

AN INVESTIGATION INTO THE USE OF THE
TRAIL MAKING TEST WITH CHILDREN
AGED 10 - 15 YEARS

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ABSTRACT

A critical evaluation of research investigating the uses of the Trail Making Test (TMT) with children and adults was undertaken. Uses of the TMT in neuropsychological and other clinical settings, as well as the relationship of TMT performance to subject and experimenter variables were considered. A shortened version of the TMT developed for children was administered to 260 normal children, between the ages of 10 years and 14 years 11 months, to examine the relationship of TMT performance to age, full scale intelligence quotient and gender variables. Comparisons of descriptive data relating to TMT performance were made between the present study and previous research of a similar nature. Further statistical analysis (multivariate analysis of variance and multiple regression analysis) showed increasing age and FSIQ to be associated with quicker performance on Part A and Part B of the TMT. The implications of these findings for further clinical use with the TMT, were considered. Limitations of the present study, in conjunction with suggestions for further research, were discussed.

SECTION 1:

THEORETICAL OVERVIEW OF THE TRAIL MAKING TEST

1.1 INTRODUCTION

1.1.1 Aims

This study has two major aims. The first is to present a critical overview and evaluation of research conducted with the Trail Making Test (hereafter referred to as the TMT), a test widely used in neuropsychological practice. While many factors relating to neuropsychological functioning in adults and children are similar, many factors set these two groups apart (see Section 1.2.1). For this reason, findings with adults may not be automatically generalized to children, and this in turn necessitates detailed, but separate consideration of the use of the TMT with both population groups.

Secondly, this is a pilot study aimed at providing data relating to performance on the TMT for a group of normal children, aged 10 through 14 years 11 months. Performance on Part A and Part B of the TMT will be examined in relation to age, full scale intelligence quotient (FSIQ) and gender variables. A primary focus will be to consider present findings in the light of Reitan's (1971) and Spreen and Gaddes' (1969) research which has been conducted in the same area. Where appropriate, corrected TMT scores taking these variables into account will be provided for use in clinical settings.

1.1.2 Rationale

The lack of normative data for South African population groups when administering psychological tests in clinical psychology is well known to practising clinicians. In neuropsychological assessment, one is made acutely aware of this problem, where in private, clinic or hospital settings, the clinician finds him/herself making inferences using normative data from foreign population groups, or using data from adults for children, or vice versa. Coupled with these problems is the lack of material providing standardised methods of administration, scoring and interpretation of certain tests used in neuropsychological practice (e.g., the TMT with children). Manuals developed by clinicians or researchers in the area are either unknown or unavailable, as they are often unpublished manuscripts, usually of foreign origin. These problems were highlighted throughout the author's clinical training, and served as a major source of inspiration for the present study.

The TMT was specifically chosen as the focus for this research for a number of reasons. Over and above certain issues outlined above, the TMT has many positive attributes. Although much contention surrounds the issue (see Section 1.2.2), the TMT is reported to be a highly sensitive instrument in differentiating brain damaged from non brain damaged patients (Gordon, 1972; Lezak, 1983; Reitan, 1955, 1958), and therefore seems to have positive diagnostic value in neuropsychological assessment. Secondly, when used as a qualitative tool, it provides valuable information about each subject being tested (e.g., Reitan, 1958), such as predictive value of occupational

rehabilitation (Lezak, 1983), and more specifically, deficits in specific neurological functions. Coupled with its clinical sensitivity, the test is also cost effective, as it is an extremely quick test to score for quantitative analysis, and the material used in the test is inexpensive.

Children were chosen for this research owing to the paucity of research investigating the uses of the TMT in this population. Findings from previous studies are promising (see Section 1.2.3), but the area remains relatively unexplored.

1.1.3 The Inception and Development of the Trail Making Test

According to Brown, Casey, Fisch, and Neuringer (1958), the TMT dates back to a prototype known as the Taylor Number Series. In its original form, the subject was required to join with a line, numbers 1 to 50, randomly scattered on a sheet of paper. In 1938, a modified version of the test was developed and it was renamed "A Test of Distributed Attention" (Partington & Leiter, 1949). In this more refined form, it was viewed as an instrument that measured motor performance and speed. With more extensive use, however, Partington and Leiter (1949), concluded that successful performance on the test was related to mental shift ability, organization and planning ability, and motor performance.

Continued use of the test showed that performance was clearly related to subjects' estimated levels of intelligence, and that the test seemed to be a relatively good measure of general mental ability

(Partington & Leiter, 1949). In its more sophisticated form, the test was renamed the Partington Pathways Test, and performance on the test was shown to have a high positive correlation with the Stanford Binet Intelligence Test. The Pathways Test gained much attention, and the U.S. War Department incorporated it into the Army Individual Test Battery of General Ability (U.S. War Department, 1944), at which point it became known as the Trail Making Test.

Following the inclusion of the TMT into the above battery, research with this test expanded to clinical settings. The test was found to be of some value in differentiating neurotic from schizophrenic patients, and was shown to have some relevance with regard to the evaluation of brain injury (Partington & Leiter, 1949).

Since its inclusion into the Army Individual Test Battery, it appears that the form of the TMT used with adults has remained fixed. In 1955 Reitan, developed a version of the test to be used with younger children, which simply consisted of shortening the adult form of the test (both Part A and Part B). While this form of the TMT has been widely used in research with children (ranging in age from 9 to 15 years) (e.g., Boll, 1974a; Reitan, 1971; Reitan & Herring, 1985) no information regarding the standardization of the test seems to have been published.

In the last four decades, the use of the TMT has been extensively investigated (e.g., Gordon, 1972; Horton, 1978; Kennedy, 1981). This

body of research will be focused on at a later stage of the paper (See Sections 1.2 following).

1.1.4 Methods of Administration, Scoring and Interpretation of the TMT

Originally, when administering the TMT as part of the Army Individual Test Battery, the examiner removed either Part A or B of the test when the subject had made an error, and did not notice and correct it before proceeding beyond three more numbers (U.S. War Department, 1944). Armitage (1946) altered this procedure enabling all subjects to complete both parts of the test, even when the test had been failed according to previous criteria. Armitage (1946) developed this method of administration as he wished to collect all possible test data in his study. Scoring for this version of administration was based on time and accuracy.

Following this method of administration and scoring, Reitan (1956) drafted a manual for administration, scoring and interpretation of the TMT, and the major use of the test was to differentiate brain damaged from non-brain damaged people. Time scores for completion of each part of the test were converted to scaled scores, and cut-off points indicating the presence of organicity were devised (Reitan, 1956).

This method of scoring was criticized in further studies (Brown et al, 1958; Goul & Brown, 1972) as cut-off points were shown to produce high percentages of false negatives and positives when attempting to differentiate brain damaged from non-brain damaged patients. A series

of researchers subsequently provided an array of cut-off points, which were more sophisticated in that they took variables other than brain damage, such as age, into account (Bornstein, 1985; Davies, 1968; Gordon, 1978; Goul & Brown, 1970;). Davies (1968) also developed normative tables in the form of percentile ranges across age decades for diagnostic purposes, and scoring of the test was based on time taken to complete each part of the TMT.

To date, it appears that the most widely used method of administration of the TMT is in accordance with Reitan's (1956) instructions. Methods of scoring and interpretation, however, differ between studies, although raw time scores and/or cut-off scores form the basis for interpretation of results (Bowler, Thaler & Bicker, 1986; Davies, 1968; Gordon, 1972; Kennedy, 1987).

It is noteworthy that no manual for administration, scoring, and interpretation of the TMT with children is documented in the literature. Furthermore, no single study in the area provides procedural explanations regarding the administration of the TMT. Performance is scored according to time taken to complete the test. It is likely, therefore, that in the administration of the TMT to children, researchers either use the manual developed for adults (Reitan, 1956), or idiosyncratic variations of this. This apparent lack of standardization brings into question the validity of comparisons between studies, and ultimately, the clinical use of such data.

1.1.5 Functions Measured by the TMT

A number of researchers have attempted to isolate functions measured by the TMT. Armitage (1946) identified a number of functions which included:

- the ability to plan ahead; i.e., in order to do well on the test, the subject must always be looking ahead, and even before starting, a quick overall plan should be formed;
- visual scanning abilities; i.e., the ability to move visual attention between stimuli while completing a task.
- ability to perceive a double relationship; i.e., the number-letter relationship in Part B of the test;
- mental shift ability; i.e., the testee must integrate the number and letter series in Part B of the test, shifting back and forth between them, while keeping the ascending sequence of both clearly in mind.

