Cognitive Flexibility in the Normal Elderly and in Persons with Dementia as Measured by the Written and Oral Trail Making Tests

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This study investigated cognitive flexibility as indexed by the Written and Oral Trail Making Test (TMT) in sixteen persons with dementia and 60 normal elderly. Written and Oral TMT performances were significantly correlated with each other and with other tests of cognitive flexibility providing an index of the convergent construct validity of these tests. Part B of the Written TMT was influenced by psychomotor ability although this was diminished by the use of a rule score B/A rather than simply Part B performance. The Oral test was not related to visual or motor skills, providing evidence for its divergent validity. Both pairs of the Written and Oral TMT were found to be sensitive to cognitive decline in dementia. Performance on both Oral and Written TMT was also influenced by age, gender, education and intellectual ability. Previous norms (e.g. ADANES) for the Written TMT which are based on relatively educated elderly, tended to provide deflated scores for the community group tested here. Some additional, preliminary normative data for both tests were compiled which take into account the influences of each of these variables.

The Trail Making Test (TMT, Army Individual Test Battery, 1944) is a test of speed for visual search, attention, mental flexibility and motor function (Spreen & Strauss, 1991; LoSasso, Rapport, and Assenbly, 1990). The TMT consists of two subtests, Part A and Part B. Both subtests require simple mental spatial skills (tracking) and basic sequencing abilities. It is assumed that Part B requires additional cognitive effort because the individual must mentally shift between two well-ordered sequences (numbers and letters). It has been suggested that when time to complete Part A is relatively much less than the time to complete Part B then the individual has difficulties in complex conceptual tracking (Lezak, 1995).

Dementia and TMT Performance

Clinicians have found that the TMT is an effective and for assessing progressive decline in dementia, even in the early stages of the disease (Gessell, Morgulis & Erber, 1985; Lezak, 1995; Razumson, Zander, Kawa & Ransnak, 1998). For example, Strohm, Bovwinick, Dunagin, Berg & Hughes (1984) found that a brief neuropsychological battery comprising of the Logical Memory and Mental Control subtests of Wechsler Memory Scale (WMS), Part A of the

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BRAIN IMAGING

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TMT and verbal fluency for letters S and P successfully discriminated persons suffering from mild senile dementia of the Alzheimer's type from healthy older persons. Timsley, Snow, Reid, Brettam, & Fisher (1987) replicated and extended these findings by showing that the above neuropsychological battery accurately distinguished severely impaired persons from both mildly senile dementia of the Alzheimer's type and other dementias.

Interpreting TMT Performance

When interpreting performance on the TMT, researchers have looked at the time taken to complete Part A and Part B, as well as the relationship between them. This has been defined as either a difference score (B-A) (Heaton, Nelson, Thompson, Burks & Fraktlin, 1983) or a ratio score (B/A) (Goldstein, Osmun, Monos & Berg, 1981). It has been agreed that both measures are sensitive to the greater cognitive demands that are assumed Part B makes (Corrigan & Hinkeldly, 1987; Lamberty, Pajunen, Chatil, Holmjas & Adan, 1984). However, since performance on both parts and especially Part B of the TMT is affected by age, intelligence, education, and possibly gender (Bennett & Raja, 1988; Corrigan & Hinkeldly, 1987; Davies, 1966; Emot, 1987; Gaulin, Gopher & Sperling, 1989; Kennedy, 1987; Lamberty, Pajum, Raisanen, Zonderman, Kavas & Remnitz, 1989; Stanton, Jefkkin, Savasina, Zyranski & Avolio, 1984; Busch-Skrin & Polak, 1983) the difference score (B-A) is less influenced by these variabilities. In contrast, the ratio of Part B to Part A (B/A) allows for greater control of such individual variability factors by effectively using the patient as his or her own control.

While the TMT has utility as a clinical measure for flexibility in the elderly it is confounded by "non-cognitive" performance factors such as primary visual and motor functioning (Kichur & Sato, 1989) which determine as part of normal biological ageing (Reisberg, 1991). Clinical interpretations of performance on the TMT is based on the assumption that Part B requires more complex cognitive processes than does Part A (Spencer & Strauss, 1991). However, this implies that the two Parts are equivalent in all respects (e.g. spatial arrangement of the circles) other than the addition of the more complex set-shifting component in Part B. Such a presupposition has been challenged by assertions that apparent A-B differences could be due to factors such as increased demands to maintain speed and visual search for Part B (Fossom, Holtmogen & Revarng, 1992; Gaulin et al., 1995; Woodrow, Meandora, Dickson, Blanchard & Christensen, 1995). Thus, the interpretation of differences in performance between Parts A and B remains controversial.

