# The Differential Contribution of Mental Tracking, Cognitive Flexibility, Visual Search, and Motor Speed to Performance on Parts A and B of the Trail Making Test

Simon F. Crowe
*La Trobe University*

Ninety-eight undergraduate students were subjected to the TMT as well as a series of derived measures from the TMT with a view to ascertaining the nature of the contribution of each to the performance. Performance on the TMT(A) was uniquely contributed to by visual search and motor speed measures, whereas the performance on TMT(B) was uniquely contributed to by the visual search and cognitive alternation measures. After controlling for the effects of TMT(A) on TMT(B), further variance in the score on TMT(B) was contributed to, in order of effect, by lowered reading level, poor skill in visual search, poor ability to mentally maintain two simultaneous sequences, as well as decrease in attention and working memory functions. The analysis indicates that, in a nonclinical sample, the TMT measures a number of different functions and the observation of impaired performance must be further investigated to ascertain the specific nature of these deficits in order to guide rehabilitation and management planning. © 1998 John Wiley & Sons, Inc. J Clin Psychol 54: 585–591, 1998.

The Trail Making Test (TMT) was originally developed as part of the Army Individual Test Battery (1944) and is one of the most commonly used tests in neuropsychological practice due to its high sensitivity in diagnosing brain impairment (Armitage, 1946; Lewinsohn, 1973; Reitan, 1958; Spreen & Benton, 1965). The task requires the subject to perform a tracking task under

I would like to thank Ben Bullock, Deanne Coles, Sally Morgan, Geraldine Nolan, and Allison Summergreene for helping to collect and analyze the data and Dr. Ben Ong for statistical advice.
Correspondence concerning this article should be addressed to Dr. Simon F. Crowe, School of Psychology, La Trobe University, Bundoora, Australia, 3083.



CCC 0021-9762/98/050585-07

two conditions. In the first part of the test (Trail A), the subject must trace a trail through a series of circles numbered from 1–25 variously spread over an A4 page. In the second part of the test (Trail B) the subject must perform an alternation between circles containing numbers and letters. The sequence proceeds from the first number to the first letter alphabetically followed by the second number and the second letter. TMT(B) contains 13 circles numbered 1–13, alternating with 12 circles lettered A–L. Performance is assessed by the time taken to complete each trial correctly (Reitan, n.d.).

Although the task is an excellent index of the presence of brain impairment, poor performance on the task is a relatively nonspecific finding because it does not indicate why the brain-impaired individual is performing poorly. Poor performance may be attributable to motor slowing, poor coordination, visual scanning difficulties, poor motivation, or conceptual confusion (Lezak, 1995) to name a few.

Clinical interpretation of the differential performance on Part A versus Part B is generally considered to reflect more complex cognitive processes in Part B (Guadino, Geisler, & Squires, 1995). A number of studies have investigated the relative nonequivalence of Parts A and B of the test, which has led some researchers to maintain that the two components are nonequivalent (Rossini & Karl, 1994).

Slowed performance on Part B compared to Part A is sometimes thought to be indicative of executive dysfunction (Pontius & Yudowitz, 1980). More specifically, it is thought to indicate impaired ability to modify a plan of action or to maintain two trains of thought simultaneously (Lezak, 1995; Reitan, 1971).

In versions of the tests that allowed the investigators to differentiate the contribution of spatial and symbolic factors to test performance, Fossum, Holmberg, and Reinvang (1992) noted that the relative difficulty of forms A and B may be due to differences in symbolic complexity and spatial arrangement and to the interaction between these two factors, a finding supported by Guadino et al. (1995).

Factor analytic studies of the test indicate that performance on Part B of the test loads on an attention factor (O'Donnell, MacGregor, Dabrowski, Oestreicher, & Romero, 1994). Moreover, performance on both parts of the test load on a visual perceptual factor (Groff & Hubble, 1981).

Studies on the TMT's ability to determine side of lesion consistently indicate that it cannot do so (Heillbronner, Henry, Buck, & Adams, 1991; Wedding, 1979).

Task performance seems to be affected by intelligence level only for those individuals at the lower end of the spectrum. Individuals of average or higher intelligence demonstrate performance levels independent of intellectual ability (Waldmann, Dickson, Monahan, & Kazelskis, 1992); however older individuals perform more poorly on the task than do younger ones (Davies, 1968; Kennedy, 1981).

In summary, previous research has indicated that the Trail Making Test is a useful measure of visual tracking, mental flexibility, and attention functions. To date however, the specific contribution of these factors, as well as their differential contribution to the two parts of the TMT, has not been comprehensively explored. This study aimed to determine the differential contribution of a number of factors previously considered to be assessed by the TMT and to account for the differences between the performance of Parts A and B of the test.