Reitan (1959) highlighted the need to comprehend and effect visuo-spatial relationships, and Alvarez (1962) pointed to the need for integration of perceptual and motor skills.

Lezak (1983) identified a number of functions assessed by the TMT, although she made the point that the test in itself did not indicate what the actual problem was. These functions included motor skills, co-ordination abilities, scanning ability, motivational factors, conceptual ability and reaction time. In a factor analytic

investigation into the abilities underlying TMT performance, Groff and Hubble (1981) identified symbolic fluency, visual perception, and fine motor activity as being important factors underlying TMT performance.

In this author's opinion, other factors involved in successful completion of the test include adequate concentration and attention, the ability to sustain a single task, and knowledge of, and a degree of proficiency with, the alphabet and numerical system.

1.2 AN OVERVIEW OF THE CLINICAL USES OF THE TMT

1.2.1. Introduction

The major body of research conducted with the TMT in clinical settings has concerned itself with adult population groups, and this in turn has provided the basis for the limited research completed with children in the same area. For this reason, research done with the TMT in both adults and children will be considered.

Rutter (1983), however, has stressed the need to consider cerebral functioning (and dysfunction) in children as a topic in its own right. There are a number of reasons for this. Firstly, he points out that findings in the area of neuropsychiatry (or neuropsychology) with adults cannot be extended to children without modification. He stresses that the effects of damage may be greatly modified by the rate of development, and the maturity, of the brain. According to Rutter, "it cannot be assumed that trauma or disease will influence skills yet to develop in the same way as those already well

established" (1983, p.ix). Thus, it is clear that factors such as age, and the rate of general and neurological development, are of crucial importance in the field of neuropsychology in children. Boll (1974a) stresses the point that when considering the nature of brain damage in children, a far larger number of potentially interfering and confounding factors exist than is the case with adults. He points out that factors such as age and rate of neurological development, as well as issues such as the onset and chronicity of the disorder, play a more crucial role in children than in adults, although these factors are of relevance to adults as well.

The concept of brain damage in children is further complicated when the complex and controversial issues relating to the concepts of minimal brain dysfunction, and the associated learning disorders are considered. The debate surrounding the diagnostic efficacy and complexity of these neurological "syndromes" has been well documented (e.g., Rutter, 1983), but the role and exact nature of cerebral involvement in these syndromes remains unclear.

In summary, when considering brain damage in children, issues such as differential diagnosis, course of pathology, and prognosis either appear to be more complex, or of a very different nature, than is the case with adults. For this reason, the use of the TMT and its role in the assessment of brain damage in children, warrants separate consideration to that of adults.

1.2.2 The Trail Making Test as an Assessment Device for Differentiating Brain Damaged and Non-Brain Damaged Adults

The literature contains numerous reports of the efficacy of the TMT as an assessment device for differentiating brain damaged and non-brain damaged subjects. Armitage (1946) provided quantitative and qualitative analyses of TMT performance in a group of brain damaged patients and normal controls. The findings showed marked variance between performance of the two groups, using both methods of analysis, on Part A and Part B of the test. Brain damaged subjects had greater difficulty correcting errors, took longer to complete the task and were less able to recognize errors than were their normal counterparts. Furthermore, their errors on Part A of the test were largely due to impulsivity and the inability to plan ahead. On Part B, some brain damaged subjects were unable to follow, and/or maintain, the number-letter sequence, and needed to verbalize this sequence, thereby adding an auditory memory aid to their performance; brain damaged patients also showed perseverative tendencies in their performance on the TMT.

In attempting to validate these findings, Reitan (1955) administered the TMT to a group of brain damaged and control patients. Brain damaged patients performed significantly worse than their normal counterparts on Part A, Part B, and Trail total i.e., Part A plus Part B, thereby lending support to Armitage's (1946) findings. Investigating a much larger sample, Reitan (1958) again found highly significant differences at all levels

of TMT performance between brain damaged and control subjects. In all cases, brain damaged patients' performance was significantly inferior to those of normal controls. Analysis of their performance (i.e., brain damaged subjects) showed that they had difficulty with spatial distribution, mental shift, and attention and concentration (Reitan, 1958). Reitan and Tarshes (1959) also showed that different patterns of performance on Part A as opposed to Part B of the TMT were promising in terms of locating lateralisation of brain lesions. In addition Fitzhugh, Fitzhugh and Reitan (1962) found that TMT performance differed in terms of chronicity and acuteness of brain dysfunction.

Providing further support for the TMT's diagnostic value, Alvarez (1962) found the TMT to differentiate between brain damaged and depressed patients, and found the performance of the latter group closely approximated that of the normal subjects reported in Reitan's (1955) study.

Brown et al (1958), looked at TMT performance in brain damaged, psychotic, other psychiatric and normal patients. Their results were somewhat contradictory to previous findings. Performance on Part A of the test was found to significantly differentiate organic and psychotic patients from normal and other psychiatric patients. Performance on Part B of the test, however, did not differ significantly between different diagnostic groups. These authors further concluded that results did not provide a cut-off score of discriminative diagnostic value with respect to the

groups tested. They did, however, find that performance on both parts of the test differed significantly between high and low intelligence quotient (IQ) groups, and that Part B showed differences in performance between younger and older age groups.

Parsons, Maslow and Morris (1964) supported these findings, and showed a high misclassification of normal and psychiatric patients to be brain damaged, using Reitan's (1958) cut-off points. Orgel and MacDonald (1967) investigated performance on the TMT with three groups of hospitalized veterans, viz., brain damaged, psychiatric and normal patients. Their findings showed no significant differences in TMT performance between the three groups tested.

Gordon (1972) addressed the conflicting research findings outlined above. In attempting to explain previous findings, he highlighted a number of issues. Firstly, the importance of age as a variable affecting TMT performance was stressed, and in his opinion, needed careful consideration when assessing performance on the test. Secondly, the nature and locality of brain damage in subjects needed to be accounted for when assessing TMT performance. Thirdly, marked variation in the composition of the brain damaged and normal samples confounded comparisons of TMT performance within, and between studies (also see Radford, Cheney, O'Leary & O'Leary, 1978, who discuss this issue in detail). Furthermore, Gordon's (1972) study showed the TMT to successfully differentiate brain damaged from non-brain damaged

patients, and that errors in diagnostic efficiency were largely related to age factors. He therefore suggested that age norms, and possibly education norms, might well increase the diagnostic sensitivity of the TMT.

Kennedy (1981) supported Gordon's (1972) findings, and concluded that inconsistencies found across different studies were largely associated with a number of subject variables, other than brain damage, which influenced TMT performance. Lezak (1983) concluded that, when subject variables such as age were taken into account, the TMT was amongst those tests that are most sensitive to the presence of brain damage. The value of the TMT as a device for diagnosing the presence of brain damage is further supported by its inclusion in a number of neuropsychological test batteries (e.g., Barret, Wheatley & Le Plant, 1983; Bowler, Thaler & Becker, 1986).

Thus, it would seem that the TMT is a highly valued test regarding its diagnostic effectiveness in neuropsychological practice. The use of single measures, such as the TMT, in making diagnostic decisions, however, needs some consideration. Reitan (1971) has shown that the effects of cortical lesions and cerebral damage are multifaceted, and that one test is often insufficient to adequately describe the individual's unique pattern of brain-behaviour relationships. Secondly, as Horton (1978) points out, when the question is not only one of diagnosis, but of management and rehabilitation, a battery of

various tests seems necessary to provide the basis for an effective intervention plan. In this author's opinion, it is primarily within the context of developing effective test batteries for neuropsychological assessment, that further research with the TMT should be located.

