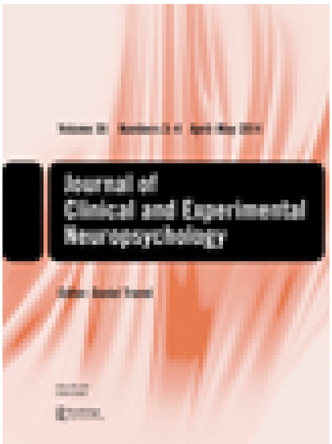

Journal of Clinical and Experimental Neuropsychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ncen20

Construct validity in the trail making test: What makes part B harder?

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Published online: 04 Jan 2008.

Journal of Clinical and Experimental Neuropsychology
1995, Vol. 17, No. 4, pp. 529-535
1380-3395/95/1704-529$6.00

Construct Validity in the Trail Making Test: What Makes Part B Harder?*

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ABSTRACT

The Trail Making Test (TMT) is primarily a test of motor speed and visual attention. In Trail Making, Part A, the subject's task is to quickly draw lines on a page connecting 25 consecutive numbers. In Part B, the subject must draw the lines alternating between numbers and letters. To determine what makes Part B harder than Part A, variations of the standard Trail Making Test were assessed. Forty college students (20 male, 20 female) were given four forms of the Trail Making Test. The results show that Trail Making, Part B with just numbers took longer to complete than the standard Part A with numbers. Part B is 56 cm longer and has more visually interfering stimuli than Part A. These results indicate that Part B is more difficult than Part A not only because it is a more difficult cognitive task, but also because of its increased demands in motor speed and visual search.

The Trail Making Test (TMT) was originally part of the Army Individual Test Battery (1944). It is a standard component of the popular Halstead-Reitan Neuropsychological Test Battery (Halstead, 1947; Reitan & Davison, 1974), and other neuropsychological batteries. The Trail Making Test is primarily regarded as a test of visual conceptual and visuomotor tracking (Lezak, 1983). In the Trail Making Test, Part A, the subject's task is to draw lines on a page as quickly as possible to connect 25 consecutive numbers. In Part B, the subject must draw the lines alternating between numbers and letters. The efficacy of this test lies in its ability to distinguish brain-damaged patients from normal control subjects with a relatively high degree of accuracy (Eson, Yen, & Bourke, 1978; Lezak, 1983; Reitan, 1971).

Clinical interpretation of performance on the TMT is based on the assumption that Part B reflects more complex cognitive processes than does Part A (Spreen & Strauss, 1991). This inference implies that the two trails are equivalent in all respects other than the addition of a more complex cognitive task in Part B. It is this assumption that is the focus of this investigation.

One interpretation of the cognitive functions involved in performance of the TMT is that Part A is reflective of right hemisphere integrity, involving visual scanning and spatial skills, whereas Part B performance is indicative of left hemisphere function, involving language and symbol manipulation and direction of behavior according to a complex plan (Golden, 1981). However, subsequent research suggests that this test may not be speciific enough to effectively localize brain injury, especially in differentiating right and left hemisphere damage (Lezak, 1983; Wedding, 1979).

While the interpretation of the TMT in terms of lateralization of functions has not gained a great deal of empirical support, the functional

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The authors would like to express their gratitude to Dr. Suparna Rajaram for her superlative review of a previous version of this manuscript.
Accepted for publication: November 15, 1994.

distinctions between the two tasks are still accepted (Lezak, 1983). Slowed performance on Part B relative to Part A is still thought to be indicative of general frontal lobe dysfunctions (Pontius & Yudowitz, 1980). More specifically, it is thought to indicate impaired ability to execute and modify a plan of action (Eson et al., 1978; Pontius & Yudowitz, 1980) or to maintain two trains of thought simultaneously (Lezak, 1983; Reitan, 1971). It has been reported that the integrity of these higher cognitive functions can be inferred by comparing an individual's performance on the two versions (Wheeler & Reitan, 1963). If time to complete Part B is greater than three times the time to complete Part A, then performance on Part B is considered impaired (Golden, 1981). However, some authors suggest that comparisons between performance on the two trails may not be that easily interpreted (Schreiber, Goldman, Kleinman, Goldfader, & Snow, 1976; Wedding, 1979). Newby, Hallenback, and Embretson (1983) suggest that the TMT assesses several cognitive functions, including receptive and expressive language functions and mental activity variables (see Lezak, 1983) such as attention, concentration, conceptual tracking, and activity rate.

