also requires switching attention between two sets of stimuli namely, letters and numbers which is an executive function. Normative studies (for example, Spreen & Strauss, 1991; Stuss et al., 1987) show that older adults, particularly those with lower levels of education, show substantial cognitive impairment on tasks requiring divided, or switched, attention. Such tasks place additional demands on cognitive information processing, which is less efficient in older adults (Ponsford, 2000).

Numerous brain studies, discussed in Albert and Killiany (2001), Raz (2000) and Scheibel (1996) have demonstrated that after age 50 years the loss of brain tissue can be accounted for, primarily, by loss of white matter. This loss is due to changes in the myelin sheath and results in a reduced efficiency and speed of conduction of nerve impulses among neurons (Albert & Killiany, 2001). Studies (Salthouse, 1996; Scheibel, 1996; Verhaeghen & Salthouse, 1997) have demonstrated that generalized age-related slowing (i.e. reduced information processing capacity) is due to loss of myelination.

Divided attention makes demands on working memory as information has to be held in memory (e.g. number sequence) while other mental operations (e.g. correct alphabet sequencing) is being carried out (Huppert, 1991). Abilities such as attention and working memory are dependant on the structural integrity of the frontal lobes which are regarded as the seat of man's highest cognitive functioning (Lezak, 1995; Raz, 2000; Scheibel, 1996; Walsh, 1994). However, this brain area is generally the one which shows the earliest, and greatest neuronal loss with increasing age.

With reference to variability, while no statistically significant difference was found between the groups, examination of the standard deviations (SD) shows a trend of increasing variability across the age groups with the highest level presenting in the 90-95 age group. Minimum range scores show a notable drop off in performance, for some individuals, in the 40-59 age group and again later. However, substantial increases in the maximum score is evident only in the 80-89 age group. It is interesting to note that even at this very old age, some individuals are performing at the same level as some individuals in the 20-39 age group. However, from 70 years some individuals are showing marked cognitive decline and this decline is marked for all individual in the 90's age group which has extremely high maximum and minimum scores.

8.7.2 Education effects

As noted above, studies have shown that the education effect is greater for Part B than for Part A of the TMT. Comparison of the means for both samples demonstrates a superior performance for all three HE groups which demonstrates an education effect however this effect is not greater than that found for TMT Part A. While a statistically significant difference was found between the means of the low and high education 60-69 and 70-79 age groups, the differences ($t = 3.00$ and $t = 2.47$ respectively) are less than those found, between these age groups, on Part A. Moreover, for Part A, the between means difference was greater for the 70-79 age groups, compared with the 60-69 age group, while for Part B the between mean difference decreases for the 70-70 age groups, from the 60-69 age groups level. In the 80-89 age groups the observed difference does not reach statistical significance.

Examination of the mean scores for each sample shows a smaller decline in performance between the 60's and 70's HE age groups compared with the LE groups however the HE 80-89 age group shows a dramatic decline (46 score points) compared with the LE group (9 score points). While it is evident that higher education results in superior performance even into very old age, it is also clear that the protective effects of education do not extend beyond 70 years. Heaton et al. (1986) have suggested that the education effect, on Part B performance, is less marked after 60 years.

Although the effects of education diminished with advancing age, performance of all three high education group was superior to that of the equivalent age low education groups. However, the only published norms for the oldest old (80+ years) (Ivnik et al., 1996), have not been stratified for education. Data which is not stratified for age and education runs the risk of failing to detect impairment in high education individuals (if compared with low education norms) or diagnosing normal older adults, with low levels of education, as impaired if their scores are compared with high education norms.

With reference to variability, the only statistically significant difference between group was that noted for the 80-89 age groups and this is accounted for by a greater increase in variability in the LE group than in the HE group. Both samples showed increasing variability with age with the highest variability presenting in the 80-89 age groups.

Given the drastic drop in mean score in the HE 80-89 age group, it seems unlikely that an older HE age group (90+) would have shown a higher variability. As the means for both 80-89 age groups were not significantly different, it can be concluded that education effects were no longer operating. However, without data for a HE 90+ age group it is difficult to reach a conclusion about differences in variability patterns in the two samples. Nevertheless, the finding of a shuttle bulge in the LE 90-95 age group (see Section 7.2.7) on this high challenge task is inconsistent with Jordan's shuttle model.