The Oral TMT

An oral paradigm of the TMT has been recently developed to provide a version that retains the sequential, multiple-component-tracking component of the task while eliminating the dependence on intact vision and motor functioning (Bicker & Axelson, 1994). This test shows similar changes across age groups to the written TMT in both normal (Bicker & Axelson, 1994) and mixed clinical populations (Johansson, Axelson, & Ricker, 1994). In addition, Ricker et al. (1994) found that the Oral TMT correlated significantly with other uses of executive functioning and was statistically unrelated to expressive language skills, thus providing some evidence for both convergent and divergent validity.

Normative Issues

The utility of clinical tests is critically reliant upon the adequacy of the normative base. The Oral TMT has no published norms. Whilst the Oral TMT is associated with the written TMT, this relationship is not exact and so the written TMT scores are inappropriate as a reference. Furthermore, the few published norms for the written TMT set themselves inadequate for non-US citizens. The norms of Davis (1968) have relatively large sample sizes but are quite old. More recent norms are based on either highly educated elderly (MODANS, north Macon, Atlanta, Long Lake, Peterson, 1996) or elderly from managerial and professional occupations (Rasmussen et al., 1994). Such samples are not representative of the general community particularly in countries such as Australia, in which educational levels are overall much lower for the contemporary elderly. This is of particular importance given the significant influence that education plays on TMT performance (Rasmussen & Gupta, 1988).

Overview and Aim of This Study

In sum, the Written and Oral TMT have obvious applications in the assessment of cognitive flexibility in elderly. There are, however, a number of issues which limit their current utility and which were addressed in this study.

Firstly, the extent to which differentially slow performance on Part B of the Written TMT represents purely cognitive factors is unclear. The development of the Oral TMT provides an oppor-

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Dicken. Thus, the performance overall.

tunity to examine the cognitive and "non-cogni-
tive" components that potentially influence per-
formance on the Wechsler version while simultane-
ously providing further construct valida-
tion of the Cuni test. While correlation cannot be
interpreted as causation, the relationships between
performances on the TMT (Written and Oral) and
related constructs (i.e. flexibility, abstracted space,
spatial function and visual search) should highlight
which processes may be considered potential con-
tributors to performance on the two tests. This was
one of the main aims of the current study.

Secondly, while it may be hypothesised that the
Oral TMT, like the written version, is sensi-
tive to dementia this has not been empirically
established. A further aim of this study was to
investigate the performance of subjects with
dementia on the Oral TMT compared to non-
demented subjects.

Thirdly, in order to examine the adequacy of
TMT scores when the MMNDS for non-U.S.
residents, the performance of a group of
Australian elderly from the general community
on the Written TMT was compared to the
MMNDS normative sample (Buck et al. 1996)
and was examined for the influences of age,
gender and education. Finally, a new set of
preliminary norms for less educated elderly on both
the Written and Oral versions of the TMT were
constructed reclassifying scores on Parts A and
B as well as the two types of difference scores
(PA-BO and A/B).

Method

Participants

The sample comprised of 76 elderly people living in
Slovenia with an average age between 55 and 89
years with a mean age of 77 years (see Table 2).

Dementia group. Sixteen participants (2 males
and 14 females) were individuals diagnosed with
dementia. Fifteen of the persons with dementia
were referred for a neuropsychological assess-
ment to a local Cydevor Hospital and assessed a positive
diagnosis of dementia based upon their neuropsy-
chological performance, medical and psychologi-
cal history and medical tests. One dementia
patient was identified as having dementia during
treatment at an inpatient clinic at Cydevor
Hospital. The dementia group included patients
who required the diagnosis of Alzheimer's Disease,
vascular dementia and dementia of a mixed type.
A diagnostically asked sample was chosen to reflect the
diversity of patients com-

ormally elderly group. A further 65 elderly people
were assessed for inclusion in the study. These
included elderly patients attending a Podbury
Outpatient Clinic and spouses of people with
dementia referred for neuropsychological assess-
ment. The Podbury Clinic was considered an
appropriate place for recruitment of participants
as large numbers of independently living elderly
people with varying levels of general health make
use of this facility. In addition, one 77-year-old
person included in the normed sample had initially
been referred for neuropsychological assessment
but performed at an average to above average
level on all tests of cognitive functioning includ-
ing the TMT tasks. Her MMNDS score was 20/20
and she was classified as no diagnosis of dementia.