The differentiation of the cognitive functions involved in executing the two TMT tasks lies in part on the assumption that Part B involves a cognitive component above and beyond Part A's requirement for visual motor search. Presumably it is this additional cognitive component that makes Part B more difficult. However, teasing out the effects of brain damage on higher functions using Part B may not be straightforward in that basic functions such as visual search and motor speed may have a more pronounced effect in Part B than in Part A. Accurate interpretation of performance on Part B relative to performance on Part A assumes that the two versions are equivalent in all respects other than the addition of the more complex cognitive processing in TMT Part B. Thus, the versions should be equal in their lengths and in complexity of visual search.

Upon close examination of the TMT, it appears that Part A and Part B differ from each other quite dramatically in the distance between targets and the complexity of visual search involved in each trail. This study was designed to directly examine the differences between the two trails with respect to their lengths (in centimeters), complexity of visual search (quantified by counting the number of targets not in sequence that lie within 3 cm of the path between each target), and cognitive difficulty (number connection vs. number-letter alternation tasks).

METHODS

Subjects

Subjects were undergraduate students from the State University of New York at Stony Brook, who were fulfilling a requirement to participate in an experiment for a course. Forty subjects, 17 to 23 years of age, participated, with equal numbers of each sex (mean age = 18.8 years, SD = 1.6 years). There was no difference in age between males and females ($p > .75$). All subjects were right-handed, reported no history of head trauma, peripheral nerve damage, nervous system disease, or psychiatric problems. All were naive to neuropsychological testing procedures.

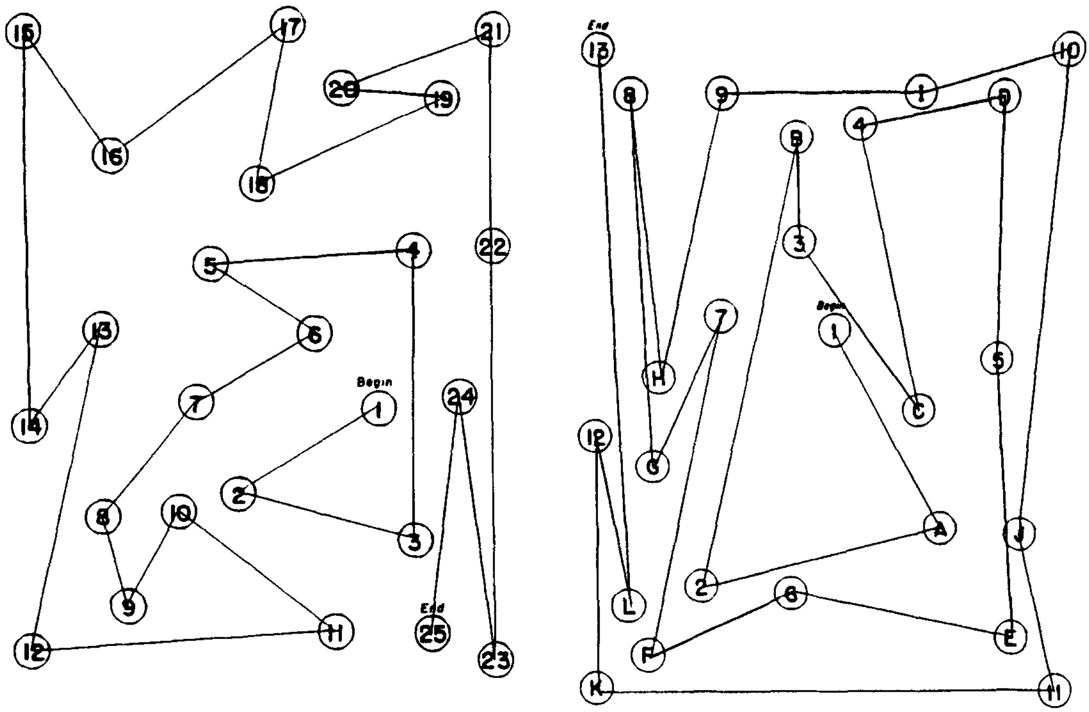
Materials

The original Trail Making Test, Part A and B was used (see Figure 1). In addition, two experimental tasks were developed for the study (see Figure 2). Trail A_{N+L} was identical to TMT, Part A with respect to the layout of the page, but had both numbers and letters, as in TMT, Part B. Trail B_N was identical to TMT, Part B with respect to the physical layout of the page, but had only numbers 1 to 25, as in TMT, Part A.