8.8 CONCLUSIONS

This study was undertaken primarily to address the paucity of normative data for older adults on commonly used neuropsychological measures. In particular, normative data was generated on a non-clinical, relatively low education sample. These data were compared with existing data on relatively high education groups to determine education effects. Results can be summarised as follows:

Age effects: The results for all tests, showed declining performance with increasing age which supports the research hypothesis. Taken together, these tests measured visuo-spatial perception, motor speed, mental flexibility and attentional functions, which according to Lezak (1983, 1995), are the functions most susceptible to age-related decline. Notable decline, for most tests, was noted from 60 years onwards with the exceptions of the FTT-PH which showed a later onset (70 years) and the TMT-B which demonstrated an earlier onset (40-59 years). These finding are, on the whole, consistent with other cross-sectional studies which show at marked decline in test performance from around 60 years.

With regards to variability, the FTT (PH and NPH) and the DSST showed a pattern of increasing variability with increasing age, followed by a decrease in very old age (90-95 years). Psychomotor speed, which is known to decline with increasing age, is the main cognitive function tapped by these tests. No consistent variability trend was evident for either of the two DS Incidental Recall Tests which measure short- term and long-term memory, respectively. In the TMT (Parts A and B), variability increased dramatically from the 60's through to the 90's. While, Part A is primarily a test of motor speed, Part B is also a measure of executive function which shows age-related decrements. The lack of a uniform pattern of variability, across the tests, demonstrates that while maintenance and decline of cognitive functioning is evident with increasing age it is also differential in nature. This finding is consistent with other studies (see Section 2.2) which have demonstrated that increasing age is associated with increased inter-individual and intra-individual variability in cognitive abilities.

Education effects: The HE groups outperformed the LE groups on all tests, except the DS

Immediate Recall test which showed similar results for both samples. This finding supports the research hypothesis and is consistent with other studies (see Section 3.1.4) which showed that performance on all tests, with the exception of short-term recall, showed education effects.

For low challenge tasks (minimal cognitive demand) such as the FTT (PH) and the TMT- Part A, the education effect was notable in the 60's and 70's age groups but less marked in the 80's age group. However, the education effect extended into the 80's for the FTT (NPH) test. The DSST and the TMT-Part B, which are higher challenge tasks, demonstrated less potent education effects from 70 years. Clearly these more cognitively demanding tasks, in conjunction with increasing neural attrition, exceed the brain reserve capacity threshold (Satz, 1993), albeit to a lesser extent, even in the more highly educated individuals.

Comparison of variability trends between the two samples showed that the 'shuttle bulge' presented at the same point, or at an earlier point, along the age axis for the high education sample as that noted for the low education sample. For the FTT-PH, the DSST and the DS Immediate Recall test, the highest level of variability, in the high education sample, occurred at an earlier point (1, 2 and 2 decades respectively) than the low education group. The high education sample therefore showed a left shuttle shift pattern of variability while the low education sample demonstrated a right shuttle shift pattern. With regards to the TMT (parts A and B) and the FTT-NPH, variability was highest for the oldest groups (80-89 years) in each sample (right shuttle shift effect). These finding therefore failed to support the research hypothesis which was based on Jordan's model. In terms of the BRC theory (Satz, 1993), which provides the explanatory power for Jordan's model, the protective effects of education should delay the onset of observable cognitive decline thus the highest level of variability in the HE group should occur at later age than that of the LE group.

The results of this study demonstrate, unequivocally, the need for age and education stratified normative data to prevent misdiagnosis in older adults. Equally clear is the need to study variability data which reveals a more accurate picture of the aging process than the study of mean performance alone.

8.8.1 Evaluation of this research

A number of notable features are evident in this research. First, education was well controlled across the age groups, with the exception of the youngest group, and the education range of 8-12 years was suitable for a sample described as relatively low education. Over 12 years would have tapped into a higher education range, while less than 8 years may have included individuals with mild mental retardation.

Second, compared with many other studies reporting normative data (see Lezak, 1995; Mitrushina et al., 1999), this study had a balanced and sufficient number of participants in each age group, with the exception of the 90-95 age group. Although this oldest group had only 13 participants the findings, which were in the expected direction, are judged to be clinically useful particularly as there is no other South African normative data for this age group.

Third, examination of variability data, in addition to mean performance, provided additional information about the effects of normal aging on the cognitive domains tapped by each test. It highlighted the inevitability of cognitive decline with advancing age as well as the diversity in the rate and magnitude of change for different individuals.