In order to be included in the normal elderly
sample, participants fulfilled similar criteria to
those used in the MMNDS research (Buck et al.
1996) (i.e. they had to be aged 50 or over, living
independently in the community with no current
central nervous system or psychiatric conditions,
no complaint of cognitive difficulty during his-
tory taking and no suggestion of physical prob-
lems that may affect cognition). Chronic medical
illness was not an exclusion criterion unless it
was sufficiently severe to potentially affect cog-
nition. Their medical, neurological and psychi-
artic histories were elicited via a semi-structured
interview. Using these criteria 5 participants were
excluded because they were identified as having a
confounding condition (e.g. borderline premor-
bid intellectual ability, literacy, severe health
problems, severe depression, partial blindness
d and possible head injury).

The remaining 60 normal elderly participants
were subdivided into three groups (each n = 20)
according to their age (1) 55 to 74 years old; (2)
75 to 83 years old; and (3) over 84 years old. These
divisions were dictated by an initial attempt to replicate
MMNDS age groupings, but

Materials

All participants underwent the screening inter-
view and a battery of psychological tests
designed to provide (1) background information
(premorbid intelligence, current cognitive func-
tioning and levels of depressed mood) (2) general
cognitive abilities (working memory, verbal and
nonverbal learning) (3) cognitive flexibility (both
Thames and two independent measures) and
(4) alphabet knowledge, motor and visual func-
tions. The screening interview and tests battery
took approximately 45 to 60 minutes to complete.
The battery included:

The battery included:

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Results

Background Characteristics of the Group

Background characteristics of the sample are depict in Table 1. A series of t tests comparing all of the cognitive test with the dementia group failed to reveal any differences in age, t(70) = -1.10, or education, t(74) = 1.30. Nor were there any differences between the groups in terms of the proportion of males to females (x² = 0.95). There were two left-handed participants in the control group, but their performance did not differ significantly from others in their corresponding age groups. IQ estimates in both groups were higher than would normally be expected given the generally lower average level of education. This could reflect either the inaccessibility of the majority, or different schooling opportunities and policies in Australia during the last half of the twentieth century compared to contemporary practice.

There was no difference between groups in estimated IQ, t(74) = 1.43. While no subject was identified as depressed on a semi-structured interview, two of the dementia subjects and five of the normal elderly reported depressed mood (i.e. a score above 13) on the GDS. In the normal elderly, 4 of these scores were in the mild range (15-19). There was no difference between the groups in terms of overall GDS scores, t(74) = 1.23. As expected dementia sufferers performed significantly more poorly on the MMSE, t(74) = -4.03, p < .001.

Neuropsychological Characteristics

Performance on the remaining standard neuropsychological tests for the dementia group and for the normal elderly is shown in Table 2. Between-group differences were analyzed using one-way analysis of variance (ANOVA). The dementia group performed poorly on all measures of general cognitive status, the Mental Control, t(74) = 4.98, p < .001, Logical Memory I, F(1,74) = 86.66, p < .01, Logical Memory II, F(1,74) = 68.84, p < .01, Visual Reproduction I, F(1,74) = 23.82, p < .01, Visual Reproduction II, F(1,74) = 55.65, p < .01. The attenuated differences between dementia and control subjects remained significant when age, education, IQ and gender were entered as covariates. The people with dementia also performed significantly more poorly than the normal elderly on Digit Symbol, F(1,69) = 7.82, p < .01, and COWAT, F(1,73) = 5.44, p < .05, but their performance did not differ significantly from control subjects on alphabet recital, finger tapping, and visual search (p > .05).