1.2.3 The Trail Making Test as an Assessment Device for Differentiating Brain Damaged from Non-Brain Damaged Children

Using Reitan's 1955 version of the TMT for children (see Reitan, 1971), Davids, Goldenberg and Laufer (1957) investigated the performance of brain damaged, psychiatric and normal subjects on the TMT. Results from the study showed normal subjects to perform significantly better than their brain damaged counterparts on all parts of the TMT. Reed, Reitan and Klove (1965) examined the performance of children with cerebral lesions on a number of neuropsychological measures, including the TMT. Performance on all parts of the TMT showed the brain damaged group to perform at a significantly lower level than the control group. These authors stressed that their findings should be regarded as preliminary. They highlighted the need for comparisons of larger groups of children with cerebral lesions to permit experimental control over variables such as lesion type, locus, severity, aetiology and age of onset. They also pointed out that analysis of their data was sensitive to mean levels of performance, and revealed nothing of intrasubject patterns of performance. Lastly, they stressed the need for the

establishment of adequate age norms, so that a firm basis for further research could be established.

Reitan (1971) and Boll (1974a) supported previous findings, and concluded that the TMT differentiated between brain damaged and normal children. Both studies showed that Parts A and B reliably reflected deficits in performance of subjects with cerebral damage. In a more recent study Reitan and Herring (1985) developed a short screening battery, including the TMT, for the identification of cerebral damage in children. In their study, both Parts A and B of the TMT were found to be accurate in classifying brain damaged children, and in differentiating them from normal controls.

While the studies outlined above provide conclusive evidence as to the TMT's sensitivity to brain damage in children, certain issues need mentioning. The use of single test measures for diagnostic purposes in neuropsychology should be regarded with caution (as was pointed out with adults). As Reitan (1971) suggests in his study with children, no single test should be seen to represent an adequate behavioural framework for the expression of brain function. He also stresses that his findings should not be interpreted to imply that the TMT by itself is an adequate test for reflecting brain-behaviour relationships in children. Furthermore, it has been pointed out that the practice of using single tests to detect brain damage, implies a model of brain function "which assumes a homogeneous response to tests by

a heterogeneous group of brain-injured children" (Herbert, 1964, quoted in Chadwick & Rutter, 1983, p.181). This viewpoint in turn tends to represent a misleading, inadequate, and oversimplified theory of brain functioning.

Thus, the use of a carefully selected battery would seem to be of more value in terms of diagnosis, assessment, and ultimately in guiding the management of cerebrally impaired children. According to Chadwick and Rutter (1983) the use of test batteries in neuropsychological assessment has many advantages. Firstly, it provides scope for a more in-depth understanding of brain-behaviour relationships. Secondly, it has the potential of contributing to syndrome definition, and treatment planning. Thirdly, test findings may well provide information relating to the functional interplay of the two cerebral hemispheres.

In considering the research looking at the diagnostic effectiveness of the TMT with children, it should also be noted that analyses of the data were based on quantitative methods of analysis. Here, level of performance - good versus poor - was the sole criterion used in deciding whether the two groups differed or not. While this method has validity, further qualitative analysis, considering factors such as plan of action, the nature of errors made, and strategy used, may provide valuable information regarding performance on the TMT in different brain damaged groups. In turn, this may well enhance

clinical management, and provide valuable insights into neurological and behavioural relationships in children.

1.2.4 The TMT with Learning Disabled Children

Rourke and Telegdy (1971) showed WISC verbal intelligence quotient (VIQ) - performance intelligence quotient (PIQ) discrepancies, in learning disabled children aged 9-14 years, to reflect the differential integrity of the two cerebral hemispheres. Rourke, Young and Flewelling (1971) extended this research, and investigated the relationship of verbal-performance discrepancies on the WISC to performance on various neuropsychological test measures, including the TMT, in learning disabled children aged 9-14 years. Their results showed that patterns of WISC verbal-performance discrepancies were significantly associated with respective patterns of performance on the neuropsychological tests used in their study. Rourke and Finlayson (1975), further investigated patterns of TMT performance in relation to VIQ-PIQ discrepancies, attempting to illuminate the role of cerebral involvement, and lateralisation of pathology, in learning disabled children.

Their results indicated that learning disabilities in children were in part due to cerebral dysfunction, and that TMT performance may be related to lateralisation of cerebral pathology. The danger of using single tests for such inferences was however stressed by these researchers. They did, however, claim that patterns of TMT performance coupled with other indications of cerebral dysfunction, especially of a lateralising

nature, may constitute sufficient evidence on which to base an inference of cerebral involvement in children with learning disorders.

The above research provides interesting findings and a good basis for further research in the area. It is disconcerting, however, to find that the complexity and controversy surrounding the diagnostic category of "learning disabilities" is at no point addressed in this research. Furthermore, details of the specific learning disabilities of children used in the respective studies are unknown. It is also necessary to point out that part of Rourke and Finlayson's (1975) study, which uses patterns of TMT performance to reflect lateralisation of cerebral involvement, is firmly embedded in adult research i.e., in Reitan and Tarshe's (1959) study. Using adult research to inform and direct research with children is necessary, and potentially productive. Interpreting similar test patterns in adults and children as having the same meaning, however, should be done with caution, and should be based on sound theoretical grounds.

1.2.5 The TMT as an Assessment Device for Differentiating Brain Damaged and Psychiatric Patients

While this section is not related to the empirical part of this study, it is reviewed as a number of important issues regarding the use of the TMT are highlighted.

Research in this area has primarily concentrated on assessing the TMT's usefulness in differentiating psychotic, and more specifically schizophrenic, patients from brain damaged patients. Brown et al (1958) identified the frequent diagnostic problem of having to distinguish between schizophrenia and brain damage in clinical practice. Brown et al (1958) and Smith and Boyce (1962) concluded from their research that the TMT was of no value in differentiating between these two groups. Goldstein and Neuringer (1966) and Boll (1974b), however, provided contradictory evidence, and concluded that both Parts A and B of the TMT were potentially effective in differentiating brain damaged from schizophrenic subjects.

While the Brown et al (1958) and Smith and Boyce (1962) studies based their findings on quantitative methods of statistical analysis, Goldstein and Neuringer (1966) provided clear and interesting qualitative observations in the differences of the two groups sampled.

Gordon (1972) attributed poor performance on the TMT by schizophrenics to low levels of motivation, and the belief that poor performance may be perceived by participants as leading to a desired goal, e.g., continued hospitalisation. King (1967) attributed poor performance by schizophrenic patients to their general psychomotor retardation, while aspects such as mental shift, needed for Part B, were not found to be responsible for poor performance. Boll (1974b) claimed that inconsistent

findings were partly due to the fact that previous studies had tended to treat brain damage as a unitary concept, or as Small, Small, Milstein and Moore (1965) noted, comparisons had been made with normative data derived from patients with mixed types of brain damage.

It should also be noted that, as Klonoff, Fibiger and Hutton (1970) point out, schizophrenia has not been ruled in or out as a category of cerebral impairment. This adds further complexity to the diagnostic difficulty in the area. Horton (1979) also stresses the need for a thorough assessment using a full battery when faced with this particular diagnostic problem. Finally, the use of qualitative, as opposed to quantitative analysis of TMT performance seems promising (Goldstein & Neuringer, 1966; Malec, 1978), but further research in the area is needed before definitive conclusions can be formulated.

As far as children are concerned, little work has been done in the area of brain damage and psychiatric disorders, and their differences in performance on the TMT. The problems in diagnosis of psychotic conditions in children (Barker, 1983; Steinberg, 1985) and their possible relationship to organic conditions (Rutter, 1983) has been well documented. In addition to this, the complex issues regarding brain damage in children (see Section 1.2.1) makes the use of the TMT as a diagnostic tool in this setting, somewhat premature.

In the research that has been conducted in the area, Davids et al (1957) found Part A of the test to differentiate between brain damaged and a mixed psychiatric group of children, while no differences on Part B of the test were observed. Problems in sampling procedures and statistical analysis lead one to regard these results with caution, and, as was the case with adults, extensive research is needed before conclusions regarding the clinical use of the TMT in this area can be reached.

1.3 TRAIL MAKING TEST PERFORMANCE AS RELATED TO SUBJECT AND EXPERIMENTER VARIABLES

1.3.1 Introduction

The conflicting findings emanating from research investigating the diagnostic usefulness of the TMT with brain damaged subjects (see Section 1.2.2 and 1.2.3) gave rise to a wealth of research, which aimed at investigating the role of experimenter variables and subject variables other than brain damage, on TMT performance.