Four, interrater reliability was enhanced since the researchers in this study, and in the two high education studies, received training in test administration from the same clinician.

The limitations of the research include the sampling artifacts discussed at the beginning of this chapter. While the gender imbalance proved not to be problematic, the higher educational mean of the youngest group and the two decade age span of the first two groups, necessitated further examination, and/or analysis, of the raw data.

With regards to the higher education mean of the 20-39 group, it is unlikely that any other South African study would find many white participants in the 20-39 age group with less than 12 years of education as this is the standard school exit level. However, the two decade age span for groups in the under 60 years category can, and should, be avoided in future research. This sampling artifact, particularly for the 40-59 age range, obscured the point along the age axis when notable cognitive decline and increasing variability becomes apparent. For example, significant decline was evident for TMT-B performance in this age group but, without further statistical analysis, it was not possible to determine if this decline was significant before 50 years.

A more general limitation, relating to any cross-sectional study, is the possibility of inadvertently including older participants who are experiencing 'tertiary aging'. In this study, every attempt was made to ensure that this was a non-clinical sample of older adults experiencing 'primary aging'. However, as pointed out by Woodruff-Pak (1997), there is no way of knowing in advance that an individual is in the phase of tertiary aging.

8.8.2 Recommendations for future research

It became apparent, during this study, that a significant number of individuals 90+ years are still high functioning yet few normative research studies have included this age group. Age is a known risk factor for Alzheimer's Dementia (AD) and the risk increases with each decade of life after 65 years (Miller & Gustavson, 2000). Since the early symptoms of AD, for example memory impairment, are also associated with normal aging, there is a critical need for appropriate normative data on all cognitive tests used in the neuropsychological assessment of the oldest old Moreover, considering that many individuals, presently in this age category, had limited access to higher education, normative data stratified for both age and education would be very valuable for clinical purposes.

The present study has contributed age stratified normative data for a South African white population with relatively low education however, it needs to be noted that age and education are not the only demographic variables which influence test performance: socio-cultural and language factors are also considered influential (Ardila, 1995). While this study is considered as an important step in the collection of normative data for a South African population, it needs to be followed by the collection of data, stratified for age and education, from other cultural groups.

The effects of education on cognitive test performance is particularly relevant in a country like

South Africa that has such a high proportion of citizens with low levels of education. According to the Central Statistical Services (CSS) (1997), 73.6 % of the total population in South African has less than 12 years of formal education. A breakdown of this figure shows no schooling (18.4%), some, or complete primary school (23 %) and some secondary school (32.2%). The percentages of individuals with less than 12 years of education within each population group are: African/Black (81.6 %), Coloured (80.1%), Indian/Asian (55.8 %) and White (31.1%). To date, there is no South African normative data for individuals with minimal, or no education, so interpreting the test scores, of almost three quarters of the population, would be very difficult.

This study also highlighted the need for a more in depth investigation of education effects. Although the study did not set out to investigate wether more highly educated individuals have a greater brain reserve capacity than individuals with lower levels of education, the results cast some doubt on Satz's (1993) BRC theory, at least in relation to its applicability to normal aging. While there was some evidence of an education effect, it is difficult to conclude that this reflects a protective effect of education in terms of BRC. It is equally possible that the more highly educated individuals have a greater amount of crystallised intelligence, are more familiar with abstract tasks and are simply declining from an initially higher level of cognitive functioning (Compton et al., 1997; Rabbitt, 1993).

Schaie (1996) emphasises ongoing education, as well as an initial high level of education, as a predictor of the maintenance of intellectual functioning well into old age. He suggests that a decline in cognitive skills results from changes in cognitive activity patterns. This notion is captured in the adage "Use it or lose it". However, studies like the present one, focus only on the level of formal education (and occupational level) but do not investigate leisure activities for both high and low education individuals pre, and perhaps more importantly post, retirement. It is possible that these activities, or lack there of, contribute to the cognitive performance of older adults with different levels of formal education. A study that investigated past and present cognitive activity of older adults would shed further light on this issue.

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APPENDIX 1

CONSENT FORM

NEUROPSYCHOLOGICAL ASSESSMENT RESEARCH

CONSENT FORM

I hereby consent to undergo a neuropsychological assessment on the following understanding:

1. The assessment will be conducted by a skilled researcher from Rhodes University and will take around 45 minutes to complete.