Procedure

All participants were tested individually and were allowed to work at their own pace on all tasks. All neuropsychological tests were administered following standard instructions. The Oral Trail Making Test was administered as follows: Part A: The participant was told "I would like you to count from 1 to 25 as quickly as you can -- 1, 2, 3, and so on. Are you ready? Begin." Time taken to complete this task was recorded. Part B: The participant was told "Now I would like you to count again, but this time you are to switch between number and letter, so you would say 1-A-2-B-3-C and so on, until I say STOP. Are you ready? Begin." The participant was then stopped once he/she reached 13 and the time recorded.

Assessment began with the collection of demographic information and the GDS, followed by the MMSE, Logical Memory I, Visual Reproduction I, TMT (Oral or Written), Mental Control, NARE, TMT (alternative version), Digit Symbol, COWAT, Finger Tapping Test, Visual Search Task, Logical Memory II, Visual Reproduction II and the semi-structured interview. Although order effects were not found in previous studies (Abrahams et al., 1990), the order of administration of the Oral and Written TMT went counterbalanced across participants. Participants who were unable to complete Part B of the Oral or Written TMT within 5 minutes were stopped and redirected to the next task.
Table 1: Demographic Characteristics of the Normal and Dementia Groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Dementia (n = 16)</th>
<th>Controls (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Males</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Hendredw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>14</td>
<td>58</td>
</tr>
<tr>
<td>Left</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>74.25</td>
<td>77.6</td>
</tr>
<tr>
<td>SD</td>
<td>6.73</td>
<td>7.57</td>
</tr>
<tr>
<td>Range</td>
<td>55-83</td>
<td>59-89</td>
</tr>
<tr>
<td>Education (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>8.81</td>
<td>8.11</td>
</tr>
<tr>
<td>SD</td>
<td>3.20</td>
<td>1.82</td>
</tr>
<tr>
<td>Range</td>
<td>6-16</td>
<td>5-18</td>
</tr>
<tr>
<td>Estimated IQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>105.00</td>
<td>107.55</td>
</tr>
<tr>
<td>SD</td>
<td>7.72</td>
<td>6.48</td>
</tr>
<tr>
<td>Range</td>
<td>95-114</td>
<td>91-117</td>
</tr>
<tr>
<td>Depression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>7.75</td>
<td>6.12</td>
</tr>
<tr>
<td>SD</td>
<td>3.07</td>
<td>4.56</td>
</tr>
<tr>
<td>Range</td>
<td>0-20</td>
<td>0-22</td>
</tr>
<tr>
<td>Current cognitive function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>24.56**</td>
<td>28.20</td>
</tr>
<tr>
<td>SD</td>
<td>3.60</td>
<td>1.38</td>
</tr>
<tr>
<td>Range</td>
<td>17-50</td>
<td>25-30</td>
</tr>
</tbody>
</table>

Note: *p < .05; **p < .01 for comparisons of people with dementia to all controls.

Table 2: Neuropsychologist Test Performance by Normal Controls and Participates With Dementia

<table>
<thead>
<tr>
<th>Neuropsychologist</th>
<th>Test (n = 20)</th>
<th>Dementia (n = 16)</th>
<th>Controls (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Cognitive Function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mental Control</td>
<td>4.94** (1.24)</td>
<td>5.48 (0.75)</td>
<td></td>
</tr>
<tr>
<td>Logical Memory 1</td>
<td>10.12** (7.14)</td>
<td>12.03 (5.77)</td>
<td></td>
</tr>
<tr>
<td>Logical Memory 2</td>
<td>5.00** (5.99)</td>
<td>21.00 (6.94)</td>
<td></td>
</tr>
<tr>
<td>Visual Reproduction</td>
<td>18.75** (7.46)</td>
<td>28.80 (6.92)</td>
<td></td>
</tr>
<tr>
<td>Visual Reproduction 2</td>
<td>8.30** (8.30)</td>
<td>22.61 (9.11)</td>
<td></td>
</tr>
<tr>
<td>Cognitive Flexibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Symbol</td>
<td>25.67** (10.47)</td>
<td>33.84 (9.91)</td>
<td></td>
</tr>
<tr>
<td>COWAT</td>
<td>26.75* (12.42)</td>
<td>34.59 (11.75)</td>
<td></td>
</tr>
<tr>
<td>Basic language, Motor and Visual Functions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alphabet Recital</td>
<td>9.71 (3.73)</td>
<td>7.95 (4.35)</td>
<td></td>
</tr>
<tr>
<td>Finger Tapping</td>
<td>38.33 (9.16)</td>
<td>40.48 (6.89)</td>
<td></td>
</tr>
<tr>
<td>Visual Search</td>
<td>20.88 (10.16)</td>
<td>30.10 (7.77)</td>
<td></td>
</tr>
</tbody>
</table>

Note: *p < .05; **p < .01 for comparisons of people with dementia to all controls.