Thus, the stimuli included TMT, Part A with numbers, as in the original test, and a Trail A with numbers and letters (Trail A_{N+L}). There was the original TMT, Part B, with numbers and letters and a Trail B with just numbers (Trail B_N).

Procedure

After signing informed consent, the four trails were administered to each subject following standardized instructions (Lezak, 1983). Subjects first completed a number-connection task, followed by a number-letter alternation task, followed by another number-connection task, and a final number-letter task. The number-connection tasks (TMT, Part A and Trail B_N) were counterbalanced for order of administration as were the number-letter alternation tasks (TMT, Part B and Trail A_{N+L}). This counterbalancing procedure resulted in four administration protocols with 10 subjects (5 male, 5 female) in each condition.



TMT Part A TMT Part B

Fig. 1. The original Trail Making Test, Part A and Part B was used.

Analysis of Trail Length and Visual Interference
Trail lengths were analyzed for the distance between targets in centimeters. The amount of visual interference for each trail was quantified by counting the number of targets not in sequence that lie within 3 cm of the path between each target.

Statistical Analysis of Subject Performance
All analysis of variance (ANOVA) with repeated measures employed Greenhouse-Geisser corrections for heterogeneity of covariance (Greenhouse & Geisser, 1959).

A two-factor (Trail X Sex) analysis of variance was used to determine differences in time to complete the four trails, within subjects and between sexes.

Post hoc pairwise comparisons of the four trails were performed using a Newman-Keuls correction for multiple comparisons. The pairwise comparison of time to complete TMT, Part A and Trail B_N was used to determine the difference between TMT, Part A and TMT, Part B without the influence of interposed letters, or increased cognitive difficulty. In order to determine the difference in time to complete TMT, Part A and TMT, Part B, given a more difficult cognitive task of alternating numbers and letters, a pairwise comparison was made between time to complete TMT, Part B and Trail A_{N+L} (TMT, Part A with numbers and letters).

To determine how much time is added to the trail by the added cognitive component of alternating numbers and letters, without the possible confounding influence of a longer or more complicated trail, a pairwise comparison was made between TMT, Part A and Trail A_{N+L} (TMT, Part A with numbers and letters). The same pairwise comparison was made between Trail B_N (TMT, Part B with only numbers) and TMT, Part B, to determine the effect of the more difficult cognitive component in TMT, Part B.

Statistical Analysis on Trail Length and Visual Interference
A one-factor (Trail layout) ANOVA was used to compare the lengths between targets for TMT, Part A and TMT, Part B. A similar one-factor (Trail layout) analysis of variance was applied to the number of visually interfering stimuli for TMT, Part A and TMT, Part B.

