The Trail Making Test as an initial screening procedure for neuropsychological impairment in older children

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Abstract

This study was designed to explore the possibility of using a brief neuropsychological test for broad-band initial screening of children with academic problems who might have neuropsychological deficits that should be more completely evaluated. Part B of the Trail Making Test was selected as the instrument for investigation. Three groups of children, aged 9–14 years, were composed for this study to represent (1) children with diagnosed brain damage or disease, (2) children who were medically normal but who were of serious concern to parents and teachers because of inadequate academic progress, and (3) a normal control group. The Brain-Damaged group required more than three times the number of seconds needed by the controls to complete the test, and the group with academic difficulties required more than twice the time of the controls. Using the limits set by the distributions of the Brain-Damaged and control groups, it was possible to identify a cutoff point that may be used for preliminary identification of children with academic difficulties who might benefit from further neuropsychological evaluation. The results of this study stand in need of cross-validation and, obviously, much additional outcome research is necessary to evaluate the efficacy and validity of the findings for screening purposes.

Keywords: Trail Making Test; Initial screening procedure; Older children; Brain damage; Learning disabilities

1. The Trail Making Test as an initial screening procedure for neuropsychological impairment in older children

A hypothesis underlying this investigation concerns the possibility that children with significant and persisting academic problems may have unrecognized brain impairment as at least


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one basis for their difficulties, even though many factors obviously may contribute to limitation in academic progress. Not uncommonly, the significance of illnesses, injuries, or adverse events, which may eventually lead to neuropsychological deficits, are obscure and often unrecognized. For example, relatively recent studies among adults of both a retrospective and prospective design have implicated significant head injuries, occurring years earlier, as being associated with the development of Alzheimer’s disease (Guo et al., 2000; Mehta et al., 1999; Plassman et al., 2000).

Similarly, histological examination of temporal lobe brain tissue removed in surgical treatment of complex partial seizures (temporal lobe epilepsy) has, in some instances, provided the first definitive evidence that the patient has, at some earlier time, suffered from encephalitis (Aguilar & Rasmussen, 1960). Thus, it is within reason to postulate that some children with definite impairment of academic abilities may have experienced occult and unknown illnesses or injuries that have contributed both to a degree of brain impairment and to the child’s academic problems.

The purpose of this investigation was to compare performances on the Trail Making Test of a group of children who had academic difficulties but no definitive evidence of brain disease or damage on medical evaluation with the performances of a group of normal controls and a group of children with diagnosed brain damage or disease.

2. Method

2.1. Participants

Three groups of children who ranged in age from 9 to 14 years were examined. Each of the 25 children in the Brain-Damaged group had independent and definitive medical evidence of structural brain damage or a clinically significant brain disorder. These children were selected primarily because of medical conditions that had caused them to be evaluated by neurologists or neurosurgeons rather than because of academic or neuropsychological problems (even though such problems were frequently present). Our aim was to compose this group on the basis of neurological diagnoses of brain damage or disease rather than on the basis of symptoms or effects of brain damage. The range of neurological diagnoses was deliberately diversified in order to improve the basis for generalization, and included the following conditions: traumatic brain injury, 8; arteriovenous malformation, 3; cerebral palsy, 3; encephalitis, 2; intracranial tumor, 2; fibrous skull growth with compression of the brain, 1; cerebral abscess, 1; major motor seizures, 3; and minor motor seizures, 2. No attempt was made to select children with regard to severity of impairment, but clinical evaluation suggested that the range extended from very mild to severe impairment. The Brain-Damaged group consisted of 15 boys and 10 girls and had a mean age of 134.46 months (S.D. 16.58).

The 50 children with academic difficulties were deliberately selected to represent a broad and relatively undefined sample of such children rather than children with more specifically defined types of learning disabilities. All of the children in this group were in the regular classroom situation and none was receiving special educational instruction or additional structured professional assistance at the time of enrollment in this study. Our purpose was to compose a
A sample of children who, in the judgment of both parents and teachers, were not making normal progress academically, and for whom there was serious concern. While the bases for problems in making academic progress might be diversified and variable in such a group, these children represent the first line of referrals, and the children with whom many clinical neuropsychologists, school psychologists, and other professionals must deal. Because of the concern felt by both parents and teachers, each of the children in this group had originally been referred to a physician (pediatric neurologist or pediatrician in most cases, but a few to family physicians, psychiatrists, and neurological surgeons) for evaluation. We included only those children in whom a detailed history and neurological examination by the physicians failed to reveal any physical or medical basis for the child’s academic problems. This group was composed of 31 boys and 19 girls and had a mean age of 135.76 months (S.D. 20.56).

The 25 children included in the control group had no identified neurological or educational problems. A pediatric neurologist had examined each of these children as a basis for including them as controls in this study, and found no historical or current basis for presuming that they had brain impairment. (Obviously, as was also true of the children having academic difficulties, this examination could not rule out occult factors that might possibly have caused brain impairment.) The group with academic difficulties differed from the controls, insofar as was determined, only with respect to academic progress. The control group had a mean age of 136.20 months (S.D. 18.26). The age differences among the three groups were not statistically significant.

