Outcome Measure	**Comprehensive Trail-Making Test (TMT)**
Sensitivity to Change	Yes
Population	Pediatrics
Domain	Neuropsychological Impairment
Type of Measure	Objective test
ICF-Code/s	B1
Description	The TMT is a measure of general brain function (see Reitan, 1979). Although trail making tests are very simple, they have been hypothesized to reflect a wide variety of cognitive processes including attention, visual search and scanning, sequencing and shifting, psychomotor speed, abstraction, flexibility, ability to execute and modify a plan of action, and ability to maintain two trains of thought simultaneously (Lezak, Howieson & Loring, 2004; Salthouse & Fristoe, 1995, and Strauss, Sherman & Spreen, 2006). Performance on the TMT is considered a robust correlate of overall measures of intelligence (Waldmann, Dickson, Monahan & Kazelskis, 1992; Steinberg, Bieliauskas, Smith & Ivnik, 2005) and a particularly sensitive indicator of neurological impairment (Reitan & Wolfson, 2004). The Trail Making Test was originally designed for use with adults. However, it has been updated to include a child version. This test is only useful for children between 9 and 14 years of age. Neyens and Aldenkamp (1996) revealed that the child version did not demonstrate the same sensitivity as the adult version. Neyens and Aldenkamp (1996) found test–retest reliability coefficients of .33 (Part A) and .56 (Part B) for the child and adolescent version of the TMT. These coefficients were derived from a sample of 59 typically developing children between the ages of 4 and 12 who were tested a total of three times with 6-month intervals between testing sessions. Neyens and Aldenkamp (1996) revealed that the child version did not demonstrate the same sensitivity as the adult version. Neyens and Aldenkamp (1996) found test–retest reliability coefficients of .33 (Part A) and .56 (Part B) for the child and adolescent version of the TMT. These coefficients were derived from a sample of 59 typically developing children between the ages of 4 and 12 who were tested a total of three times with 6-month intervals between testing sessions. **Comprehensive Trail Making Test (CTMT):** Given the low reliabilities of the adult and children's versions of the TMT, frequent use of adult measures for children, and limited validity studies with children, The Comprehensive Trail Making Test (CTMT; Reynolds, 2002) was designed to include children in the standardization and to off-set many of the psychometric deficiencies of the original TMT. The CTMT utilizes five trails instead of two and provides a nationally normed sample that includes children down to the age of 11. The five trails of the CTMT increase at various levels of difficulty to measure resistance to distraction, inhibition, task switching, and cognitive flexibility (Reynolds, 2002). According to Reynolds (2002), the CTMT is specifically useful for detecting "frontal lobe

	deficits, problems with psychomotor speed, visual search and sequencing, and attention; and impairments in set-shifting” (p. 5). The CTMT procedure consists of five trials that are designed to highlight and isolate specific components of performance. Some of the CTMT trials present extraneous stimuli that must be ignored so that they do not distract the respondent from the target stimuli. Other trials of the CTMT provide some Arabic numerals as target stimuli (e.g., “9”) and some written number words as stimuli (e.g., “nine”). Switching between numerical and lexical cues from one stimulus to the next in a manner that is not readily predictable requires greater selective visual cue perception, more mental flexibility and greater sustained attentional ability than the original TMT tasks. Reynolds (2002) explains that the CTMT Trial 1 is an analog procedure to the original TMT— Part A procedure. As such it is heavily dependent on sustained attention, as well as basic sequencing and visual–spatial scanning skills. CTMT trials 2 and 3 increase the complexity of the sustained attention and visual search features of the task by adding simple (Trial 2) and both simple and complex (Trial 3) distractor stimuli to the visual array. The subject must sustain attention and focus attention selectively on the target stimuli for these trials. Introduction of both numerical and lexical number stimuli as targets on CTMT Trial 4 in a random alternation sequence requires the subject to seek the next logical target stimulus regardless of its appearance. More cognitive flexibility is required to complete this task than was necessary on the prior trials. CTMT Trial 5 in part mimics the original TMT—Part B alphanumeric alternation sequence, but it adds the additional difficulty component of empty distractor circles. **How it’s administered:** The five trials of the CTMT procedure are described in the test manual as follows (Reynolds, 2002, p. 2): “Trial 1. The examinee draws a line to connect in order the numbers 1 through 25, each contained in a plain black circle.” “Trial 2. The examinee draws a line to connect in order the numbers 1 through 25, each contained in a plain black circle. Twenty-nine empty distractor circles appear on the same page.” “Trial 3. The examinee draws a line to connect in order the numbers 1 through 25, each contained in a plain black circle. Thirteen empty distractor circles and 19 distractor circles containing irrelevant line drawings appear on the same page.” “Trial 4. The examinee draws a line to connect in order the numbers 1 through 20, where 11 of the numbers are presented as Arabic numerals (e.g., 1, 7) and the remaining numbers are spelled out in English language form (e.g., Nine).” “Trial 5. The examinee draws a line to connect in alternating sequence the numbers 1 through 13 and the letters A through L, beginning with 1 and drawing a line to A, then 2, then B, and so on until all numbers and letters are connected. Fifteen empty distractor circles appear on the same page.”
Properties	All internal consistency values for the five CTMT trial measures meet or exceed a value of .70, and the reliability value for the Composite Index