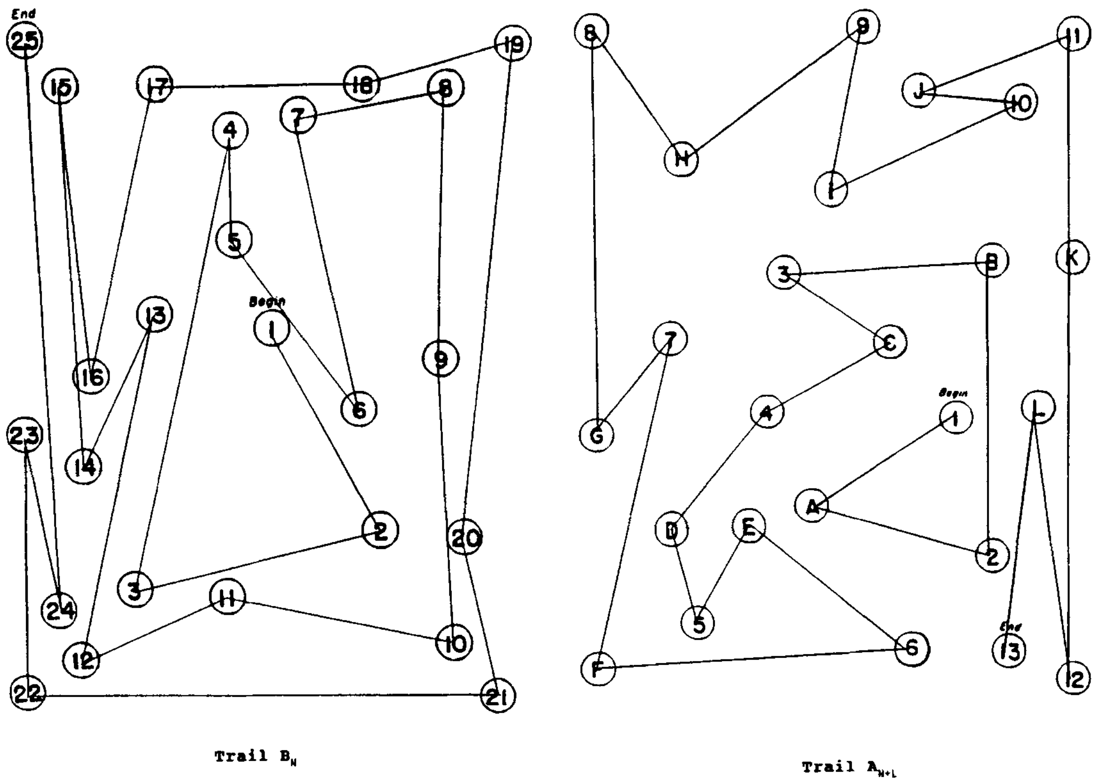


Fig. 2. Two experimental trails were compared against the originals, Trail B_N (TMT, Part B with numbers only) and Trail A_{N+L} (TMT, Part A with numbers and letters).

RESULTS

Results of Analysis on Subject Performance

The results of the two-factor (Trail X Sex) analysis of variance revealed a significant main effect for trail ($F(3,114) = 55.68$, $p < .001$). As demonstrated in Figure 3, time to complete TMT, Part A was shortest, followed by time to complete Trail B_N (TMT, Part B with numbers only). Trail A_{N+L} (TMT, Part A with numbers and letters) took slightly longer than Trail B_N, and TMT, Part B took the longest to complete. A significant main effect for sex was obtained ($F(1,38) = 5.13$, $p < .05$) such that male subjects took longer than females to complete each trail. No significant interactions between Trail and Sex were obtained ($p > .37$). Therefore, all further post hoc comparisons were performed collapsing across sex.

Post hoc comparisons of the four trails, using a Newman-Keuls correction for multiple comparisons, revealed that all trails differed at the $p < .01$ level of significance. The post hoc comparison between time to complete TMT, Part A and Trail B_N was significant ($p < .001$) revealing that TMT, Part B took longer to complete than TMT, Part A even after removing the effect of the number-letter alternation task. Similarly, the comparison between Trail A_{N+L} (TMT, Part A with numbers and letters) and TMT, Part B with numbers and letters revealed that TMT, Part B took significantly longer to complete ($p < .001$). Trail Making Test, Part B took 9.01 s longer to complete than Trail A with numbers and letters, lending further support to the finding that TMT, Part B takes longer regardless of its cognitive component.