2.2. Data collection and analysis

The Trail Making Test for Children (Reitan & Wolfson, 1992) was individually administered to each child by a carefully trained technician who was not aware of the child’s diagnosis or of the group to which the child was assigned in this study. The Trail Making Test consists of two parts (A and B), each of which contains 15 circles distributed on a sheet of paper. In Part A, each circle contains a number from 1 to 15, and after the subject completes a sample of the test, the child is instructed to begin at the number 1 and to locate and draw a pencil line to 2, then to 3, and so on until reaching the number 15. Part B has both numbers and letters within the 15 circles, and the subject is instructed to alternate between them as the numerical and alphabetical sequences progress. The child begins at 1, locates and draws a line to A, then to 2, then to B, and so on until completing the test. The score for each part of the test is the number of seconds required for completion. Complete instructions for administration and scoring are given in Reitan and Wolfson (1992). Part B is more demanding than Part A and, while performances on both parts have been shown to be impaired among brain-damaged children (Reitan, 1971). Part B appears to be the more sensitive. Thus, analyses and group comparisons in this study centered on Part B. The reader should be aware, however, that standard procedure requires that Part A be given before Part B, and the validity of results may be affected if this sequence is not followed.

As with the other tests included in the Halstead–Reitan Neuropsychological Test Battery for Older Children (Reitan & Wolfson, 1992), raw scores on the Trail Making Test can be converted into Neuropsychological Deficit Scale (NDS) scores. The advantage in this procedure is that NDS scores are on a common scale and reflect the clinical significance of the performance. NDS scores of 0 correspond with excellent and/or perfectly adequate performances;
a score of 1 indicates a normal but not excellent performance; a score of 2 corresponds with performances that show mild-to-moderate impairment; and a score of 3 indicates serious and significant deficits. NDS scores also limit the range of the extremely poor raw scores that are sometimes seen among severely brain-damaged children, and this limitation of variability, in turn, may represent an advantage in statistical analyses and group comparisons. Data analyses in this study were done on both raw-score and NDS-score distributions. (Information regarding raw-score/NDS score transformations for Part B of the Trail Making Test is presented at the end of this paper for the reader’s convenience. More complete information has been published in Reitan & Wolfson, 1992.)

3. Results

Table 1 presents raw-score means and standard deviations on Part B of the Trail Making Test (Trails B) for each group and statistical comparisons of the distributions for each pair of groups.

The Brain-Damaged group required more than three times the number of seconds needed by the controls to complete the test, and the group with academic difficulties required more than twice the time of the controls. It is not surprising that statistical comparisons yielded highly significant probability levels in comparisons of the controls with the other two groups. The Brain-Damaged group also performed more poorly than the group with academic difficulties at a significant level. Analyses based on NDS scores yielded even larger t-ratios than those found in the analyses of raw scores when comparing the controls with each of the other groups. However, there was no significant difference between the NDS scores of the Brain-Damaged group and the Academic Difficulties group. The reason for this finding stemmed from the extremely poor scores of some of the brain-damaged children, which augmented the raw-score mean for the Brain-Damaged group, coupled with the consistency of impairment shown by the children with academic difficulties, which led to a large proportion of children in the Academic Difficulties group earning NDS scores of 2 or 3. This latter point is demonstrated by the distributions of NDS scores shown in Table 2.

First, Table 2 shows that most of the control children (76%) scored in the normal range (NDS scores of 0 and 1), whereas 24% showed mild-to-moderate impairment. This finding is
Table 2
Distributions of three groups of children according to clinically significant categories (NDS scores) on Part B of the Trail Making Test

<table>
<thead>
<tr>
<th>NDS score</th>
<th>Controls</th>
<th>Brain-Damaged</th>
<th>Academic Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>f %</td>
<td>f %</td>
<td>f %</td>
</tr>
<tr>
<td>0</td>
<td>7 28</td>
<td>3 12</td>
<td>4 8</td>
</tr>
<tr>
<td>1</td>
<td>12 48</td>
<td>2 8</td>
<td>7 14</td>
</tr>
<tr>
<td>2</td>
<td>6 24</td>
<td>8 32</td>
<td>21 42</td>
</tr>
<tr>
<td>3</td>
<td>0 0</td>
<td>12 48</td>
<td>18 36</td>
</tr>
<tr>
<td>Total</td>
<td>25 100</td>
<td>25 100</td>
<td>50 100</td>
</tr>
</tbody>
</table>

expected in an unselected group of controls, considering the variability in general intelligence and other factors that occur in such a group. Earlier studies have shown correspondence between relatively poor neuropsychological test scores of children classified as controls, according to criteria similar to those used in the current study, and problems experienced in academic progress (Reitan & Boll, 1973).

The more significant finding shown in Table 2 concerns the poor performances of both the brain-damaged children and children with academic difficulties. Eighty percent of the brain-damaged children and 78% of the children with academic difficulties showed evidence of impairment on Trails B (NDS scores of 2 or 3). Thus, the group with academic difficulties was impaired essentially as frequently (though not as severely) on Trails B as were the children with diagnosed brain damage and/or disease.

