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Sensitivity of the comprehensive trail making test to traumatic brain injury in adolescents

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Abstract

The current study examined the sensitivity of the Comprehensive Trail Making Test (CTMT Reynolds) to neurocognitive deficits in adolescents with traumatic brain injury (TBI). Participants included 60 adolescents, 30 who had sustained TBI and 30 healthy controls (HC) that were individually matched to the TBI sample on age, gender, ethnicity, and geographical region. For both the TBI and HC groups the mean age was 15.0 years (S.D. = 2.3 years, range = 11–19). The TBI group had a mean IQ of 81.7 (S.D. = 14.9), had sustained moderate to severe brain injury, and was assessed an average of 21.1 months (S.D. = 20.7) following injury. The TBI group performed approximately 2 standard deviations below the control sample mean on each of the five CTMT trails as well as on the composite index and these differences were significant ($p < .001$). Significant correlations were present between the CTMT trails and clinical variables associated with brain injury severity. Finally, receiver operating characteristic analyses indicated good classification of the TBI and control cases for the CTMT, although some variability in classification accuracy was present among the various trails. Results suggest that the CTMT is sensitive to TBI in adolescents but continued research is needed with larger samples of individuals with TBI and other types of neurological disorders to further establish the present findings.

Keywords: Comprehensive Trail Making Test; Traumatic brain injury; Adolescents; Sensitivity; ROC analysis

It is estimated that over 1.4 million people in the United States sustain mild to severe traumatic brain injuries (TBI) each year, with at least 500,000 of those individuals being children or adolescents (Langlois, Rutland-Brown, & Thomas, 2004). Approximately 30,000 of these children will have permanent disabilities at an estimated life-time cost of up to four million dollars per person (Max, MacKenzie, & Rice, 1991; Langlois, Thurman, Alverson, Dunn, Guerrero, & Sniezek, 1999). Motor and sensory deficits are common following TBI, as are neurocognitive deficits. The most consistent neurocognitive finding is slowed information processing, although deficits in attention and concentration are also common (Felmingham, Baguley, & Green, 2004). These neurocognitive deficits can create great challenges for rehabilitation and educational placement (Kraemer & Blancher, 1997; Lowther & Mayfield, 2004) and as such, there is increased demand for instruments that can reliably assess disturbances in complex cognitive abilities in adolescents with TBI. There are a growing number of nationally standardized neuropsychological tests that have become available

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in recent years for adolescents. However, many lack appropriate evaluation in clinical populations that would help to establish their sensitivity to brain damage and criterion validity in various neurological disorders. The Comprehensive Trail Making Test (CTMT; Reynolds, 2002), based on the Trail Making Test (TMT), offers particular promise along these lines. The TMT was itself based on an adaptation of the test of distributed attention, which was developed as an alternative way of assessing intellectual function (Partington, 1949). Soon thereafter, it was renamed the Partington's Pathways Test which was used to assess brain injury in adults (Partington & Leiter, 1949). It was subsequently included in the Army Individual Test Battery (1944) where it received its current name and was later incorporated into the Halstead-Reitan Neuropsychological Battery (Reitan & Wolfson, 1992). Despite being well over 60 years old, the TMT continues to be among the most often used neuropsychological tests in clinical practice, and is also often used in research settings to investigate complex cognitive processes in neurological and psychiatric disorders (Rabin, Barr, & Burton, 2005). The TMT assesses a number of neurocognitive abilities including psychomotor speed, complex attention, visual scanning and mental flexibility, and has been repeatedly demonstrated to be sensitive to brain injury in children and adults (Boll, 1974; Jaffe et al., 1993; Reed, Reitan, & Klove, 1965; Reitan, 1955, 1958, 1971). In its adult version, it is administered in two parts, A and B. In Part A, the subject is instructed to connect a series of 25 numbered circles in sequence. In Part B, the subject is to connect another series of circles on a paper, however this time alternating between a numerical and alphabetical sequences (i.e., the subject starts at "1", and then draws a line to "A", then "2", then "B", and so on). Both sections are timed and the subject receives a score based on the amount of time (in seconds) taken to complete each part of the test. Youth between the ages of 9 and 14 years complete a shortened version, referred to as the TMT for older children, and youth between the ages of 5 and 8 years complete the progressive figures test (PFT).