The post hoc comparison of time to complete

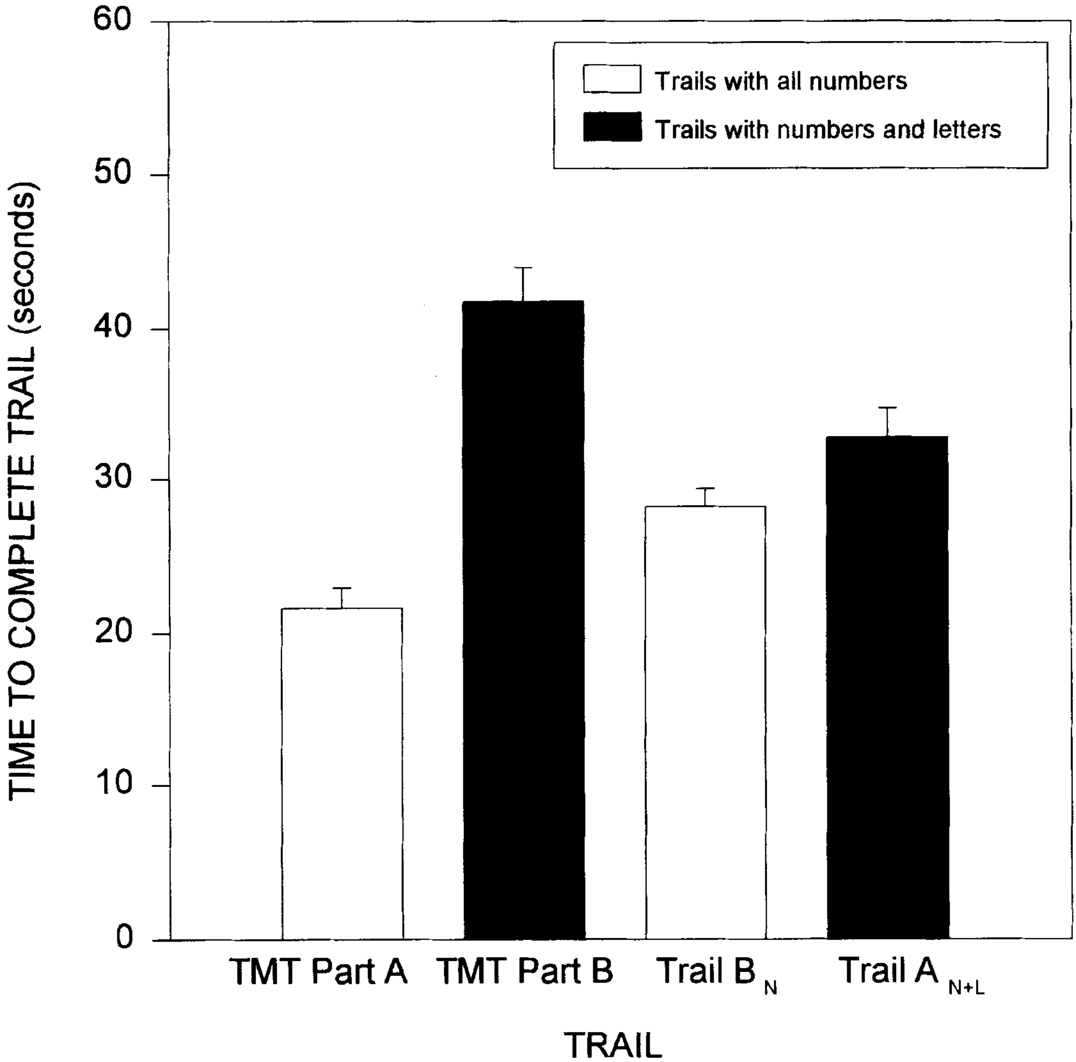


Fig. 3. Mean (+1 standard error) time to complete TMT, Part A, TMT, Part B, Trail B_N (TMT, Part B with numbers only), and Trail A_{N+L} (TMT, Part A with numbers and letters) for all 40 subjects.

TMT, Part A and Trail A_{N+L} was significant ($p < .001$); Trail A_{N+L} (TMT, Part A with numbers and letters) took 11.09 s longer to complete than TMT, Part A. Similarly, the post hoc comparison of time to complete Trail B_N (TMT, Part B with just numbers) and TMT, Part B was significant ($p < .001$); subjects took an average of 13.56 s longer to complete Trail Making Test, Part B than they did to complete Trail B_N, indicating that the cognitive component of TMT, Part B adds significantly to the time to complete this trail.

Results of Analysis on Trail Length and Visual Interference

The one-way ANOVA on the distance between targets for TMT, Part A and TMT, Part B revealed a significant main effect ($F(1,46) = 4.4$, $p < .05$), with the distances between targets in TMT, Part B longer than in TMT, Part A. Trail

Making Test, Part A has a mean distance between targets of 7.8 cm (SD = 3.2) and TMT, Part B has a mean distance between targets of 10.2 cm (SD = 4.5).

A one-way ANOVA on visual interference for TMT, Part A and Part B yielded a significant main effect ($F(1,24) = 7.85$, $p < .01$), indicating more visually interfering stimuli between targets for Part B. Trail Making Test, Part A has on average, less than one visually interfering stimulus between each target, while Part B averages more than one.

DISCUSSION

This study was designed to explore what makes TMT, Part B harder for most subjects to perform than TMT, Part A. The results reveal that there are several factors that may contribute to the difference in time to complete the two trails. On average, Part B has an additional 2.4 cm between each target, resulting in Part B being 56.9 cm longer than Part A. This difference in trail length could be one factor making TMT, Part B harder.

While TMT, Part A rarely has any other item in the path between each target and the next, Part B has, on average, more than one item, creating visual interference in the path. In total, Part A has 11 items that are within 3 cm of the path that a subject's pencil will follow. TMT, Part B has 28 items that are within 3 cm of the path. This difference in the amount of visual interference in the trails is another possible factor contributing to the increase in time to complete Part B.

When the trail itself was held constant and only the number-letter task was added, it took subjects 11 s longer to complete Trail A_{N+L} than TMT, Part A and 13.5 s longer to complete TMT, Part B than Trail B_N. This difference was most likely due to the more complex cognitive processes involved in alternating between number and letter.