The results shown in Table 2 suggest that the best NDS cutoff point for minimizing false positives and false negatives for both children with academic difficulties and children with diagnosed brain damage or disease is represented by a scores of 1 and 2, which corresponds with a cutoff score of 37/38 s as previously reported by Reitan and Wolfson (1992). The reader should note, however, that when using this cutoff point 24% of the controls fell in the impaired range and 20% of the brain-damaged children fell in the normal range. These results confirm the expectation that a single brief test, scored only for level of performance, probably cannot be expected to approach a perfect classification of brain-damaged and control subjects.

4. Discussion

The frequency with which the children with academic difficulties scored poorly on Trail B represented a somewhat surprising finding, inasmuch as the frequency (though not severity) was essentially the same as that of children with definite brain damage or disease. This result also confirmed the sensitivity of Trails B to neuropsychological factors that are associated with problems in making academic progress.

The reasons that Trails B appears to be especially sensitive to factors underlying difficulties with academic achievement are undoubtedly multiple and complex, but previous findings have demonstrated the general sensitivity of the test to impaired brain functions in children (Boll,
Earlier research, in turn, has suggested that impairment of neuropsychological functions, at least to a degree, is present in a high proportion of children with learning problems in school (Reitan & Boll, 1973; Reitan & Wolfson, 1988, 1992).

The general sensitivity of Trails B to brain damage and disease has also been demonstrated repeatedly in groups of adults with heterogeneous brain involvement (Alvarez, 1962; Reitan, 1955, 1958; Reitan & Wolfson, 1993, 1995). These studies have been based on groups with diversified types and locations of brain involvement, suggesting that the test does not draw upon selected or delimited areas of the brain, but instead is sensitive to the status of the brain regardless of whether the damage is focal or diffuse or the type of pathological involvement. In a study directed to this question, Reitan and Wolfson (1995) found that lesions involving any of the major areas of the cerebral hemispheres (anterior left, posterior left, anterior right, posterior right) showed equivalent impairment on Trails B performances. These findings, supported by extensive clinical experience, have led to the conclusion that among single measures, Trails B is second only to the Category Test in the Halstead–Reitan Battery as a general and consistent indicator of the biological status of the brain (Reitan & Wolfson, 1992).

The studies cited above indicate that the Trail Making Test, though relatively simple and quick to administer, taps the adequacy of brain functions through its content, format, and requirements for completion. The weaknesses of a test that is generally sensitive to brain damage, however, is that one cannot be sure of the biological basis for poor performances, inasmuch as it may be due to involvement of any part of the cerebral hemispheres; nor can one be sure which neuropsychological functions are impaired, since the requirements of the test are diversified and involve the use of symbols, the ability to deal effectively with spatial configurations, and the ability to demonstrate flexibility in shifting between numbers and letters while keeping both sequences in mind simultaneously. This degree of complexity, however, in the form of a rather quick and seemingly simple task, is exactly what is needed in a screening test. Thus, the results suggest that the Trail Making Test may be useful in identifying children who should receive comprehensive neuropsychological examinations.

The consistency with which impaired scores occurred in the group with academic difficulty merits further consideration. Conceivably, this finding could have resulted from many different etiologies, such as emotional disorders, behavioral disturbances, and other possible factors. However, considering the studies cited above, as well as findings reported in the neuropsychological literature generally in the area of learning disabilities (Reitan & Wolfson, 2001), it would appear likely that subtle impairment of brain functions is a significant factor.

The combined effects of these studies led to the conclusions that subtle impairment of brain functions, and dependent neuropsychological capabilities, appears to be a far more common basis for academic difficulties and certain behavioral disorders than has generally been recognized, and that these children need to be identified so that educational and teaching practices, treatment, and management can be offered within a neuropsychological framework when brain impairment has been identified.

Finally, the limitations of this study and the need for further research must be mentioned. As with any study, the results obtained must be subjected to cross-validation as well as verification in clinical practice. While the results suggest that Trails B scores may be useful in identifying children who need more comprehensive neuropsychological examination, we have
no follow-up data at this point, either with children who do well or who do poorly on Trails B, to support this conclusion. Obviously, a great deal of additional work is needed to validate the efficiency of any screening procedure, and the present findings represent only a promising starting point in this process.

It would also appear likely that a single, brief test will not be sufficient to achieve a satisfactory degree of accuracy for screening purposes. The results of this study have led us to explore the use of a 1-h battery as a second phase of the screening process. Preliminary and unpublished findings suggest that progressive testing of this type, evaluated with regard to defined cutoff points determined within limits of distributions of scores of groups of brain-damaged and control children, may serve to selectively identify those children who need comprehensive neuropsychological evaluation. In such a context, results on Trails B would represent only the first step in this process.

Transformation of raw scores to NDS scores for older children on the Trail Making Test—Part B

<table>
<thead>
<tr>
<th>NDS score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw score (s)</td>
<td>27 or less</td>
<td>28–37</td>
<td>38–69</td>
<td>70 or more</td>
</tr>
</tbody>
</table>

References