The CTMT differs from its predecessor in that it consists of five trails rather than two, and was designed to provide an enhanced assessment of frontal lobe functioning through additional assessment of inhibition skills on several trails, as well as the addition of a new set-shifting task (Reynolds, 2002). The CTMT was designed to assess these complex abilities in individuals with brain dysfunction resulting from acquired and developmental disorders. Although norms are available for the CTMT on a large stratified national sample for individuals between the ages of 11 and 74 years, little information is available regarding its sensitivity to brain damage in clinical populations, particularly those involving children and adolescents. Along these lines, during the standardization process, two special populations were examined, including 30 teenagers diagnosed with a learning disability, and 28 adults that had suffered a cerebrovascular accident (CVA). The adults with CVA obtained *T*-scores on the CTMT trails ranging between 32 and 36 and a composite index score of 33, and the LD group obtained scores between 40 and 45 with a composite index score of 42 (mean *T*-score = 50). While providing support for the sensitivity of the CTMT to some forms of brain dysfunction (particularly CVA), information for other clinical groups such as those with TBI is currently unavailable. Given that the CTMT can be utilized to evaluate neurocognitive deficits in children and adolescents with brain injury, the current study investigated the validity of the CTMT in adolescents with TBI to examine its sensitivity to brain damage.

1. Method

1.1. Participants

Sixty adolescents participated in the study, including 30 who had sustained TBI and 30 non-brain injured controls (HC) selected from the CTMT standardization sample. Participants in the TBI group were selected from a consecutive series of 565 cases referred to a pediatric restorative care facility for neuropsychological assessment over a period of 5 years. Of the 565 cases, 263 evidenced TBI and 147 of these cases were 11 years of age or older. Of the 147 adolescent TBI participants, 30 were administered the CTMT as part of a comprehensive neuropsychological evaluation.[1] Thus, all had sustained a traumatic brain injury and had evidence of structural brain damage that was established by comprehensive neurological evaluation utilizing appropriate neuroimaging, laboratory, and examinational findings. Of the thirty individuals included in the TBI group, 6 individuals (20%) had sustained an open head injury and 24 individuals (80%) had sustained a closed head injury. With regard to the cause of TBI, 15 (50%) were involved in a motor vehicle accident, 5 (17%) had sustained a gunshot wound, 4 (13%) were pedestrians struck by a motor vehicle, 3 (10%) were

[1] TBI adolescents who were included in the present study ($n = 30$) were demographically (i.e., age, gender, ethnicity) similar to the larger sample of TBI adolescents who were not administered the CTMT ($n = 147$).

injured in a 4-wheel ATV accident, 1 (3%) was injured due to a fall, and the remaining 2 (7%) had other causes of TBI. Neuropsychological assessments were conducted from 5 to 71 months following injury (mean = 21.1, S.D. = 20.7). Glasgow Coma Scale scores (GCS; Teasdale & Jennett, 1974) were available for 23 participants. Using the general GCS classifications of mild (13–15), moderate (9–12), and severe (8 or less), GCS scores indicated that on average our group had sustained severe TBI (mean = 6.5, S.D. = 3.8) when considered together with evidence indicating presence of structural brain damage (Donders & Warschausky, 1997). Of the 30 individuals in the TBI group, 27 were administered a version of the Wechsler Intelligence scales which indicated a Full Scale IQ of 81.7 (S.D. = 14.9).