The results indicate that direct comparisons between performance on Trail Making Test A and Part B should be made with caution. TMT, Part B is more complex than Part A on several levels. Exceptionally slowed performance on TMT, Part B could indicate cognitive impairment, but may also indicate defects in motor speed or visual search. In sum, relatively poor performance on Trail Making Test, Part B may overestimate cognitive deficits because of the difference between the trails over and above the added cognitive difficulty.

If a pure measure of higher cognitive processing is being sought under experimental conditions, a more reasonable comparison would be between performance on TMT, Part A and performance on Trail A with numbers and letters (Trail A_{N+L}). Given that TMT, Part B is a more complex trail than TMT, Part A, it would be useful to use TMT, Part B and Trail B with just numbers (Trail B_N) if the goal is to measure cognitive performance in the context of a more complicated array of visual stimuli. However the clinical efficacy of such comparisons can not be known without further investigations into the psychometric properties of these alternate versions.

Previous studies on the TMT have reported that gender differences in performance on the trails are not significant (e.g., Heaton, Grant, & Matthews, 1986; Kennedy, 1981; Reitan, 1971; Spreen & Strauss, 1991), yet the present study demonstrated that in our sample of college-aged subjects with equal levels of education, females were significantly faster than males in completing some of the trails. When sex differences were assessed by independant one-way ANOVAs, the female advantage was only significant in the experimental versions, Trail A_{N+L} and Trail B_N. Further research would be necessary to validate such a gender difference.

CONCLUSION

The results of this study support the conclusion of Newby et al. (1983) that the TMT should best be conceptualized as reflecting a combination of several cognitive functions. Within the clinical setting, the greater time taken to complete Part B appears to reflect an increased demand on motor, visual, and higher cognitive processes. Additional slowing in brain-damaged patients could reflect deficits in any or all of these domains.

Future research into the demographic and neuropsychological factors that affect performance on the TMT could provide valuable insight into the constructs measured by this test thereby enhancing its clinical interpretation.

REFERENCES

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

Eson, M. E., Yen, J. K., & Bourke, R. S. (1978). Assessment of recovery from serious head injury. *Journal of Neurology, Neurosurgery, and Psychiatry, 41*, 1036-1042.

Golden, C. J. (1981). A standardized version of Luria's neuropsychological tests. In S. Filskov & T. J. Boll (Eds.), *Handbook of clinical neuropsychology* (pp.). New York: Wiley-Interscience.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrics, 24*, 95-112.

Halstead, W. C. (1947). *Brain and intelligence*. Chicago: University of Chicago Press.

Heaton, R.K., Grant, I., & Matthews, C.G., (1986). Differences in neuropsychological test performance associated with age, education, and sex. In I. Grant & K.M. Adams (Eds.), *Neuropsychological assessment of neuropsychiatric disorders* (pp.100-120). New York: Oxford University Press.

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

Lezak, M. D. (1983). *Neuropsychological assessment*. New York: Oxford University Press.

Newby, R. F., Hallenback, C. E., & Embretson(Whitely), S. (1983). Confirmatory factor analysis of four general neuropsychological models with a modified Halstead-Reitan Battery. *Journal of Clinical Neuropsychology, 5*, 115-133.

Pontius, A. A., & Yudowitz, LL. B. (1980). Frontal lobe system dysfunction in some criminal actions as shown in the Narratives Test. *The Journal of Nervous and Mental Disease, 168*(2), 111-117.

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

Reitan, R. M., & Davison, L. A. (1974). *Clinical neuropsychology: Current status and applications*. Washington DC: V. H. Winston & Sons.

Schreiber, D.J., Goldman, H., Kleinman, K.M., Goldfader, P.R., & Snow, M.Y. (1976). The relationship between independant neuropsychological and neurological detection of cerebral impairment. *Journal of Nervous and Mental Disease, 162*, 360-365.

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests: Administration, norms, and commentary*. New York: Oxford University Press.

Wedding, D. (1979). *A comparison of statistical, actuarial, and clinical models used in predicting presence, lateralization, and type of brain damage in humans*. Unpublished doctoral dissertation, University of Hawaii (As cited in Lezak, 1983).

Wheeler, L., & Reitan, R.M. (1963). Discriminant functions applied to the problem of predicting cerebral damage from behavioral tests: A cross-validation study. *Perceptual and Motor Skills, 16*, 681-701.