2. The assessment will involve a brief interview and a variety of intellectual tasks which will not be harmful and are usually enjoyed by testees.

3. The data obtained from this testing will be used for group research and publication purposes.

4. Individual results will remain totally confidential and anonymous.

I further understand that the aim of this study is the collection of scores on selected neuropsychological tests from a normal population for comparative purposes with individuals who may have impairments in cognitive functioning.

Signed:---

Date:---

APPENDIX 2

INTERVIEW QUESTIONNAIRE

MINI-MENTAL STATE EXAMINATION

NEUROPSYCHOLOGICAL ASSESSMENT

PRE-ASSESSMENT INTERVIEW

Name:______________________ Date:________________

Sex: ______________________ Age: ________________

Number of Years of Education:________________

Standard/Grade Repeated: ____________________

Highest Academic Level:______________________

Average Mark/Symbol obtained in Final Year:______________________

Reason for Discontinuing Education:.____________________________

Other Qualifications:____

Occupation:____

Fluency in English Language: Home Language / Education Medium / Work Medium (circle)

HEALTH HISTORY

Head Injury / Neurological Disorder:____________________________

Psychological Disorder:_____________________________________

Chronic Physical Disorder:___________________________________

Comments:____

____

Sedative Medications ______________________________________

Alcohol/Substance Abuse:___________________________________

Vision: Normal / Corrected / Impaired (circle)

Hearing: Normal / Corrected / Impaired (circle)

PRELIMINARY TEST SCORES

MMSE:...

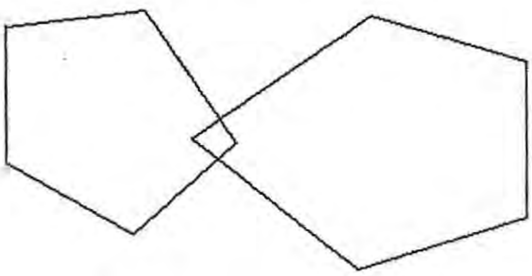
FTT: (preferred hand).........................

FTT: (non-preferred hand)...................

MINI MENTAL STATE EXAMINATION

Name: ____________________ Date: ____________________

		SCORE	POINTS
ORIENTATION			
• What is the:	year?	______	1
	season?	______	1
	month?	______	1
	day?	______	1
	date?	______	1
• Where are we:	country?	______	1
	province?	______	1
	town/city?	______	1
	street?	______	1
	building?	______	1
REGISTRATION			
• Respondent to name three objects which have been named by tester (1 point each)		______	3
ATTENTION / CALCULATION			
• Spell WORLD backwards (1 point per correct letter).		______	5
RECALL			
• Respondent to recall three objects named in Question 3 (1 point each).		______	3
LANGUAGE			
• Respondent to name pencil and watch as tester points to these (1 point each).		______	2
• Respondent to follow a 3-stage command: "Take this paper in your right hand, fold it in half, and put it on the floor" (1 point per correct step).		______	3
• Respondent to repeat: "No ifs, ands or buts".		______	1
• Respondent reads and obeys: "CLOSE YOUR EYES".		______	1
• Respondent writes a sentence of his/her choice. (Sentence should contain a subject, object, and should make sense.)		______	1
• Respondent copies the design below. (Sides and angles to be preserved, and intersecting sides to form a diamond shape).		______	1



TOTAL: ______ 30

APPENDIX 3

COGNITIVE TESTS AND TEST INSTRUCTIONS

1. Finger Tapping Test
2. Digit Symbol Substitution Test
3. DSST Incidental Recall: Immediate and Delayed Tests
4. Trail Making Test: Parts A and B

FINGER TAPPING TEST

Name:_______________________________ Date:_______________________________

INSTRUCTION: "Are you right or left-handed? Place both your elbows on the table and using your preferred (right/left) hand only, touch each finger to your thumb in turn starting with your index finger (examiner models what is required). Practice that. When I say go, I would like you to do this as fast as you can until I tell you to stop. Be sure to touch each finger and do not go backwards. Are you ready? Go.."

"I would like you to repeat this test using your other hand. Practice that. Are you ready? Go."

* The examiner notes the time taken for 20 taps (5 sets of 4 taps) per hand.