Cases in the HC group did not have learning disabilities, TBI, or other neurological or developmental disorders. They were selected from the CTMT standardization sample to individually match each TBI participant on age, gender, ethnicity, and geographical region of residence, in that order of importance. In cases where more than one individual in the standardization sample matched a particular TBI case on all the selection criteria, random selection was used to identify the standardization sample case that was included in the HC group. Using these criteria, matches from the standardization sample on all four matching criteria were identified for 24 TBI participants. The remaining six individuals were matched on age, gender, and ethnicity, but not on geographical region. The matching procedure resulted in highly comparable samples, with each group composed of 10 females and 20 males, who were an average of 15.0 years old (S.D. = 2.3 years, range = 11–19 years), and were 56.7% European American, 23.3% Hispanic American, and 20.0% African American. All participants in the TBI group were from the South region of the U.S., with 80% of the HC group residing in the South, 13.3% in the West, 3.3% in the Northeast, and 3.3% in the Midwest. The differences between the groups in geographical region were not significant (chi square = 6.67, d.f. = 3, $p > .05$).

1.2. Measures

The CTMT was standardized on a nationally stratified sample of 1664 individuals which were selected based on the U.S. 2000 census data to represent the United States population in sex, gender, education, race/ethnicity, family income, geographical region, educational attainment of adults, and disability status. Samples were obtained from 17 states and represented each of the four major U.S. geographic regions utilized in the 2000 U.S. census (Northeast, South, Midwest, and West). The standardization sample included individuals aged 11–74 years distributed across the following 9 age groups (in years): 11–13, 14–16, 17–19, 20–29, 30–39, 40–49, 50–59, 60–69, and 70–74. Categories for race included White, Black and other, and for ethnicity African American, Hispanic, Asian American, Native American and other. The reliability (internal consistency) of the composite index ranged from .91 to .95 across the various age groups, with comparable estimates for the learning disabled and CVA groups (.90–.95). Raw scores from each trail can be converted to *T*-scores and percentiles, while the composite index can be represented as a *T*-Score, quotient score ($M = 100$, S.D. = 15), *z*-score, Stanine or percentile (Reynolds, 2002).

The CTMT Trail 1 is similar to TMT' Part A in which the participant connects a series of encircled numbers from 1 to 25 that are arranged across a sheet of paper. Trail 2 of the CTMT is similar to Trail 1 in that the participant is asked to connect a series of encircled numbers from 1 to 25. However, in Trail 2 the complexity of the task is increased by the inclusion of 29 empty distracter circles on the same page. Participants are to connect the numbered circles in sequence while ignoring the empty distracter circles. As in Trails 1 and 2, Trail 3 requires the test subject to connect in order a series of circles numbered 1–25. However included on the page are 13 empty distracter circles and 19 distracter circles containing various line drawings. In Trail 4, the complexity is increased again with the participant asked to connect the numbers 1 through 20 in order, however 11 of the numbers are presented as Arabic numerals (e.g., 1, 2, and 3), and 9 of the numbers are spelled out (e.g., one, two, and three). Trail 5 of the CTMT is similar to Part B of the original TMT in which the participant is asked to connect both numbers and letters of the alphabet in a specific ascending manner (1, A, 2, B, 3, C,. . .). Trail 5 is different than Part TMT B because it includes 15 empty distracter circles that appear on the same page in order to increase the level of complexity of the task (Reynolds, 2002). The *T*-scores from the five trails are summed and the sum is converted to a composite index based on the standardization sample. Lower scores indicate greater severity of brain dysfunction for all CTMT scores examined in this study.

1.3. Procedures

The CTMT was administered as part of a comprehensive neuropsychological evaluation which was conducted at a pediatric restorative care facility. All assessments were administered according to standard criteria by a licensed

pediatric neuropsychologist or doctoral level graduate students who were extensively trained to reliably and validly administer the tests while under the supervision of the pediatric neuropsychologist. Raw scores for each of the five trails on the CTMT were converted to age-corrected *T*-scores and the composite index was calculated according to standard procedures (Reynolds, 2002).