1.3.2 The Relationship of Age to TMT Performance in Adults

Brown et al (1958) were amongst the first researchers who claimed that age should be taken into account when assessing TMT performance. Davies (1968) addressed the effects of age and brain damage on TMT performance. In her normative study with subjects across age decades, TMT performance was found to be clearly related to age. She showed that applying Reitan's (1955) cut-off scores to this group of normal subjects, grossly

misclassified in subjects the 70's age range as brain damaged. Using the same cut-off points in the younger decades, misclassification was approximately double that of Reitan's. In her research conducted with brain damaged and normal controls, Davies (1968) again found Reitan's (1955) cut-off scores to misclassify both normal and brain damaged subjects. She concluded that cut-off criteria established for young samples could give seriously misleading results when applied to older age groups, and she suggested the need for age corrected cut-off points when using the TMT as a diagnostic assessment device.

These findings were supported by Goul and Brown (1970), who concluded that the TMT was a useful screening device for differentiating brain damaged and non-brain damaged patients, if age was taken into account, in the form of age corrected cut-off points. They stressed the need for age corrected norms and cut-off points, but pointed out that these would not necessarily cross validate to all settings. This in turn brought into question the need to develop norms appropriate to each setting in which the TMT might be used. Boll and Reitan (1973), however, refuted the need for age corrected cut-off points, and concluded that Reitan's (1955) original cut-off points were applicable across all ages, and were as valid as those developed by Davies (1968) and Goul and Brown (1970).

In a more recent study, Kennedy (1981) examined these findings, accrediting these differences to methodological and procedural

differences across studies. Considering Boll and Reitan's (1973) study, he pointed out that this study was based on correlational data only, and contained very few subjects in older age intervals. These factors brought the validity of their findings regarding the absence of age effects on TMT performance into question. He further pointed out that the above studies ignored education and, with the exception of Goul and Brown (1970), IQ, as variables influencing TMT performance. Kennedy (1981) showed Goul and Brown's (1970) cut-off point to most accurately classify older subjects in his sample, as brain damaged. Further, Kennedy (1981) found that age significantly affected TMT performance, and that a trend of poorer performance with increasing age across decades was observed on Parts A and B of the test.

Stanton, Jenkins, Savageau, Zyzanski and Aucoin (1984) provided further evidence which showed that advanced age contributed to slower performance on the TMT, and concluded that this must be taken into account if the TMT "is to be used in clinical practice as an adjunct to differential diagnosis of potential organic brain dysfunction" (p.317). Bornstein (1986) assessed the applicability of cut-off points with selected neuropsychological measures, including the TMT, and suggested the necessity to adjust standard cut-off scores with correction factors for subject variables such as age and education. Hence, this body of research offers strong support for the need to take age into account when assessing TMT performance.

1.3.3 The Relationship of Age to TMT Performance in Children

The effect of age on TMT performance in adults has been investigated at a fairly gross level of age decades (Davies, 1968) or intervals of five years (Boll & Reitan, 1973). The emphasis has been to look at poorer performance with increasing age in the light of the ageing process, and accompanying deterioration in motor, intellectual and cognitive functioning (Kramer & Jarvik, 1979). Owing to the dynamic process of general and neurological development in children, however, the age variable assumes a different perspective in the light of performance on neuropsychological and other measures. Because of the major intellectual and cognitive changes in middle childhood, and development in skills such as fine motor co-ordination, a general trend for improved performance on many neuropsychological measures with increasing age may be expected. The effect of age on TMT performance in children has therefore been investigated at yearly intervals (Reitan, 1971; Spreen & Gaddes, 1969), where the focus has been to assess whether test performance improves with increasing age.

Spreen and Gaddes (1969) provided mean levels of performance on Parts A and B of the TMT, for children aged 9 through 15 years. Although their data was not subjected to statistical analysis, means across yearly age ranges showed a tendency for quicker performance on both Parts A and B of the test, for males and females, as they grew older. Differences in cell sizes across

yearly age intervals (e.g., 92 subjects at 12 years and 14 subjects at 13 years), coupled with the lack of statistical analysis of the effects of age differences on TMT performance, render conclusions drawn from this data speculative. Reitan (1971) also found males and females to perform better on both Parts A and B of the TMT as they grow older. Reitan's results across the six year age range (9 through 14 years) are based on the performance of 98 subjects only, and the nature of the distribution of subjects across the yearly age intervals is not mentioned. Furthermore, mean performances of subjects at yearly age intervals were presented in rather inaccurate graphic form, from which little meaningful information could be gleaned (see Reitan, 1971, p.578). These factors, in conjunction with the absence of statistical verification of the observed trends of age effects on TMT performance, and the absence of some measure of dispersion of TMT scores at the respective age intervals, detracts considerably from the usefulness of Reitan's (1971) results.

Hence, while these studies provide some indication that TMT performance in children improves with increasing age, it is clear that more rigorous research in the area is needed.

1.3.4 The Relationship of Trail Making Test Performance to Intelligence Quotient and Educational Background in Adults

Research examining the relationship of TMT performance and intelligence quotient show consistent findings.

Reitan (1959) showed strong positive correlations between TMT performance on both Part A and Part B of the TMT and general intelligence measurement. His findings also showed that this correlation did not differ for brain damaged and non-brain damaged subjects. Davids (1957) found the same correlation between IQ and TMT performance with normal subjects, but found no such relationship between these two variables in brain damaged and psychiatric groups. Brown et al (1958) and Goul and Brown (1970) however, found positive correlations between IQ and TMT performance for brain damaged and non-brain damaged patients. Furthermore, Goul and Brown (1970) found positive correlation between TMT performance (Parts A, B and A + B) and verbal intelligence quotient (VIQ), performance intelligence quotient (PIQ) and full scale intelligence quotient (FSIQ).

Boll and Reitan (1973) provided strong support for these findings, and showed that performance of brain damaged and non-brain damaged subjects on both Parts A and B of TMT correlated significantly with verbal, performance and full scale IQ's. Thus, these findings show that as IQ increases, TMT performance improves.

Parsons et al (1964) were amongst the first researchers to investigate the relationship of education to TMT performance. A positive correlation between TMT performance and level of education was demonstrated. Gordon (1972) found TMT performance to correlate significantly with education in brain damaged

patients, but not in non-brain damaged controls. Prigatano and Parsons (1976) provided strong support for the influence of educational background on TMT performance. These findings were supported by Stanton et al (1984), who provided evidence based on a much larger sample, showing that higher levels of education resulted in improved performance on all parts of the TMT.

It seems clear then, that increasing IQ and higher levels of education are significantly associated with improved TMT performance, and should be taken into account when assessing the significance of TMT performances in diagnostic settings.

1.3.5 Trail Making Test Performance as related to IQ and Educational Variables in Children

Davids et al (1957), looking at the diagnostic efficiency of the TMT in children, found a significant correlation between performance on Part B of the test and general IQ, and concluded that the test might be used as a quick measure to gauge intelligence in normal children. As far as brain damaged and psychiatric patients were concerned, they found no significant relationship between IQ and TMT performance. In a more thorough study, Boll and Reitan (1973) investigated performance on both parts of the TMT as related to the entire Wechsler Bellevue Scale, i.e., FSIQ, VIQ, PIQ and all subtests of the scale. The study involved both brain damaged and normal controls. In the brain damaged group, they reported that all but two Wechsler variables viz., picture completion and comprehension, correlated significantly with Part A of the test, and all but one variable

(object assembly) correlated significantly with Part B. Within the control group, however, only three variables correlated with either Part A or B of the test, viz., information and digit symbol with Part A, and digit symbol with Part B.

Hence, in the light of contradictory findings, further research in the area is needed before conclusions regarding the association of IQ to TMT performance can be reached with greater certainty.

To this author's knowledge, the association of educational differences in children, and their relationship to TMT performance has not been investigated. This could partly be due to the fact that age differences and educational attainment may be closely linked in many children. There are of course many children in which age and level of education are not directly related. In order to discriminate between the respective associations of age and education to TMT performance, it would be valuable to conduct research with such population groups.

1.3.6 Gender Differences and TMT Performance

Davies (1968) investigated the performance of males and females on the TMT, and found no significant differences between the sexes in each respective age decade. When combining all age groups, however, men were found to be slightly quicker than women. Kennedy (1981), Chavez, Trautt, Brandon, and Steyaert (1983) and Stanton et al (1984) however, found no differences in performance on the TMT across the sexes.