SCORE (Time taken to complete 20 taps):

Preferred Hand:_________________Secs

Non-preferred Hand:_____________Secs

DIGIT SYMBOL SUBSTITUTION TEST

Name: ______________________________ Date: ________________________________

INSTRUCTION: "Look at these little boxes or squares. You will notice that each has a number in the upper part and a sign in the lower part. Every number has a different sign" (indicate). "Now down here (point to sample) there are some more of the boxes, but this time they have only the numbers on top and the spaces below are empty. You have to put into each of the spaces the sign that belongs (corresponds) to the number at the top. The first number is 2, so we have to put in ithis sign (pointing to the key, examiner fills in the 2-sign). The next is 1, so we put in this mark" (indicate and fill in sign).

- * The examiner then fills in the rest of the example personally, asking the subject in each case to point out the appropriate sign. When all the examples have been filled in, say: "Now I want you to go on from here yourself and put into each space the sign that belongs to the number at the top. Fill each in order as it comes and do not leave any out. When I say begin, work as quickly as you can and see how many you can do in 90 seconds".
- * If subject has not completed the second row within 90 seconds, mark the point reached within the time limit, then allow them to complete the row.
- * Refer to scoring instruction

SCORE (Number correct in time limit): _____

DIGIT SYMBOL INCIDENTAL RECALL TEST: IMMEDIATE

The examiner puts the completed Digit Symbol test form out of the subject's view, and presents the recall form. INSTRUCTION: "Now I want to see how many of the signs you can fill in from memory. The upper part of these boxes are numbered 1-9, and I want you to put into each lower part, the sign that corresponds with the number."

SCORE (Number correct): ______

X. SYFERS VERVANG DEUR SIMBOLE.
X. DIGIT SYMBOL SUBSTITUTION.

NAAM
NAME .... Datum
Date ....

SLEUTEL
KEY

1	2	3	4	5	6	7	8	9
—	И	⊐	L	U	O	Λ	X	=

VOORBEELD SAMPLE								TOETS BEGIN TEST BEGINS																
2	1	3	1	2	4	3	5	3	1	2	1	3	2	1	4	2	3	5	2	3	1	4	6	3
1	5	4	2	7	6	3	5	7	2	8	5	4	6	3	7	2	8	1	9	5	8	4	7	3
6	2	5	1	9	2	8	3	7	4	6	5	9	4	8	3	7	2	6	1	5	4	6	3	7

Aantal korrek 120" Number correct 90"	Aantal half korrek 120" Number half correct 90"	TOTAAL 120" TOTAL 90"

X. SYFERS VERVANG DEUR SIMBOLE.

X. DIGIT SYMBOL SUBSTITUTION.

Name:____________________________ Date:________________

SLEUTEL

KEY

1	2	3	4	5	6	7	8	9

DIGIT SYMBOL INCIDENTAL RECALL TEST: DELAYED

INSTRUCTION: "Remember the test with the numbers and the signs. I would like you to fill in as many of the signs as you can recall. Remember to match the correct sign with each number".

SCORE (Number correct): _____

X. SYFERS VERNANG DEUR SIMBOLE-VERTRAAG

X. DIGIT SYMBOL SUBSTITUTION- DELAYED

Name:______________________________ Date:__________________

SLEUTEL

KEY

1	2	3	4	5	6	7	8	9

TRAIL MAKING TEST

Name: ______________________________ Date: ________________

INSTRUCTION: "This test consists of two parts, part A and part B and we will start with part A" (give participant a pencil and place part A sample sheet on table in front of participant). "On this page there are some circled numbers and I want you to draw a line from 1 joining up all the numbers until you reach the end. Begin at number 1 (point), draw a line from 1 to 2 (point), then from 2 to 3 (point), 3 to 4 (point) and so on until you reach the end. Do not worry about neatness but draw as fast as you can. Ready..? Begin".

* Observe closely and point out errors to participant. Explain mistakes to subject and repeat instructions. When participant has successfully completed the sample, say: "Let's try the next one. On this page the numbers are from 1 to 25 and you work in the same way as before. Begin at number 1 (point), draw a line to 2 (point), then 2 to 3 (point) 3 to 4 (point) and so on until you reach the end. Remember to work as quickly as you can without missing out a number. Are you ready...? Begin".

* Start timing as soon as instruction is given.