1.4. Data analysis and hypotheses

Multivariate analysis of variance (MANOVA) was used to compare the HC and TBI groups on the five CTMT trails and, in the case of a significant finding, univarite analyses of variance (ANOVAs) were used to compare the groups on the individual CTMT trails. The CTMT composite index was also examined separately using ANOVA. Based on the extensive literature documenting the sensitivity of the TMT to brain damage, and the data reported in the CTMT test manual for the CVA group, it was predicted that our TBI group would obtain significantly lower scores than the HC group on all CTMT trails and the composite index score. Associations among the five CTMT trails for each group were also examined using correlational analyses to determine whether there were similar patterns of associations in the TBI and HC groups. There was no basis to make specific predictions regarding these associations, although it is the case that associations among subtests as well as factor structures may vary based on the clinical population under investigation. Correlations between the CTMT scores and clinical variables (GCS and time since injury) were calculated in the TBI group to determine whether the CTMT was sensitive to brain injury. It was anticipated that significant positive correlations would be present between the CTMT and these clinical variables, indicating that higher scores on the CTMT would be associated with less severe injury and longer periods of recovery following injury. Finally, receiver operating characteristic (ROC) analyses were accomplished for each of the CTMT trails as well as the composite index. The ROC analyses were used to determine the sensitivity and specificity of the CTMT scores in distinguishing between the TBI and HC groups. It was predicted that the CTMT composite index would attain higher classification accuracy than any of the individual trail scores.

2. Results

MANOVA comparing the HC and TBI groups on the five CTMT trails indicated a significant effect for group, $F(1, 58) = 35.03$, $p < .001$. As can be seen from Table 1, ANOVAs examining each trail separately indicated that on all five trails of the CTMT, the TBI group performed worse than the HC group ($p < .001$). ANOVA results comparing the groups on the CTMT composite index also indicated that there was a significant difference between the HC and TBI groups $F(1, 58) = 35.42$, ($p < .001$).

Pearson correlations were then used to examine the pattern of associations among the CTMT scores in the TBI and HC groups. All correlations were significant for both groups (see Table 2) even after Bonferonni correction ($p < .0017$), with the exception of the correlation between Trails 1 and 4 for the HC group ($r = .50$, $p < .005$). The correlations for the TBI group were somewhat higher than for the HC group ranging from .66 to .93, compared to .50 to .90 for the HC group. The largest differences were present between the HC and TBI groups for the correlations between CTMT Trails 1 and 4 ($r = .50$ and .76, respectively) and Trails 3 and 5 ($r = .61$ and .81, respectively).

To determine sensitivity to the severity of brain injury, correlations were also examined between the CTMT scores, Glasgow Coma Scale (GCS) scores, and time since injury. Given that the GCS is an ordinal measure, Spearman

Table 1
Descriptive statistics and results of the ANOVAs comparing the HC and TBI groups on the CTMT trails and composite index score

CTMT	TBI		HC		*F*	*p*
	Mean	S.D.	Mean	S.D.	d.f. = 1, 58	
Trail 1	34.77	13.58	51.67	14.97	20.98	.001
Trail 2	33.17	13.41	50.23	13.70	23.77	.001
Trail 3	33.87	13.19	51.17	12.83	26.53	.001
Trail 4	32.87	14.43	52.13	13.09	29.34	.001
Trail 5	34.27	12.30	52.67	11.95	34.53	.001
Composite Index	31.83	12.91	51.20	12.29	35.42	.001

Table 2
Correlations between the CTMT scores for the TBI group (correlations above the diagonal) and HC group (correlations below the diagonal)

CTMT trails	Trail 1	Trail 2	Trail 3	Trail 4	Trail 5	Composite
Trail 1	–	.77*	.74*	.76*	.69*	.89*
Trail 2	.71*	–	.77*	.66*	.71*	.87*
Trail 3	.59*	.81*	–	.85*	.81*	.93*
Trail 4	.50	.69*	.69*	–	.78*	.91*
Trail 5	.59*	.57*	.61*	.73*	–	.89*
Composite Index	.82*	.90*	.87*	.84*	.82*	–

Note: *$p < .001$.