With regard to children, Reitan (1971) found overall means for performance on Parts A and B of the TMT to be almost identical for boys and girls. Although Spreen and Gaddes (1969) provided data for male and female performance on the TMT, they did not investigate whether differences between the two groups existed. Therefore, as Reitan's (1971) study is the only one in the literature which addressed this issue, further investigation into the association of gender to TMT performance is necessary.

1.3.7 TMT Performance as related to other subject and experimenter variables

In attempting to explain the conflicting findings found in much of the research conducted with the TMT, Parsons et al (1964) investigated the effects of experimenter variables, order of test administration, ego involvement of the testee, behavioural agitation and anxiety on TMT performance. None of these variables were found to significantly affect TMT performance. Chavez et al (1983) investigated the effects of test anxiety on a number of neuropsychological tests, including the TMT. Their findings showed that anxiety did not affect performance on any of the neuropsychological measures, including the TMT. However, it appears that the effects of factors such as anxiety on TMT performance in children have received no attention in the literature, and it is necessary therefore that research in the area should be conducted.

SECTION 2

EMPIRICAL INVESTIGATION INTO THE USE OF THE TRAIL MAKING TEST WITH CHILDREN

2.1 Introduction

The present study was designed to address the need for more rigorous research which investigated the association of age, FSIQ and gender to TMT performance in normal children. Criteria for selection were based on the theoretical issues discussed in the preceding review, and exclusion criteria used by Spreen and Gaddes' (1969) in their study. Thus, children with a history of one or more of the following were excluded from participating in the present study: learning disorders, school failure, epilepsy, head injury, or any other evidence of cerebral damage, and severe emotional or behavioural problems

2.2 Methodology

2.2.1 Subjects

The participants in the study were 260 school children (123 boys and 137 girls) between the ages of 10 years and 14 years 11 months. All children were drawn from three primary schools and one middle school (standard 6 and 7 pupils), forming part of a private day school establishment in Cape Town.

2.2.2 Apparatus

The revised version of the TMT, developed for children by Reitan in 1955, was administered to all participants. The test is made up of two parts, Part A and Part B (see Appendix I).

Part A consists of a sheet of paper with a series of circles printed on each side of the page. In the centre of each circle is a number, which ranges from 1-15 for the test proper, and from 1-8 for the practice sample, which is on the reverse side of the page. The circles are spatially arranged in a random order. The subject is required to use a pencil to join the circles, in ascending order, as quickly as possible.

Part B of the test is similar in structure to Part A, except that the circles in this case contain either numbers or letters. The test has numbered circles ranging from 1-8, and letters ranging from A-G, while the practice sample has numbers 1-4, and letters A-D. The testee is required to join the circles in ascending number-letter sequence (i.e. 1 to A, A to 2, 2 to B, B to 3 and so on), ending with the number 8.

The TMT was administered according to Reitan's (1956) instructions for adults, as no formal method of administration for children was documented in the literature. Test performance was scored in terms of time taken to complete the test.

When instructions for the test proper were given, only the first three circles of Part A, and the first four circles on Part B, respectively, were pointed to, in conjunction with the verbal

instructions. This differs from Reitan's manual for adults, where four circles in Part A, and six in Part B, are shown to prospective testees.

2.2.3 Procedure

Permission to conduct the research was granted by the joint principals' committee of the four schools involved. All prospective subjects were addressed by the researcher, in accordance with the requests of the respective principals. The aims of the study were explained to all prospective subjects in the most simple terms possible. As information on actual selection criteria was seen as being potentially harmful both to participants and to those excluded from the study, the children were informed that selection for participation in the study was random.

Class lists for children within the standards three to seven were obtained from all four schools involved. The subjects' ages to the closest month were calculated (15 days or more added 1 month to age). Children were then divided into the following age groups, in years and months: 10 to 10.11 (Std 3); 11-11.11 (Std 4); 12-12.11 (Std 5); 13-13.11 (Std 6); and 14-14.11 (Std 7). Full scale intelligence quotient (FSIQ) scores were obtained from each pupil's educational record card. These scores were derived from the New South African Group Test (NSAGT), a group IQ test administered to the subjects in Standards 3 and 5. Subjects were further divided into the following IQ categories,

following IQ categories, according to the NSAGT: 90-111: average; 112-119: above average; 120-126: superior; 127+: gifted. Where possible, an attempt was made to obtain equal numbers of subjects across age, FSIQ groupings and gender. A problem in the procedure was encountered with the standard 3 subjects (10-10.11) who had not been tested on the NSAGT at the time testing for this study was scheduled. The researcher was forced, therefore, to test as many subjects as possible in this age range and sort subjects into respective IQ categories once this assessment had been completed. This resulted in the greater number of subjects, and unequal cell sizes, in this age group (see results).

Once subjects were chosen, they were seen by the researcher in small groups, where they were once more informed of the aims of the study. All subjects were given the opportunity to withdraw from the study. Only four subjects declined to participate, and substitutes were therefore tested.

Subjects were individually tested in an office allocated at each of the respective schools, and were given the opportunity to ask questions before and after testing. Testing was conducted between June and August 1987.

Fifteen of the subjects used in the study were excluded from the statistical analysis of results. Four of these had not completed testing owing to heightened levels of anxiety; seven were excluded owing to interruptions during testing; and a further

four were excluded owing to technical problems with the stop watch used for timing.

Of the remaining 245 participants, 23 subjects within the 10 to 10.11 age group had not completed the IQ assessment by the time analyses of results were computed, and were therefore excluded from most of the analyses.

2.3 RESULTS

2.3.1 Descriptive and Comparative Statistics

The means and standard deviations for overall performance on Parts A and B of the TMT for the present sample, and Reitan's (1971) study, are presented in Table 1. Differences in means between the studies were analysed using t-tests, which yielded highly significant results for both parts of the TMT (See Table 2). Means for performance on Parts A and B were lower for the present study, indicating superior performance for the present sample.

Table 1

Means and Standard Deviations for all subjects on Parts A and B of the TMT

	Present Study				Reitan (1971)			
	*Mean	Std.Dev.	N	Age Range	Mean	Std.Dev.	N	Age Range
Part A	11.18	3.03	245	10-14.11yrs	14.95	5.79	98	9-14.11yrs
Part B	23.14	8.41	245		32.25	13.31	98	

*Values expressed in seconds for completion of each task

Table 2t-Test Comparisons of Mean TMT performance between the present study and Reitan's (1971) study

df	Part A	Part B	t critical
341	5.89**	10.76**	2.326; $p < .02^{**}$

Descriptive statistics for performance on Parts A and B are presented for the present study, and Spreen and Gaddes' (1969) study, in Table 3. (Results marked with a + in this table were adapted by Spreen and Gaddes from Knight's (1966) study, and this accounts for missing data in the table.)

Large discrepancies in means, standard deviations, ranges, and minimum and maximum values between the two studies were evident. In all cases, values for these measures across each age interval were considerably lower in the present study. Less variation in TMT performance across age was reflected by the smaller standard deviations in the present study. It should be noted that the greater means and standard deviations in the Spreen and Gaddes (1969) study can be largely attributed to the maximum values across each age range in their study.

Differences in means between the studies were examined using t-tests, and yielded significant results across age ranges for both parts of the TMT (See Table 4). (It was not possible to examine differences between studies at the 14 year old age range, as data was missing from

the Spreen and Gaddes (1969) study.) This again indicated superior performance across age in the present study. Reasons for these differences between the present study, and the Spreen and Gaddes (1969) and Reitan (1971) studies respectively will be discussed at a later stage in this paper (See Section 2.4).