Oral TMT: Construct Analyses

Pearson product-moment correlations between the Oral and Written TMTs and Digit Symbol, COWAT, the ability to say the alphabet, finger tapping and visual search are detailed in Table 3. Both parts of the Oral TMT as well as the derived part scores (B-A and B/A) were moderately correlated with other tests of cognitive flexibility (both parts of the Written TMT, Digit Symbol and COWAT). These results support the convergent validity of the Oral TMT as a measure of cognitive flexibility. The Oral TMT was also moderately correlated with the efficiency of alphabet recital. Unexpectedly, Part A was moderately correlated with both visual search and finger tapping. However, the other indices (Part B, B-A, B/A) were not correlated, thus supporting the independ-
MOANS Normative Data

Normal elderly participants' raw scores were converted to MOANS standard scores and percentile ranks. The mean standard scores for the normal elderly in this study were 7.7 on Part A and 8.3 on Part B compared to the expected mean of 10 developed using MOANS populations. To ensure that sub-clinical depression (as indicated by low mood on the GDS) was not a confound factor in the low mean scores of the normal elderly relative to the MOANS sample, the means were also calculated for the normal group excluding the five subjects with depressed mood scores. These means were essentially identical, i.e., 8.0 on Part A and 8.3 on Part B. The number of participants in each MOANS percentile rank is graphically represented in Figure 1. Visual inspection of Figure 1 indicates that the mid-points for both Part A and Part B fall between the 15th and 25th percentile. The mean scaled scores of the two populations were compared using one-sample t-tests. These analyses confirmed that the MOANS sample and the sample employed in the present study have different means (p < .05) on Part A; i.e., 48 on Part A, 48 on Part B, and 44 on Part C, which are not different, of the Written TMT. The variances of the two samples were not statistically different.

Influence of Age, Education, IQ and Gender

In order to examine differences on the different versions of the TMT according to age, education, IQ and gender, participants were subdivided into groups based on these characteristics and this is depicted in Table 3. In order to empirically determine the relationship between these variables and

### Table 3

<table>
<thead>
<tr>
<th>Tests</th>
<th>Oral TMT</th>
<th>Written TMT</th>
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<tbody>
<tr>
<td></td>
<td>Part A B/A</td>
<td>Part A B/A</td>
</tr>
<tr>
<td>Written TMT - A</td>
<td>.42** .49**</td>
<td>.47** .53**</td>
</tr>
<tr>
<td>Written TMT - B</td>
<td>.35** .41**</td>
<td>.58** .57**</td>
</tr>
<tr>
<td>Written TMT - I/A</td>
<td>.51** .56**</td>
<td>.52** .53**</td>
</tr>
<tr>
<td>Olog Symbol</td>
<td>.54** .51**</td>
<td>.49** .54**</td>
</tr>
<tr>
<td>Efficiency of alphabet</td>
<td>.41** .48**</td>
<td>.56** .58**</td>
</tr>
<tr>
<td>Finger Tapping</td>
<td>.42** .43**</td>
<td>.38** .44**</td>
</tr>
<tr>
<td>Visual Search</td>
<td>.17** .09**</td>
<td>.56** .56**</td>
</tr>
</tbody>
</table>

Note. * p < .05  ** p < .01.