Table 3
Correlations between CTMT scores and clinical variables for the TBI group ($n = 30$)

CTMT	Glasgow Coma Scale		Time since injury	
	r	*p*	*r*	*p*
Trail 1	−.38	.04	−.04	.42
Trail 2	−.46	.02	.22	.12
Trail 3	−.38	.04	.35	.03
Trail 4	−.18	.22	.32	.05
Trail 5	−.26	.13	.13	.25
Composite Index	−.36	.05	.25	.10

Note: Significance levels (p) are for one-tailed tests.

correlations were used. Results of the analyses are presented in Table 3. Results indicated significant correlations between the GCS and CTMT Trails 1, 2, and 3, as well as the composite index ($p < .05$). Significant correlations were also present between time since injury and CTMT Trails 3 and 4 ($p < .05$).

Finally, the sensitivity and specificity of each trail of the CTMT and the composite index were examined using receiver operating characteristic (ROC) analyses. Results of the ROC analyses are presented in Table 4, including the area under the ROC curves (AUCs), as well as standard errors and confidence intervals. Results indicated that all of the CTMT scores provided a significant increase in classification accuracy over chance ($p < .0001$). The AUC is a general indicator of the CTMT scores' ability to distinguish between the TBI and HC groups. An AUC of 1.0 indicates perfect classification while an AUC of 0.5 indicates classification no better than chance. AUCs between .80 and .90 are considered to be indicative of "good" classification accuracy (see Hosmer & Lemeshow, 2000). Therefore, the AUCs in the current study indicate good predictive discrimination between individuals with, and without, TBI. Fig. 1 presents the ROC curves for CTMT Trails 4 and 5 as well as the composite index score. These three curves are presented because they have the highest overall classification accuracy (largest AUCs) and all three have essentially the same shape. Pairwise comparisons among the curves were conducted to determine if the differences between AUCs were significant (Hanley & McNeil, 1983). The only significant difference occurred between the AUC for the composite index in comparison to Trail 2 (difference = −.060, $p < .05$), indicating that the AUC for the composite index was significantly larger than for the Trail 2 score.

Table 4
Results of the ROC analyses for the CTMT trails and composite index

Curve	AUC	S.E.	95% CI of area
CTMT Trail 1	0.82	0.056	0.71–0.93
CTMT Trail 2	0.81	0.057	0.70–0.92
CTMT Trail 3	0.83	0.053	0.72–0.93
CTMT Trail 4	0.85	0.053	0.75–0.95
CTMT Trail 5	0.87	0.047	0.78–0.97
CTMT Composite	0.87	0.049	0.77–0.96

Note: AUC = area under curve, $p < .001$ for all AUCs.