Table 3

Time Score in Seconds for TMT Performance by Age

TMT : PART A

Present Study

Age	N	Mean	Std.D.	Min.	Max.	Range
10-10.11	58	12.94	2.99	8.16	20.00	11.8
11-11.11	46	11.36	2.70	6.94	18.31	11.4
12-12.11	52	10.74	2.83	5.53	17.10	11.6
13-13.11	44	11.24	3.09	7.53	21.25	13.77
14-14.11	45	9.17	2.19	5.10	12.63	7.5
Overall :	245	11.17	3.03	5.1	21.25	16.15

Spreen and Gaddes (1969)

Age	N	Mean	Std.D.	Min.	Max.	Range
10	51	19.8	5.7	10	42	32
11	51	17.4	6.3	9	37	28
12	92	16.3	5.7	7	43	36
13	14	14.9	7.6	9	39	30
+14-15		14.0		8	30	22
Overall:		16.48		7	43	36

TMT : PART B

Present Study

Age	N	Mean	Std.D.	Min.	Max.	Range
10-10.11	58	29.32	9.33	17.03	54.00	36.9
11-11.11	46	22.73	6.50	10.69	40.28	29.6
12-12.11	52	23.33	8.44	10.06	49.95	39.9
13-13.11	44	21.80	6.32	9.60	36.88	27.8
14-14.11	45	16.68	6.43	9.72	27.81	18.1
Overall:	245	23.14	8.41	9.60	54.00	44.4

Spreen and Gaddes (1969)

Age	N	Mean	Std.D.	Min.	Max.	Range
10	51	47.5	15.4	18	84	66
11	51	41.7	15.8	15	122	107
12	92	35.7	12.5	14	90	76
13	14	35.4	19.5	17	99	82
+14-15	-	31.0	-	13	50	37
Overall:	-	38.3	-	13	122	109

Table 4

t-Test Comparisons of Mean TMT Performance between the present study and
Spreen and Gaddes (1969) across Age

Age Range	df	Part A	Part B	t crit
10-10.11	107	5.76**	5.38**	2.39; p < .02**
11-11.11	95	4.28**	5.31**	2.39; p < .02**
12-12.11	140	4.73**	4.51**	2.32; p < .02**
13-13.11	56	2.00*	2.91**	2.00; p < .05*
				2.39; p < .02**

There were, however, similar trends which existed between these studies (see Tables 1 & 3). Perusal of mean scores reflects improved

performance on both parts of the TMT with increasing age. (This trend was statistically analysed and will be presented in the following sub-section.) It was also evident that standard deviations in the studies were considerably larger for Part B than for Part A. This reflects more variation in Part B, which may be attributed to the greater difficulty and complexity of the task, and consequently, to the increased times associated with completion of this task. It should be pointed out, however, that neither Spreen and Gaddes (1969) nor Reitan (1971) analysed these trends statistically. Owing to missing data, this cannot be done for their studies in this paper.

Means and standard deviations for performance on Parts A and B across FSIQ categories for the present study, are presented in Table 5. The trend for improved performance with increasing FSIQ was apparent for both parts of the TMT, but seemed more pronounced for Part B, which is the more complex of the two tasks. It therefore seemed likely that Part B required higher levels of intelligence for successful completion. (These trends were statistically analysed and are presented in the following sub-section.)

Table 5Time Score in Seconds for TMT Performance by FSIQ

		<u>Trail A</u>		
FSIQ		N	Mean	Std.Dev.
Average:	90-111	60	12.08	2.89
Above Average:	112-119	56	11.10	3.05
Superior:	120-126	51	11.05	2.87
Gifted:	127+	55	9.97	3.05
<hr/>				
Overall		222	11.07	3.04
<hr/>				

		<u>Trail B</u>		
FSIQ		N	Mean	Std.Dev.
Average:	90-111	60	25.19	8.73
Above average:	112-119	56	25.43	9.29
Superior:	120-126	51	21.08	7.75
Gifted:	127+	55	19.28	6.36
<hr/>				
Overall:		222	22.84	8.51
<hr/>				

2.3.2 Further Statistical Analyses

Data were subjected to a multivariate 3-way analysis of variance (MANOVA) so that the interaction of age, FSIQ, and gender in terms of performance on the TMT could be examined. MANOVA was used for the analysis of data in order to avoid the increased probability of a Type I error with two separate 3-way analyses of variance (3-way ANOVA). MANOVA was therefore used in preference to a number of univariate tests.

As time was the basic unit used to measure performance on Parts A and B of the TMT, the distribution of scores was positively skewed. Consequently, performance on these variables did not meet the assumptions of normality of distribution, a prerequisite for conducting parametric tests. In order to meet these assumptions, raw time scores for performance were subjected to logarithmic transformation (Kirk, 1968). There was no significant three way interaction between age, FSIQ and gender (multivariate $F(24,362) = 1.05; p > .05$). Similarly, all possible two way interaction effects on the MANOVA yielded insignificant results (age by sex: multivariate $F(8,362) = 0.63; p > .05$; age by FSIQ multivariate $F(24,362) = 0.94; p > .05$; sex by FSIQ: multivariate $F(6,362) = 1.68; p > .05$). The MANOVA, however, yielded significant main effects for age and FSIQ, but not for gender (age: multivariate $F(8, 362) = 11.15; p < .001$; FSIQ: multivariate $F(6,362) = 5.64, p < .001$; gender: multivariate $F(2,181) = 1.22, p > .05$). Consequently, univariate analyses of variance for age and FSIQ main effects were examined for both dependent variables, i.e., Parts A and B of the TMT. These findings are presented in univariate ANOVA summary tables adapted from the MANOVA (See Table 6). Univariate analyses of variance yielded significant main effects for age and FSIQ at each of the dependent variables.

Table 6

Univariate ANOVA tables adapted from the MANOVA

TMT : Part A

Source	SS	DF	MS	F
Age	2.42	4	.607	10.62**
FSIQ	1.13	3	.377	6.60**
Sex	0.0858	1	.086	1.50
Age/FSIQ	0.705	12	.059	1.03
Age/Sex	0.102	4	.026	0.45
FSIQ/Sex	0.437	3	.145	1.55
Age/FSIQ/Sex	0.973	12	.081	1.42
Error	10.4	182	.057	

p < .05*

p < .001**

TMT : Part B

Source	SS	DF	MS	F
Age	7.098	4	1.774	20.42**
FSIQ	2.014	3	0.148	7.73**
Sex	0.148	1	0.671	1.70
Age/FSIQ	0.755	12	0.063	0.72
Age/Sex	0.206	4	0.052	0.60
FSIQ/Sex	0.419	3	0.139	1.61
Age/FSIQ/Sex	0.568	12	0.047	0.55
Error	15.81	182	0.087	

p < .05*

p < .001**

The main effects for age and FSIQ for all parts of the TMT needed further analysis, so that differences between the respective age groups and FSIQ groups could be tested for significance. This was done using the revised Tukey's (HSD) pairwise comparisons formula for unequal cell sizes (Games & Howell, 1976). Results of the Tukey's tests are presented in Table 7.

Table 7Tukey's Comparisons for TMT Performance Across Age

Part A

	10-10.11	11-11.11	12-12.11	13-13.11	14-14.11
10-10.11	-		**	*	**
11-11.11		-			**
12-12.11			-		*
13-13.11				-	**
14-14.11					-

Part B

	10-10.11	11-11.11	12-12.11	13-13.11	14-14.11
10-10.11	-	**	**	**	**
11-11.11		-			**
12-12.11			-		**
13-13.11				-	**
14-14.11					-

q crit = 3.98; df 5;85; q < .05*

q crit = 4.82; df 5;85; q < .01**

Tukey's Comparisons for TMT Performance Across FSIQ

Part A

		90-111	112-119	120-126	127+
Average	90-111	-			*
Above Average	112-119		-		
Superior	120-126			-	
Gifted	127+				-

Part B

		90-111	112-119	120-126	127+
Average	90-111	-		*	**
Above average	112-119		-	*	**
Superior	120-126			-	
Gifted	127+				-

q crit = 3.74; df 4,104; $q < .05^*$

q crit = 4.60; df 4,104; $q < .01^{**}$

The pairwise comparisons for Parts A and B across age yielded similar results, with the exception of the difference between the 10-10.11 and 11-11.11 age group, which was significant for Part B, but not for Part A. Tukey's comparisons yielded insignificant results throughout the middle age ranges (i.e., 11-11.11; 12-12.11; 13-13.11) on both Parts of the TMT. Each age range differed significantly from the oldest (14-14.11) group, on Parts A and B. The youngest group (10-10.11) differed significantly from all older age groups, with the exception at Part A, mentioned above. The general trend was for better performance on both Parts of the TMT with increasing age.