* If the participant goes wrong, call the error to his/her attention immediately for correction. Timing includes time taken to correct errors. When part A is completed, move to part B and say:

  "We will now try part B. On this page there are numbers and letters. Begin at number 1 (point) and draw a line to the letter A (point). Now continue the line from A to 2 (point), 2 to B (point), B to 3 (point), 3 to C (point) and so on until you reach the end. Remember to draw from a number to a letter and from a letter to a number in the correct order. Are you ready to try it../? Begin".

* When the sample has been completed correctly, move to the next page and say:

  "This task is the same as the one you have just completed but it is longer. Begin at number 1 (point) and draw a line to the letter A (point). Now continue the line from A to 2 (point), 2 to B (point), B to 3 (point), 3 to C (point) and so on until you reach the end. Remember to work as fast as you can, drawing from a number to a letter to a number in the correct order. Are you ready..? Begin".

* Start timing as soon as instruction is given.

* If the participant goes wrong, call the error to his/her attention immediately for correction. Timing <u>includes</u> time taken to correct errors.

<u>SCORE</u> (Time taken to complete task, including error correction):

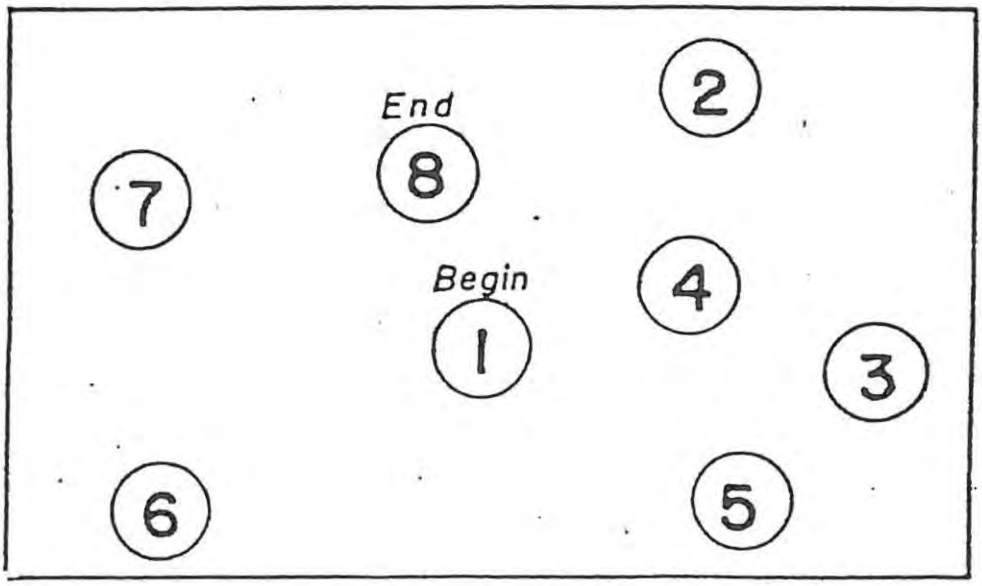
Part A:_________________________Secs

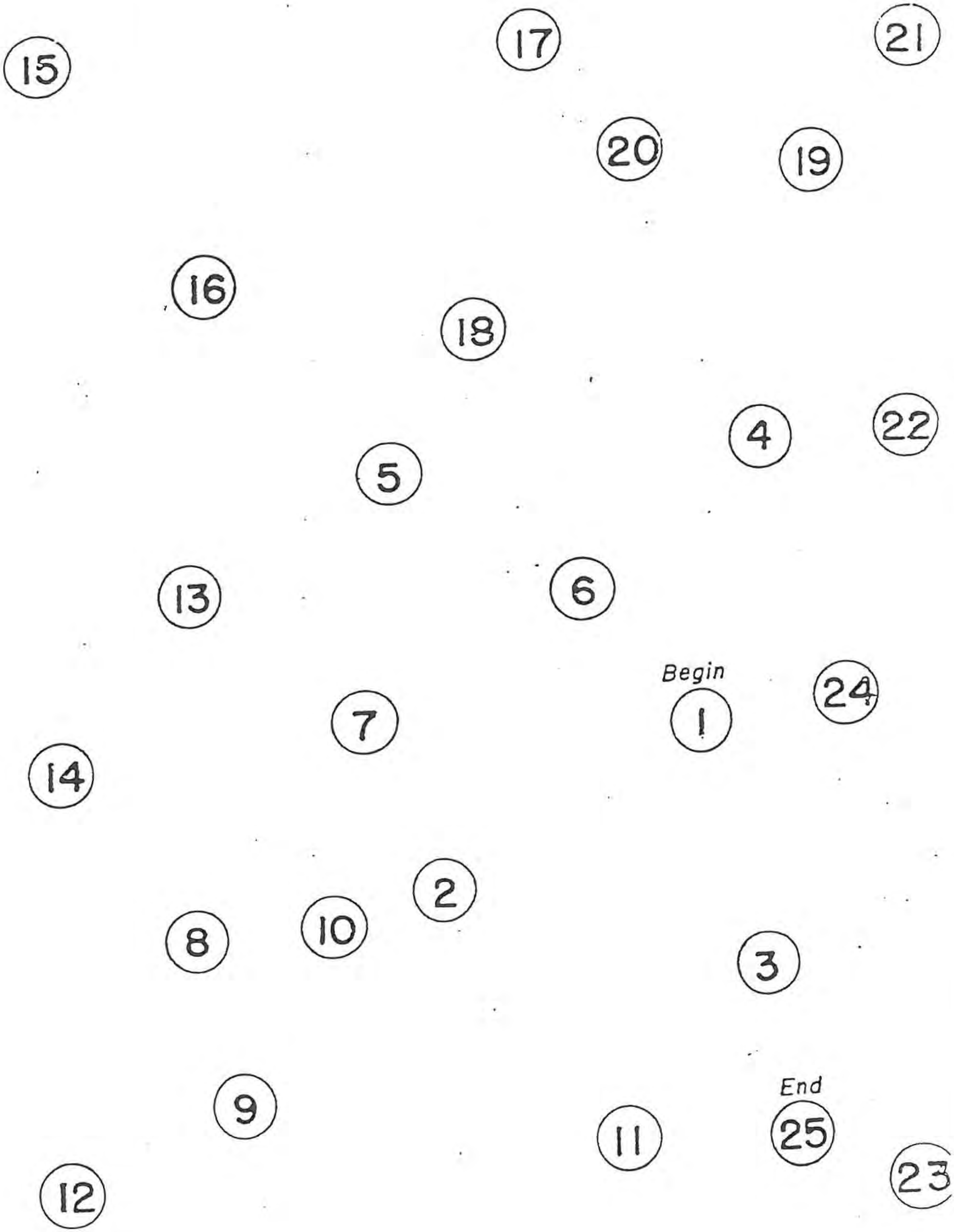
Part B:_________________________Secs

TRAIL MAKING

Part A

SAMPLE



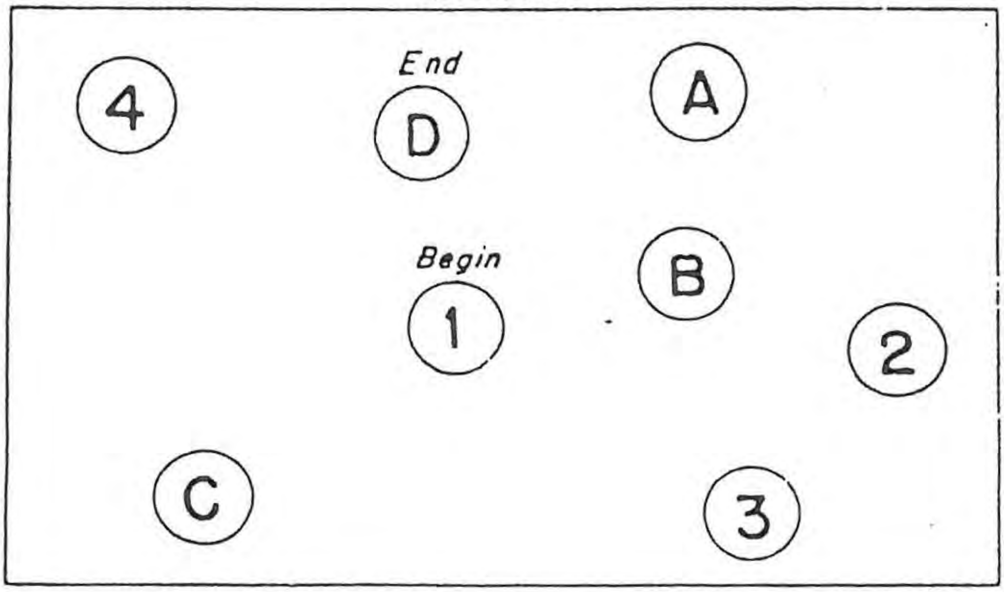


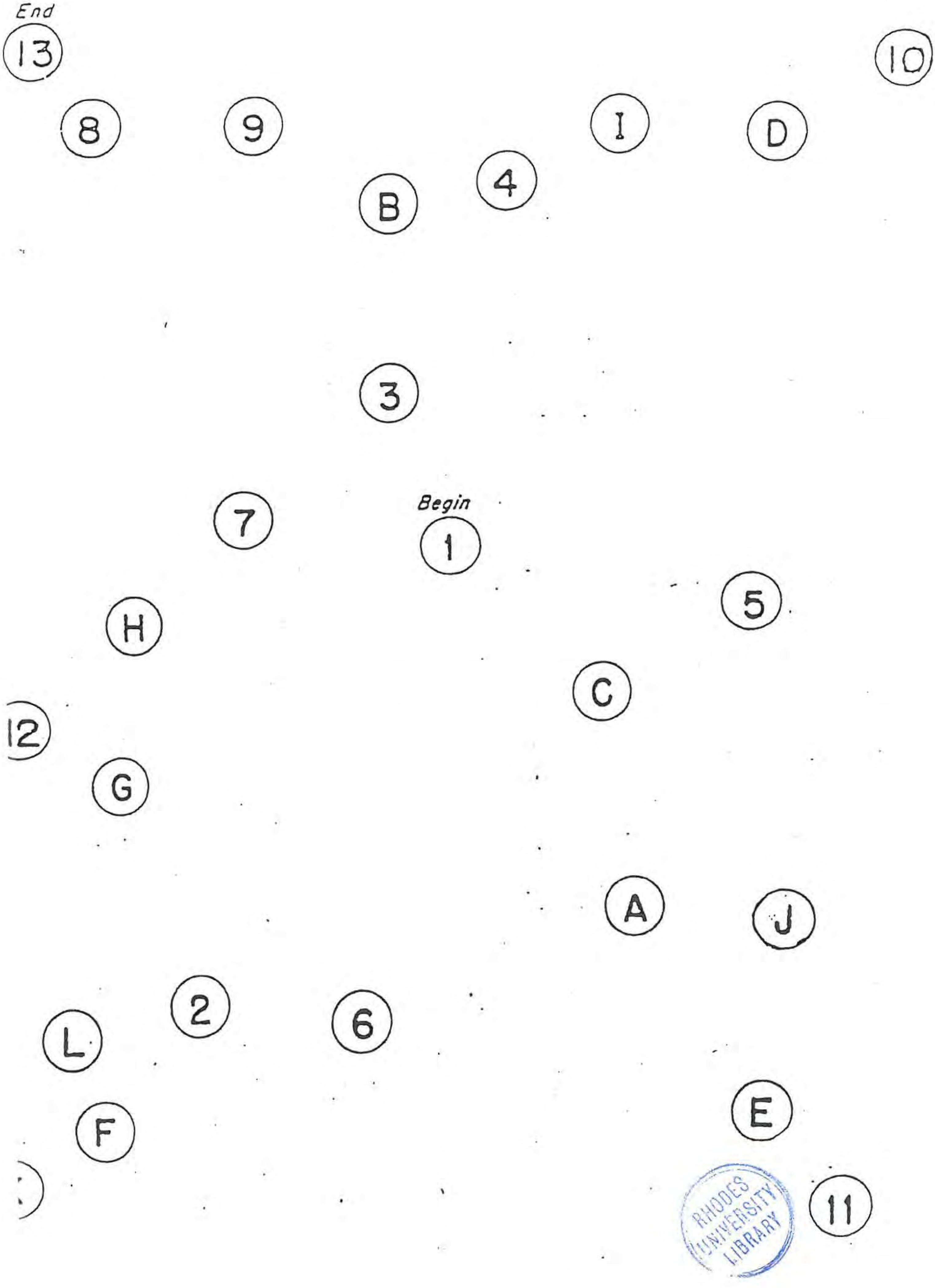
21
17
15
20
19
16
18
22
4
5
6
13
Begin
1
24
7
14
2
10
8
3
End
9
25
11
23
12

TRAIL MAKING

Part B

SAMPLE




End
13
10
8
9
I
D
4
B
3
Begin
7
1
5
H
C
12
G
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J
2
6
L
F
E
11