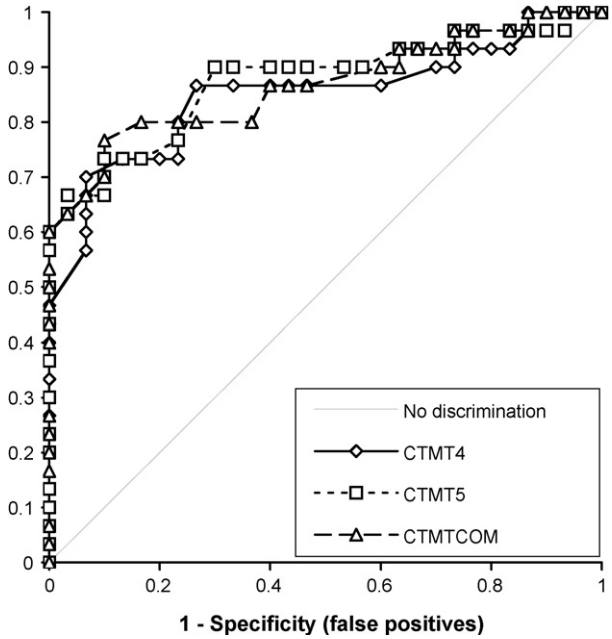

Fig. 1. Receiver operating characteristic curves CTMT Trail 4 (CTMT4), Trail 5 (CTMT5), and the Composite Index (CTMTCOM), for differentiating between individuals with and without traumatic brain injury.

Table 5
Receiver operator characteristic analysis for the CTMT composite index score

Index score	Sensitivity	Specificity	TP	TN	FP	FN
16	0.0	100.0	0	30	0	30
20	20.0	100.0	6	30	0	24
25	40.0	100.0	12	30	0	18
30	50.0	100.0	15	30	0	15
35	60.0	100.0	18	30	0	12
40	76.7	90.0	23	27	3	7
45	80.0	63.3	24	19	11	6
50	90.0	40.0	27	12	18	3
56	93.3	30.0	28	9	21	2
61	96.7	26.7	29	8	22	1
65	96.7	13.3	29	4	26	1
71	100.0	10.0	30	3	27	0

Note: Sn = sensitivity; Sp = specificity; TP = true positives; TN = true negatives; FP = false positives; FN = false negatives. Specificity and sensitivity are reported as percentages, while TP, TN, FP, and FN are the number of individuals in the TBI group ($n = 30$) or the HC group ($n = 30$) who are correctly or incorrectly classified.

Table 5 contains sensitivity and specificity estimates, as well as true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN) for CTMT composite index scores corresponding to approximately .5 standard deviation increments for the CTMT *T*-scores. These scores can be useful in determining appropriate cut points based on a particular testing situation. Sensitivity and specificity estimates in the table are percentages, while TP, TN, FP, and FN are number of cases in each category. For example, if a CTMT composite index score of 40 is used as the cut point, 23 of the 30 TBI participants were correctly classified as brain damaged (TPs), and 27 of the 30 healthy controls are correctly classified (TNs), yielding sensitivity and specificity estimates of .77 and .90, respectively.

3. Discussion

The current study examined sensitivity of the CTMT to identify neurocognitive deficits in a sample of adolescents with TBI. When compared to a matched group selected from the CTMT standardization sample, the TBI adolescent

group performed much worse on all CTMT scores that were examined, obtaining scores that were roughly 2 standard deviations below the comparison sample mean. Thus, the CTMT appeared to be sensitive in detecting TBI in adolescents, supporting its criterion validity. This performance was expected based on the extensive literatures that have demonstrated the sensitivity of the child and adult versions of the TMT to various forms of brain dysfunction (Reitan, 1955, 1971; Reitan & Wolfson, 2004). Additional evidence was provided regarding sensitivity of the CTMT to severity of brain injury through correlations with clinical variables, such as GCS scores and time since injury. For both of these variables, some but not all of the CTMT scores evidence significant positive correlations possibly suggesting that some of the CTMT scores are more sensitive than others to severity of brain injury.

While factor analysis of the CTMT could not be accomplished in this TBI sample due to limited sample size, the pattern of correlations between the individual trails were examined. The general pattern was for the TBI sample to obtain somewhat higher correlations than the HC groups, with notable differences present between the groups for the correlations between Trails 1 and 4, and Trails 3 and 5, with the TBI group obtaining higher correlations in both cases. Factor analysis of the standardization sample data identified two factors for the CTMT, with the first composed of Trails 1 through 3 (i.e., simple sequencing), and the second composed of Trails 4 and 5 (complex sequencing). Given the apparent differences in pattern of correlations between the TBI and HC groups, it may also be that the factor structure of the CTMT varies as a result of neurological condition. Because some variation in factor structures of other intellectual and neuropsychological measures have been found for various populations (e.g., compare Allen et al., 1998; Burton, Ryan, Paolo, & Mittenberg, 1994, and Ward, Ryan, & Axelrod, 2000) the present preliminary findings in this TBI sample suggest that further examination of the CTMT factor structure in clinical populations is warranted.