## METHOD

### *Participants*

The sample consisted of 98 undergraduate students from La Trobe University in Melbourne, Australia and their families or acquaintances (49 men and 49 women). Participants were screened for previous loss of consciousness or other neuropathology. Only two participants reported loss of consciousness of longer than 30 minutes. On inspection, the data of these participants was not considered to be discrepant from that of the rest of the sample and these participants were included in the final analysis (See Table 1 for details regarding the demographic features of the sample).

### *Procedure*

The participants performed the TMT, as well as a series of derived measures from the TMT, with a view toward ascertaining the nature of the contribution of each to the performance.

The measures included: (a) a standard score for reading as determined by the Wide Range Achievement Test-Version 3 (WRAT–3; Wilkinson, 1993); (b) digit, letter, and block span forward and reversed (letter span was determined by the use of a similar format to digit or block spans with the substitution of letters as stimuli and performance was scored in the same manner as the former tasks) as assessed by the Wechsler Memory Scale-Revised (Wechsler, 1987); (c) a modified version of the TMT(A) and (B) that assessed the time for completing the motor sequence of connecting the circles in each case by eliminating the numbers and letters and connecting the circles together with a dotted line and requiring the subject to trace the dotted line; (d) assessment of the time required to say the alphabet, count to 26, and recite the sequence alternating between numbers and letters up to 26 (i.e., 1, a, 2, b, 3, c etc.). For the final variable of alternation, the time taken to recite the letter and number sequences was deducted from the time taken to perform the alternation; and (e) a further modified form of the TMT that eliminated the alternation of numbers and letters on the TMT(A and B) by presenting the same sequence of circles but running from 1–13 and from A–L, with a view toward operationalizing the visual search without the alternation in each case.

## RESULTS

The means and standard deviations for each measure are presented in Table 1. It is interesting to note that as previously observed by Guadino et al. (1995), the time taken to complete the longer trail [TMT(B)] may add three seconds to the performance of the task.

**Table 1.** *Demographics and Scores of the Subjects in the Respective Domains*

| Factor | Variable | *M* | *SD* | MIN | MAX |
|---|---|---|---|---|---|
| Outcome variables | TMT(A) | 24.7 | 5.9 | 13 | 47 |
| | TMT(B) | 50.3 | 11.8 | 26 | 80 |
| Premorbid factors | AGE | 23.4 | 3.1 | 18 | 28 |
| | EDUCATION | 14.0 | 2.3 | 10 | 19 |
| | WRAT READING | 101.0 | 9.0 | 64 | 118 |
| Motor | MOTOR (A) | 12.1 | 2.9 | 7 | 20 |
| | MOTOR (B) | 15.3 | 3.2 | 9 | 24 |
| Search | SEARCH (A) | 21.9 | 5.7 | 13 | 38 |
| | SEARCH (B) | 29.0 | 7.2 | 16 | 52 |
| Switching | ALTERNATION | 54.6 | 18.3 | 26 | 80 |
| | DIGITS (Forward) | 9.1 | 2.0 | 5 | 12 |
| | DIGITS (Backward) | 7.2 | 2.0 | 3 | 11 |
| Attention and concentration | BLOCKS (Forward) | 8.7 | 1.7 | 5 | 12 |
| | BLOCKS (Backward) | 8.5 | 2.0 | 3 | 11 |
| | LETTERS (Forward) | 6.7 | 1.5 | 3 | 11 |
| | LETTERS (Backward) | 6.5 | 2.0 | 3 | 11 |

**Table 2.** *Correlations of the Variables of Interest with Each Other*

| Variable | TMT(A) | TMT(B) |
|---|---|---|
| WRAT READING | −.07 | −.42** |
| MOTOR | .27** | .31*** |
| SEARCH | .57*** | .51*** |
| ALTERNATION | .20* | .53*** |
| DIGITS (Forward) | −.03 | −.23** |
| DIGITS (Backward) | −.08 | −.21* |
| BLOCKS (Forward) | −.02 | −.08 |
| BLOCKS (Backward) | −.39*** | −.25** |
| LETTERS (Forward) | −.03 | −.23** |
| LETTERS (Backward) | −.11 | −.31*** |

*Note.*—Correlation of TMT(A) with TMT(B) = .42***
(*$\alpha$ < .05; **$\alpha$ < .01, ***$\alpha$ < .001)

The contribution of each of these measures to the performance of the TMT(A) and (B) were then subjected to a series of multiple regressions (Tabachnick & Fidell, 1996). The results for the correlations between each of the variables are presented in Table 2.

A standard multiple regression was applied to the time taken to perform the TMT(A) using WRAT Standard Reading Score, time required to complete the motor sequence for Trail A, time required to complete the search for targets, time to alternate between number and letters, and digit letter and block span forward and backwards (See Table 3).