<table>
<thead>
<tr>
<th>TABLE 4</th>
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<tbody>
<tr>
<td><strong>Means and Standard Deviations for Oral and Written TMT Performance (sec.) for Each Subject Group</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>All Controls</th>
<th>25-64 years</th>
<th>12-19 years</th>
<th>20-25 years</th>
<th>25-30 years</th>
<th>30-35 years</th>
<th>35-40 years</th>
<th>40-45 years</th>
<th>45-50 years</th>
<th>50-55 years</th>
<th>55-60 years</th>
<th>60-65 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral/psychological Test</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
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<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Written TMT – Part A</td>
<td>87.52 (29.57)</td>
<td>58.77 (20.72)</td>
<td>41.19 (18.75)</td>
<td>60.22 (30.95)</td>
<td>67.86 (18.43)</td>
<td></td>
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<tr>
<td>Written TMT – Part B</td>
<td>56.48 (27.21)</td>
<td>31.99 (17.43)</td>
<td>16.61 (6.47)</td>
<td>27.33 (10.83)</td>
<td>31.16 (14.72)</td>
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<tr>
<td>Written TMT difference score</td>
<td>179.14 (71.57)</td>
<td>54.66 (25.49)</td>
<td>51.44 (28.06)</td>
<td>51.44 (28.06)</td>
<td>51.44 (28.06)</td>
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<tr>
<td>Written TMT ratio score</td>
<td>3.65 (1.45)</td>
<td>2.11 (0.83)</td>
<td>2.11 (0.83)</td>
<td>2.11 (0.83)</td>
<td>2.11 (0.83)</td>
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<tr>
<td>Oral TMT – Part A</td>
<td>11.08 (2.22)</td>
<td>7.53 (2.53)</td>
<td>6.93 (2.53)</td>
<td>6.93 (2.53)</td>
<td>6.93 (2.53)</td>
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<tr>
<td>Oral TMT – Part B</td>
<td>144.78 (128.49)</td>
<td>114.28 (114.28)</td>
<td>94.63 (54.63)</td>
<td>94.63 (54.63)</td>
<td>94.63 (54.63)</td>
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<tr>
<td>Oral TMT difference score</td>
<td>132.71 (111.18)</td>
<td>42.23 (23.94)</td>
<td>39.98 (25.38)</td>
<td>39.98 (25.38)</td>
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<td>Oral TMT ratio score</td>
<td>13.41 (9.57)</td>
<td>6.30 (3.80)</td>
<td>5.66 (3.04)</td>
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Note. *p < .05; **p < .01

**Figure 3**
Number of control subjects in MONANS percentile nora.

TMT performance, correlations were performed and the results of these are summarized in Table 6. As seen in Table 6, age was moderately correlated with all indices of the TMT except Part A and B of the Oral TMT. This relationship remained unchanged when statistically controlling for education, estimated IQ and gender. Inspection of Table 4 reveals that TMT performance was slower for the oldest group relative to the younger two groups. The obtained results are consistent with previous research indicating that the total time to complete the TMT (especially Part B) is significantly longer for the oldest participants than for the younger ones. Fisher’s transformations revealed that both parts of the Written TMT were significantly more strongly correlated with age compared to both parts of the Oral TMT, r(57) = -0.89, for Part A and r(57) = -0.52 for Part B. This suggests findings that as people get older their psychomotor speed deteriorates and so their performance on the Written TMT is further affected. However, the IVA results suggest that the written TMT may be more age-sensitive than the Oral TMT, independent of sex differences.

The control group was divided into those who had completed the minimum amount of secondary schooling (9 years of education or more) and those who had not. As seen in Table 5, Level of formal education was moderately correlated with all indices of the TMT except Part A of both Oral and Written TMT. In Table 5 it is apparent that individuals with less than 9 years of formal education performed slower on Part B of the Oral and Written TMT than individuals with 9 or more years of formal education. This confirms the earlier comparison with MONANS norms. Less educated individuals are slower than their more educated counterparts especially on Part B of TMT.

Consistent with previous research, estimated pre-morbid IQ was associated with performance on TMT. All indices except Part A of the Oral TMT showed a moderate correlation. As can be seen in Table 5, subjects with an estimated Average IQ performed slower on Part B of the Oral and Written TMT than subjects with estimated High Average or Superior IQ.

Gender was also correlated with TMT performance. Specifically, as can be seen in Table 5, male subjects performed better than female subjects on Part A of the Oral TMT and Part B of the Written TMT.