With regard to sensitivity and specificity, ROC analyses indicated that the CTMT provided good classification of TBI and HC cases. Some differences were present between the CTMT trails with regard to classification accuracy, with Trail 5 and the composite index providing the best overall classifications. Part B of the original TMT is more sensitive to brain damage than Part A, and so the increased sensitivity of Trail 5 to brain damage might be expected given that it is the most similar of the CTMT trails to the TMT Part B. The Composite Index performs equally well to Trail 5 and provides a more reliable index of neurocognitive function because it is based on multiple trails. In comparison to the adult and child versions of the TMT, the CTMT appears to evidence comparable levels of sensitivity and specificity (Mittelmeier, Rossi, & Berman, 1989; Reitan, 1955; Reitan & Wolfson, 2004), although direct comparisons among studies are difficult to achieve because of differences in the scaling of the tests, particularly as it regards age corrections and standardization of raw scores for the CTMT. The findings are also consistent with the observation that as with the TMT, the number of individuals who are erroneously classified as brain damaged is expected given the variability in factors relevant to neuropsychological test performance such as intelligence in unselected control groups like the one used here (Reitan & Wolfson, 2004). Of course, misclassification of some of the TBI participants as non-brain injured is also anticipated because it is probably not reasonable to expect that a single test could approach perfect classification even when it has been demonstrated to be sensitive to the effects of brain damage through group comparisons (Reitan & Wolfson, 2004).

Although significant differences were present between the HC and TBI groups on all of the CTMT scores that were examined, the relatively small sample size of the TBI group precluded the finding of differences between the AUCs in the ROC analyses, with the exception of the difference between the composite index and Trail 2 (Hanley & McNeil, 1982). It is also the case that given this sample was composed of individuals who sustained moderate to severe brain injury, the performance of the CTMT in less severely injured cases has yet to be determined. However, given that there were significant correlations between CTMT scores and variables reflecting severity of impairment, it might be expected that the sensitivity and specificity of the CTMT would decrease when cases reflected mild injury. Finally, while the intent of this investigation was to provide the first evaluation of the CTMT in adolescents with brain injury, the mean age of individuals in the TBI group was 15.0 years old, with the youngest 11 years of age. While the age of the current sample was constrained by the lower limit of the CTMT normative sample (11 years), the present results are applicable to adolescents and additional research with younger children is needed. Nevertheless, the current findings support the CTMT's utility in TBI. Of course, continued research investigating its psychometric properties in adults and children with other neurological disorders would be useful. With regard to sensitivity to brain damage in other neurological disorders, many studies have shown that the TMT is sensitive to anterior and posterior lesions in the right and left hemispheres as well as to heterogeneous forms of brain damage (e.g., Goldstein & Neuringer, 1966; Reitan & Wolfson, 1995). Whether the CTMT will exhibit similar sensitivity remains to be seen, although given the similarities between the CTMT and the TMT, it would be expected that the CTMT may provide a more general indication of the

biological status of the brain rather than to any particular lesion location or neuropathology. It is important to point out that the present results cannot address the issue of the CTMT's unique sensitivity to frontal lobe damage. However, the results do provide support for its sensitivity to TBI, which is characterized by more diffuse damage, and in this sense, are consistent with prior research with the TMT that suggests it is a good indicator for the overall integrity of the biological status of the brain. Future research with the CTMT will need to be conducted with other brain damaged groups to assist in determining if the CTMT is more appropriate as a screening instrument, specialized assessment tool to assist in localizing TBI (i.e., frontal lobe), or can be used for both purposes.

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