Tukey's comparisons for FSIQ showed the gifted and average FSIQ levels to differ significantly from each other for Part A ($q < .05$) and Part B

($q < .01$) of the TMT. All other Tukey's comparisons for Part A across FSIQ categories yielded insignificant results. For Part B, the average and above average FSIQ categories (i.e., 90-111 and 112-119) both differed significantly from the superior and gifted FSIQ groupings (i.e., 120-126 and 127+). It was therefore clear that FSIQ differences significantly affected performance on Parts A and B of the TMT, and that improved performance was associated with increasing FSIQ. The above findings showed performance on Part B to be more sensitive to FSIQ differences than Part A. This may be attributed to Part B being the more complex task which requires higher levels of intelligence for successful completion.

Simple correlations were performed between age, FSIQ and gender, and each DV respectively, in order to quantify the relative contribution of each IV, to variation in performance on each DV. The correlation matrix is presented in Table 8.

Table 8 : Correlation Matrix for all variables

Log B	.481***			
FSIQ	-.294***	-.304***		
Gender	.074	.090	.004	
Age	-.370***	-.467***	.008	-.027
	Log A	Log B	FSIQ	Gender

$p < .001$ ***

(Note: Log A and Log B are logarithmic transformations of Part A and Part B of the TMT)

From the above table, it is clear that age and FSIQ correlated significantly with Parts A and B of the TMT. Correlations between

gender and each respective DV yielded insignificant results, and for this reason, the association of gender to each DV was not quantified.

It is important to note that negative coefficients for age and FSIQ across each part of the TMT were yielded in the simple correlations. These reflect decreasing time scores, i.e., quicker/better performance, with increasing age and FSIQ. These findings obviously match those from the Tukey's pairwise comparisons conducted on the significant age and FSIQ main effects.

In the light of both age and FSIQ being significantly associated with TMT performance, it may seem surprising that the correlation between these IV's is insignificant. This finding is best explained by the fact that FSIQ scores are in themselves age corrected.

The contributions of age and FSIQ to variation in performance on Part A were 13.7% and 8.6% respectively (age: $R = .137$; FSIQ: $R = .086$). The contributions of age and FSIQ to variation in performance on Part B of the TMT were 21.8% and 9.2% respectively (age: $R = .218$; FSIQ: $R = .092$). These findings show that the contribution of age to variation in performance on Parts A and B of the TMT was greater than that of FSIQ. Results also show that both variables account for a greater amount of variation in performance on Part B than Part A of the TMT.

The variation in scores, on Parts A and B of the TMT due to age and FSIQ together, were quantified using multiple regression analyses.

The variation in scores on Part A accounted for by these IV's was 22.13% (RSQ = .2213). Thus, almost 79% of the variation in scores on Part B is accounted for by factors other than age and FSIQ. The variation in scores on Part B accounted for by the same IV's was 30.81% (RSQ = .3081). Thus almost 70% of the variation on Part B are due to factors other than age and FSIQ. It is clear that age and FSIQ have contributed substantially to variation in TMT performance, and the implications of these findings will be discussed in the following section.

2.4 DISCUSSION

Comparisons of the results between the present study, and the Reitan (1971) and Spreen and Gaddes (1969) studies showed striking differences. Values for descriptive statistics were considerably lower for the present study. Furthermore, comparative statistics showed mean performances in the present study to differ significantly from, and to be superior to, mean performances in the Spreen and Gaddes (1969) and Reitan (1971) studies. A number of factors are considered in an attempt to explain these differences.

Firstly, differences in sampling procedures in the three studies are likely to have contributed substantially to these discrepancies. The sample in the present study was stratified according to age range, gender, and FSIQ. Furthermore, stringent exclusion criteria were used for the selection of subjects in the present study, whereas subjects in the Reitan (1971) study may be construed as comprising a convenience sample, insofar as participation in the study was

voluntary, in response to postal canvassing. The exclusion criterion for participation in Reitan's (1971) study was that of known brain damage in prospective subjects. In the Spreen and Gaddes (1969) study, subjects were drawn from a number of different schools in the area where the study was conducted, and the sample was "considered as representative of a middle class Western Canadian school population" (p.170). In contrast, the sample in the present study cannot be seen as representing the general school population in the Western Cape, as nearly all participants came from a middle-upper to upper class socio-economic background, and were attending an elite private school.

It seems clear therefore that the nature of the samples tested in the studies were quite different. It is possible that superior performance on the TMT in the present sample is associated with higher socio-economic background, which may be linked with higher IQ levels and superior levels of education.

The considerably smaller standard deviations in the present study reflect that the present sample was far more homogeneous than the Reitan (1971) and Spreen and Gaddes' (1969) samples. It should also be noted that the considerably smaller ranges for TMT performance in the present study as opposed to Spreen and Gaddes (1969) study also reflect the greater homogeneity of the present sample. When considering extreme scores on TMT performance, the low minimum and maximum values reflect the superior performance of the present sample.

Further, stratification procedures for FSIQ were used in the present study, but neither Reitan (1971) nor Spreen and Gaddes (1969) stratified or described their samples with respect to FSIQ. It is noted that, with stratification procedures in this study, 162 of the 222 subjects had FSIQ's greater than 111. Furthermore, almost half the subjects in the present study had FSIQ's greater than 119. In the light of the differences in sampling procedures between the studies outlined above, it seems plausible that the general FSIQ level in this study was far higher than the FSIQ distribution in the Reitan (1971) and Spreen and Gaddes (1969) studies. This was partly reflected in the mean FSIQ for the present sample of 118 as compared with the mean FSIQ of 112 in Spreen and Gaddes' (1969) sample. The omission of some measure of dispersion of FSIQ scores (including that of the standard deviation), in the latter study, however, necessitates caution in drawing definitive conclusions from this comparison. It should be noted that the Reitan (1971) study provides no data relating to IQ.

In the light of strong statistical evidence for improved TMT performance with increasing FSIQ in the present study, it may be concluded that factors relating to IQ outlined above have, in part, contributed to the differences in TMT performance between this and the other studies. That is, low means on TMT performance in the present study seemed directly related to the high FSIQ levels of the present sample.

In addition, differences in TMT performance between studies may be attributed to methods of administration of the test. It has been pointed out that no standardised set of instructions for administration of the version of the TMT developed for children is documented in the literature. Whether such a manual exists is unknown. In view of this, it seems likely that certain aspects of the administration of the TMT differed between the studies. If this was the case, this may have partly accounted for the differences in TMT performances between these studies. The following examples illustrate how differences in the administration may affect performance on the TMT. Firstly the number of circles pointed to in conjunction with verbal instructions by the tester may differ between studies, if standardised instructions are not followed. The number of circles shown would obviously influence time taken to complete the task. Secondly, the experimenter's reaction time in pointing subjects to their mistakes, and the manner in which this is done (i.e., verbose vs. succinctly) will also affect the time taken to complete the test.

Implications of the results yielded by the statistical analyses in the present study need further discussion. It was clear that increasing age and FSIQ were associated with improved performance on Parts A and B of the TMT. It was also shown that a considerable portion of the variance of TMT performance was accounted for by these variables. Thus, it becomes clear that, while the TMT was primarily designed to measure cerebral functioning, it is also reflecting age and FSIQ. This is a weakness in the test, and brings into question the validity, and the usefulness of this test in neuropsychological or clinical

settings. Unless these variables are controlled for, the validity of the test is considerably undermined. This study, then, highlights the need for the development of age and IQ corrected norms, if the TMT is to be of diagnostic value in neuropsychological practice with children. In view of this, it is necessary for an IQ assessment to be completed before the TMT can be used as a diagnostic screening device. Consequently, this brings into question the efficacy of the TMT as a quick screening device for brain damage or cerebral involvement, in children. This does not, however, preclude the use of the test in a neuropsychological battery, or, as a qualitative tool, which provides information regarding brain-behaviour relationships in children.

Statistical analyses yielded insignificant findings for differences in TMT performance between males and females, which supports Reitan's (1971) results. In view of these findings, it seems likely that there are no gender differences in TMT performance, where older children (10-15 years) are concerned.

It is possible that other confounding variables have affected TMT performance in the present study. Although levels of anxiety were not quantified for subjects in the present study, clinical observations showed that visibly anxious children performed poorly on the TMT, and this seemed more pronounced on Part B. While studies with adults have claimed that anxiety is not associated with TMT performance (Parsons et al., 1964; Chavez et al., 1983), this issue has not been considered in children. In view of the above observations, it would

seem important that future research address the effect of anxiety on TMT performance in children.