Table 3 displays the standardized regression coefficients (B), the standardized regression coefficients ($\beta$), the semipartial correlations (Sri$^2$), $R^2$ and the adjusted $R^2$. The $R$ for the regression was significantly different from zero, $F(10,87) = 5.89$, $p < .0005$. Only two of the independent variables contributed significantly to performance prediction on TMT(A); these were search Sri$^2$ = .138 and motor speed Sri$^2$ = .039. Altogether, 40% (34% adjusted) of the variance in performance of TMT(A) could be predicted by knowing the scores on the variables of interest.

**Table 3.** *Standard Multiple Regression of Reading, Attention, Motor, Search, and Alternation on TMT(A) Performance*

| Variables | B | $\beta$ | Sr$^2$ (unique) |
|---|---|---|---|
| WRAT | .14 | .21 | .023 |
| MOTOR (A) | .43 | .21 | .039* |
| SEARCH (A) | .52 | .51 | .138*** |
| ALTERNATION | .05 | .16 | .014 |
| DIGITS (Forward) | .13 | .05 | .001 |
| DIGITS (Backward) | −.52 | −.18 | .016 |
| BLOCKS (Forward) | .29 | .08 | .005 |
| BLOCKS (Backward) | .40 | −.11 | .006 |
| LETTERS (Forward) | −.12 | −.03 | .001 |
| LETTERS (Backward) | .23 | .08 | .003 |

*Note.*—Explained variance, .246; joint variance, .160; Unexplained variance, .596.
Adjusted $R^2$ = .40; $R^2$ = .34; $R$ = .68***.
*$\alpha$ < .05; **$\alpha$ < .01, ***$\alpha$ < .001.

**Table 4.** *Standard Multiple Regression of Reading, Attention, Motor, Search, and Alternation on TMT(B) Performance*

| Variables | B | $\beta$ | $Sr^2$ (unique) |
|---|---|---|---|
| WRAT VIQ | −.27 | −.21 | .023 |
| MOTOR (B) | .44 | .12 | .009 |
| SEARCH (B) | .52 | .31 | .058** |
| ALTERNATION | .21 | .33 | .053** |
| DIGITS (Forward) | .17 | .12 | .014 |
| DIGITS (Backward) | .10 | .02 | .001 |
| BLOCKS (Forward) | −.14 | −.02 | .001 |
| BLOCKS (Backward) | −.73 | −.11 | .007 |
| LETTERS (Forward) | .41 | .05 | .001 |
| LETTERS (Backward) | −.42 | −.07 | .002 |

*Note.*—Explained variance, .169; joint variance, .294; unexplained variance, .463. Adjusted $R^2 = .46$; $R^2 = .40$; $R = .68$***.
*$\alpha < .05$; **$\alpha < .01$, ***$\alpha < .001$.

A standard multiple regression was applied to the time taken to perform the TMT(B) using the same scores as previously assessed, with the exception that time required to complete the motor sequence was completed for Trail B and the time required to complete the search for targets was completed using the B trail. (See Table 4).

The $R$ for the regression was significantly different from zero, $F(10,87) = 7.50$, $p < .0005$. Only two of the independent variables contributed significantly to performance prediction on TMT(B); these were search $Sri^2 = .058$, and alternation $Sri^2 = .053$. Altogether, 46% (40% adjusted) of the variance in performance of TMT(B) could be predicted by knowing the scores on the variables of interest.

One of the aims of this study was to assess the added contribution of these components to the performance of TMT(B) as distinct from TMT(A). To achieve this end, a hierarchical regression was undertaken adding TMT(A) to the equation as the first step. Table 5 displays the

**Table 5.** *Hierarchical Multiple Regression Reading, Attention, Motor, Search, and Alternation on TMT(B) Performance*

| Variables in order of entry | B | $\beta$ | $Sr^2$ (incremental) |
|---|---|---|---|
| 1) TMT(A) | .85 | .42 | .179*** |
| 2) WRAT VIQ | −.52 | −.39 | .154*** |
| 3) MOTOR (B) | .39 | .11 | |
| SEARCH (B) | .46 | .28 | .098*** |
| 4) DIGITS (Forward) | .62 | .10 | |
| DIGITS (Backward) | .17 | .03 | |
| BLOCKS (Forward) | −.34 | −.05 | |
| BLOCKS (Backward) | −.22 | −.03 | |
| LETTERS (Forward) | .02 | .00 | |
| LETTERS (Backward) | −.55 | −.09 | .016** |
| 5) ALTERNATION | .20 | .32 | .048** |

*Note.*—Explained variance, .496; unexplained variance, .504. Adjusted $R^2 = .496$; $R^2 = .432$; R = .70***.
*$\alpha < .05$; **$\alpha < .01$, ***$\alpha < .001$.

results of the regression. $R$ was significantly different from zero at the end of each step. After step 5, with all of the predictors added to the equation, $R = .70$, $F(11,86) = 7.70$, $p < .0005$. After the TMT(A), WRAT–3 reading score, motor and search scores, and measures of attention span had been added, an additional $Sri^2 = .048$ unique variance to the $R^2$ was added by the alternation task.