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<tr>
<td>Education, ( M = 15.1, SD = 3.5 )</td>
<td>4.1 (2.97)</td>
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<td>4.1 (2.97)</td>
<td>3.0 (2.56)</td>
<td>2.9 (2.46)</td>
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<td>Per mewn ym ( r = .23 )</td>
<td>6.3 (2.95)</td>
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<td>5.4 (3.20)</td>
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<td>Estimated IQ ( M = 79, r = .24 )</td>
<td>7.6 (3.25)</td>
<td>7.1 (3.34)</td>
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<td>Gender ( M = 30 )</td>
<td>6.6 (2.95)</td>
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<tr>
<td>Adjusted ( M = 23 )</td>
<td>6.6 (2.95)</td>
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<td>( N = 30 )</td>
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**Table 3.**

**Discussion**

The present study compared the performance of a group of people with dementia with a group of normal elderly on two versions of the Trail Making Test. The dementia group had received a formal diagnosis of dementia on the basis of neuropsychological, neurological and medical grounds. In contrast, the normal elderly were screened for any identifiable psychiatric or neurological conditions, obvious signs of cognitive decline and for general health. The absence of dementia within this group was supported by the finding that all participants scored above the standard cut-off of 24 on the MMSE. However, it should be noted that two of the normal elderly had scores of 25 and six had scores of 26. Reference to the most useful cut-off score for screening...
The study of the Trail Making Test (TMT) as a measure of cognitive flexibility has been extensively researched. The TMT is designed to assess not only cognitive flexibility but also psychomotor ability. The TMT was not influenced by variability in visuo-spatial skills. The use of different score tables, especially the IVA ratio, appeared to eliminate this psychomotor component and may therefore be the most useful written TMT scores for assessing cognitive flexibility per se. Part B and the difference scores of the Oral TMT were not related to visual or motor function and can be considered a useful alternative test of cognitive flexibility, especially for people for whom visual motor deficits represent significant confounding influences.

The finding that correlations between related and unrelated conditions were generally in the expected directions was encouraging. Correlations between neuropsychological measures were generally robust. The specific Fischer Z transformation tests designed to analyze the magnitude of differences between correlation coefficients confirmed that measures of convergent validity were generally more highly correlated than measures of divergent validity. This does not preclude the possibility that specific correlations due to other, irrelevant sources of variance. The construct validity of both forms of TMT would be further strengthened if these results were replicated using other measures of both theoretically related and unrelated constructs.

Both forms of TMT were sensitive to cognitive decline in a sample of elderly. It should also be noted that there was no difference in the pattern of dementia versus control group results for the various Part A, Part B, B-A, B-A/IVA indices of the Oral and Written TMT.

The present results also demonstrate that MOANS assessive data for the Written TMT are inappropriate for individuals with lower levels of education. In the MOANS sample (Global et al., 1996) most participants had completed 13 to 15 years of formal education, whereas in the present cohort the average education was 8 years. There are no education-level breakdowns in the MOANS report. Furthermore, this lower level of education is typical of contemporary elderly people in many communities. Written TMT performance of the present sample was not significantly different when compared to the MOANS sample. Consequently, when using MOANS normative data with this less educated cohort, the majority of individuals would be allocated to lower percentile ranks and possibly described as having cognitive impairment.
having poor problem-solving skills without taking into account this education factor. There is a clear need for TMT norms that are stratified by age, education level, IQ and gender.

In line with previous research (Abraham et al., 1996; Bornstein & Sega, 1988; Kenney, 1981; Statman et al., 1994), the present study refines the adverse impact of age on both Oral and Written TMT performance, in particular, Part B. The influence of education and intelligence was also confirmed. Individuals with fewer years of formal education performed significantly slower on both Oral and Written TMT than those more educated counterparts. Similarly, those with higher intellectual ability (estimated IQ) performed faster on the Oral and Written TMT than those with lower intellectual ability.

The results revealed that gender influences Oral and Written TMT performance. Males performed significantly better than females on both Part A of the Oral TMT and Part B of the Written TMT. Although the two groups did not significantly differ in their performance on the other parts of TMTs, there was a trend towards males being faster. This is contrary to previous studies reporting a female advantage on Oral TMT performance (e.g. Girolamo et al., 1995). Research with larger numbers of males is needed to investigate further the reliability of gender differences in Oral and Written TMT performance.

The present study demonstrated that age, gender, education and intellectual ability must be considered when interpreting both Oral and Written TMT performance. This study enhances the normative database for both tests by providing some additional data on performance of normal elderly, taking into account the above characteristics. Further studies with larger numbers of subjects are needed to establish extensive normative data for these two tests of cognitive flexibility. Moreover, the present study employed a diagnostically mixed sample of people with dementia. Future research could determine whether there are differences in Oral TMT performance amongst groups of people with differing types of dementia.

References