It was clear that subjects who made a mistake while completing either part of the TMT became flustered when this was pointed out, and they generally showed poorer performance than other subjects on the TMT. This highlights a confounding effect in the present method of administration and scoring of the TMT. That is, administration procedures require the tester to point the testee to mistakes for immediate correction. This leads to anxiety, which may result in poorer performance on the TMT. It would seem necessary therefore, that current procedures of administration and scoring of the TMT be revised. Procedural changes, which would eliminate the effect of variables such as anxiety, should seriously be considered. A suggested revision may be to score the test on a time and accuracy basis, which would eliminate the need for the examiner to point out mistakes to the testee.

2.5 CONCLUSIONS

The present study was conducted to obtain data relating to TMT performance from a sample of normal children, aged 10 through 14 years 11 months. In spite of the wide use of neuropsychological assessment procedures, there is a scarcity of normative data relating to performance on these measures for the population groups on which they are used in South Africa. The present study was undertaken to address this issue with regard to the TMT. A further aim of the study was to investigate the association of age, FSIQ and gender variables with

respect to TMT performance in children. Age and FSIQ were significantly associated with TMT performance, and some implications of these findings have been discussed in the previous section of this paper.

In conclusion, it is necessary to consider the limitations, and further implications, of this study, as well as to provide suggestions for further research. Firstly, a number of points regarding the possible clinical use of the results yielded in the present study should be considered. The applicability of the data to the general population of children is doubtful in view of the nature of the sample tested in this study (see discussion). Should these results be used in clinical settings, the population group whom they represent must be kept in mind. It seems necessary that future research should investigate TMT performance in a more representative sample of normal, school going children in the Western Cape.

Before further research is conducted with the TMT in children, it is imperative that standardised methods of administration and scoring of the TMT for children be developed. It is possible that such procedures exist, but clarity as to whether this is the case or not, is needed. This will ensure a more stable basis for future comparisons between studies. It has also been pointed out that aspects of administration and scoring of the TMT detract from the validity of the test, and that further research should address this issue.

A second limitation detracting from the validity of these results concerns the IQ measure used in the present study. For practical reasons, it was not possible to assess subjects' IQ's on an individual basis. For this reason, FSIQ's were taken from the NSAGT, the group IQ test used in South African schools. The relative inaccuracy of group IQ tests as opposed to individual IQ assessments is well known. The use of the NSAGT also precludes investigation into the relationship of IQ subtests and TMT performance, which would have provided further insights into functions measured by the TMT. In addition, the NSAGT has a strong verbal loading, which precludes investigation of the relative association of TMT performance to performance IQ versus verbal IQ. What present findings did show, however, was that FSIQ must be taken into account when assessing TMT performance and it was suggested that this is best done in the form of IQ corrected norms.

The present study also provided strong evidence for improved performance on Parts A and B of the TMT with increasing age. This highlights the need for age to be taken into account when assessing TMT performance. In the present study, however, a close association between level of education and age exists with children in each age group having the same level of formal education i.e., for 10-10.11 years : 5 years formal education; for 11-11.11 years: 6 years formal education and so on). Thus the significant relationship of age with TMT performance in the present study may also reflect an association between education level and TMT performance.

It seems important therefore that the nature of the association of age and possibly education level with TMT performance be investigated. It is obvious that age in itself cannot affect TMT performance. The skills or abilities that develop with increasing age (e.g., fine motor co-ordination, cognitive development) are the factors which likely affect TMT performance. It is necessary that research attempt to isolate these factors. The same holds true for the possible association of educational level to TMT performance. One would need to establish what factors, if any, associated with higher levels of education, affect TMT performance; for example, factors such as cognitive development. These questions are of theoretical and practical interest, and should be addressed in further research.

In sum, much of the research reviewed in this paper has found the TMT to be a valuable tool in neuropsychological diagnosis. These findings apply to both adults (Gordon, 1972; Lezak, 1983; Reitan, 1955, 1958), and children (Davids et al., 1957; Reitan, 1971; Reitan & Herring, 1985). The present study, however, has highlighted a number of problematic issues regarding further clinical use of the TMT with children, viz., the effects of variables such as IQ and age, and methods of scoring and administration, on TMT performance. It is felt that these issues should be urgently addressed to ensure future efficacy of the TMT.

Hopefully, this paper will make a contribution to the growing body of neuropsychological research in South Africa, and serve to stimulate further research in this area.

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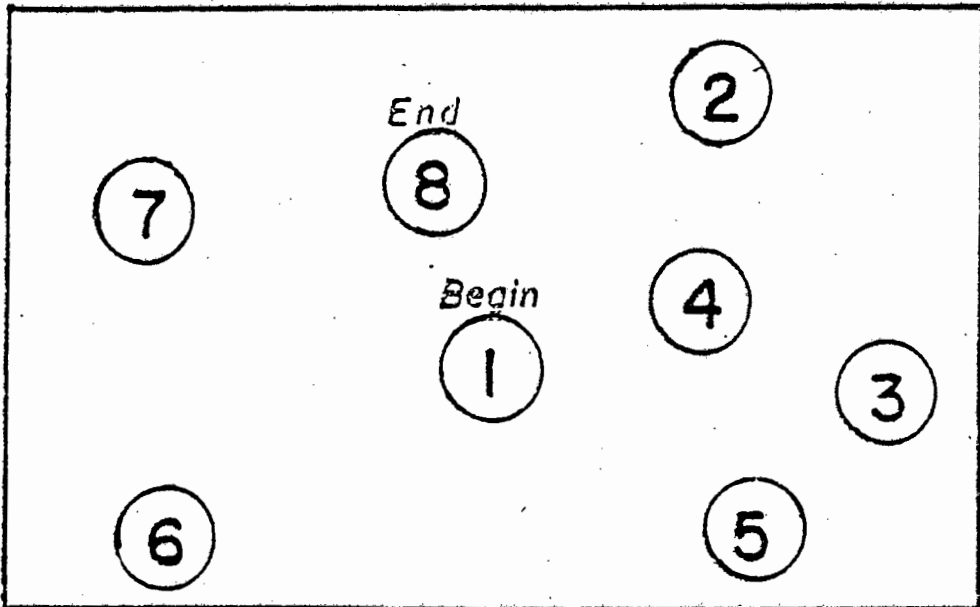
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TRAIL MAKING

Part A

SAMPLE



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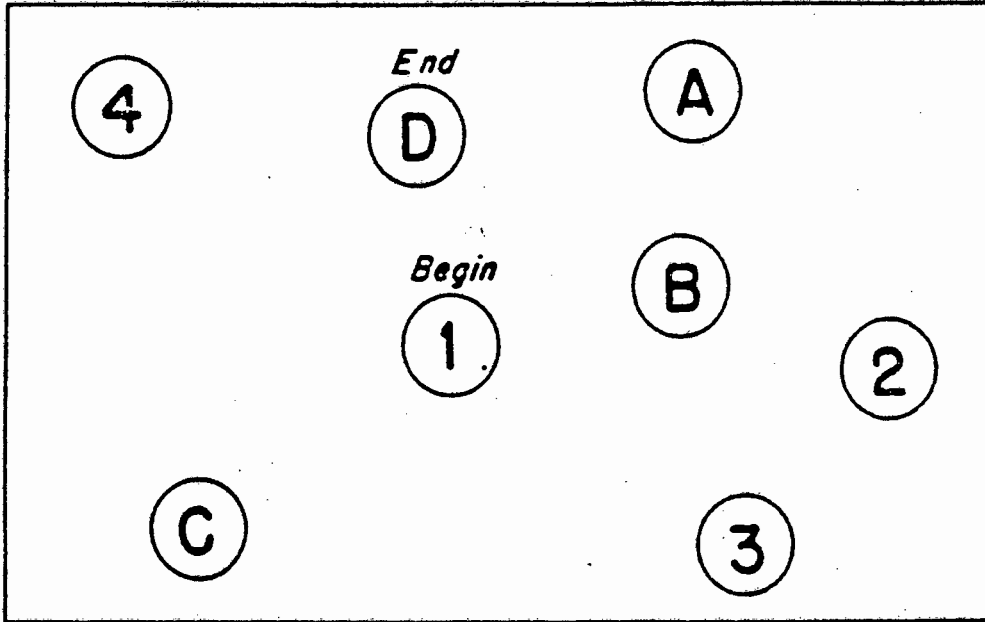
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Part B

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