## DISCUSSION

The results of this series of linear regressions reveals that in nonclinical individuals, TMT(A) uniquely measures visual search and motor speed, whereas TMT(B) measures visual search and cognitive alternation of operations.

After controlling for the influence of the factors measured by TMT(A) on the performance of TMT(B), poor performance on TMT(B) may be contributed to, in order of effect, by lowered verbal IQ, poor skill in visual search, poor ability to mentally maintain two simultaneous sequences, as well as decreases in attention and working memory functions.

The results of this study underline the fact that the TMT is a complex task that loads on a number of cognitive skills, including visual search, motor speed, reading level, ability to alternate a number and a letter sequence, and attention, as well as a large chunk of further unexplained variance.

The finding of poor performance on this task, although clearly indicating pathology, is, however, relatively nonspecific in terms of the causes of this poor performance. Diagnostic or rehabilitation strategies must call on more concise instrumentation to determine needs-based rehabilitation strategies.

## REFERENCES

Armitage, S.G. (1946). An analysis of certain psychological tests used for the evaluation of brain injury. *Psychological Monographs, 60* (Whole Number 277).

Army Individual Test Battery. (1944). *Manual of directions and scoring*. Washington, D.C.: War Department, Adjutant General's Office.

Davies, A. (1968). The influence of age on Trail Making Test performance. *Journal of Clinical Psychology, 24*, 96–98.

Fossum, B., Holmberg, H., & Reinvang, I. (1992). Spatial and symbolic factors in performance on the Trail Making Test. *Neuropsychology, 6*, 71–75.

Groff, M.G., & Hubble, L.M. (1981). A factor analytic investigation of the Trail Making Test. *Clinical Neuropsychology, 3,* 11–13.

Guadino, E.A. Geisler, M.W., & Squires, N.K. (1995). Construct validity of the Trail Making Test: What makes Part B harder? *Journal of Clinical and Experimental Neuropsychology, 17*, 529–535.

Heilbronner, R.L., Henry, G.K., Buck, P., & Adams, R.L. (1991). Lateralised brain damage and performance on Trail Making A and B, digit span forward and backward, and Tactual Performance Test memory and location. *Archives of Clinical Neuropsychology, 6,* 251–258.

Kennedy, K.J. (1981). Age effects on Trail Making Test performance. *Perceptual and Motor Skills, 52,* 671–675.

Lewinsohn, P.M. (1973). *Psychological assessment of patients with brain injury*. Unpublished manuscript, University of Oregon, Eugene.

Lezak, M.D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford.

O'Donnell, J.P., MacGregor, L.A., Dabrowski, J.J., Oestreicher, J.M., & Romero, J.J. (1994). Construct validity of neuropsychological tests of conceptual and attentional abilities. *Journal of Clinical Psychology, 50,* 596–600.

Pontius, A.A., & Yudowitz, L.B. (1980). Frontal lobe system dysfunction in some criminal actions as shown in the narratives test. *Journal of Nervous and Mental Disease*, *168*, 111–117.

Reitan, R. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills*, *8*, 271–276.

Reitan, R. (1971). Trail Making Test results for normal and brain-damaged children. *Perceptual and Motor Skills*, *33*, 575–581.

Reitan, R. (n.d.) *Trail Making Test: Manual for administration and scoring*. Indianappolis: Indiana University Medical Center.

Rossini, E.D., & Karl, M.A. (1994). The Trail Making Test A and B: A technical note on structural nonequivalence. *Perceptual and Motor Skills*, *78*, 625–626.

Spreen, O., & Benton, A. (1965). Comparative studies of some psychological tests for cerebral damage. *Journal of Nervous and Mental Disease*, *140*, 323–333.

Tabachnick, B.G., & Fidell, L.S. (1996). *Using multivariate statistics* (3rd ed.). New York: Harper Collins.

Waldmann, B.W., Dickson, A.L., Monahan, M.C., & Kazelskis, R. (1992). The relationship between intellectual ability and adult performance on the Trail Making Test and the Symbol Digit Modalities Test. *Journal of Clinical Psychology*, *48*, 360–363.

Wechsler, D. (1987). *The Wechsler Memory Scale-Revised Manual*. New York: Harcourt Brace Jovanovich.

Wedding, D. (1979). *A comparison of statistical, actuarial and clinical models used in predicting presence, lateralisation and type of brain damage in humans*. Unpublished doctoral dissertation, University of Hawaii.

Wilkinson, G.S. (1993). *WRAT–3: Wide Range Achievement Test administration manual* (3rd ed). Wilmington, DE: Wide Range.