	score is .92. Internal consistency estimates of .80 or higher are reported for composite samples of elderly subjects, some ethnic minority groups, and a sample of stroke patients. Test–retest reliability values for the five trials of the CTMT range from .70 to .78, which are quite high values for a speeded measure. Interrater reliabilities are exceptionally high for the five trials of the CTMT (range .96–.98). MANOVA indicated that there was a significant difference between the TBI and control groups on the CTMT trails, $F(5, 236) = 31.6$, $p <.001$, partial n2 = .401. Significant differences ($p < .0001$) between the TBI and control groups were present for all CTMT trail scores. ANOVA also indicated significant differences between the groups for the composite index. Large effect sizes (Cohen's d) were also present for all CTMT scores. The control group's scores approximated the standardization sample mean, and the TBI group's scores fell approximately 1.5 standard deviations below the control group on most CTMT scores, with the composite index score placing them in the mildly to moderately impaired range of performance on the basis of recommended cut offs in the test manual (Reynolds, 2002). To determine whether differences in injury severity were accounting for differences among the age-level groups on the CTMT composite index, a Kruskal–Wallis test was used to compare the four age levels on Glasgow Coma Scale (GCS) scores, which were available for 80 of the TBI participants. Results were not significant, Kruskal– Wallis(3) = 4.35, $p = .23$. However, Spearman correlations calculated between the GCS scores and the CTMT composite index for the entire TBI group indicated significant correlations for Trail 3, $r(80) = .24$, $p = .03$, and for Trail 5, $r(80) = .24$, $p = .03$, suggesting that more severe injury, as reflected by lower scores on the GCS, was also associated with lower CTMT scores on these trails.
Advantages	• Easy to administer. • No clinical training is necessary. • Tests, specific cognitive processes (i.e, processing speed and cognitive flexibility). • Normative information is available, especially for children aged 11+ • CTMT has excellent internal, test-retest and interrater reliability. • Specific research have looked at TBI in children with significant main effects • Can be used to determine injury severity
Disadvantages	• CTMT is paid • Instructions can be confusing for some individuals. • Can be frustrating for people who lose track of where they are and cannot proceed. Participants who are very cognitively impaired may not

	be able to complete the task, which must be dealt with statistically (e.g., set a maximum time for noncompleters). • Test doesn't give a clear indication of function which is impaired, this needs to be interpreted. • The examiner must carefully monitor a participant's performance to accurately score errors. The reliability of test administration can vary by examiner's reaction time in noticing errors and pointing them out, which introduces imprecision. • More severe motor impairment may influence results.
Additional Information	The TMT for children was a revised version of the adult TMT. Due to the lower sensitivity and test-retest reliability of the child version, it is recommended that the CTMT be used instead.
Reviewers	Vicki Anderson Cathy Catroppa

References

Armitage, S. G. (1946). An analysis of certain psychological tests used for the evaluation of brain injury. *Psychological Monographs, 60*(1), i.

Bornstein, R., Baker, G., & Douglass, A. (1987). Short-term retest reliability of the Halstead-Reitan Battery in a normal sample. *The Journal of nervous and mental disease, 175*(4), 229-232.

DesRosiers, G., & Kavanagh, D. (1987). Cognitive assessment in closed head injury: Stability, validity and parallel forms for two neuropsychological measures of recovery. *International Journal of Clinical Neuropsychology*.

Dikmen, S. S., Heaton, R. K., Grant, I., & Temkin, N. R. (1999). Test–retest reliability and practice effects of expanded Halstead–Reitan Neuropsychological Test Battery. *Journal of the International Neuropsychological Society, 5*(04), 346-356.

Ehrenstein, W. H., Heister, G., & Cohen, R. (1982). Trail Making Test and visual search. *Archiv für Psychiatrie und Nervenkrankheiten, 231*(4), 333-338.

Heilbronner, R. L., Henry, G. K., Buck, P., Adams, R. L., & Fogle, T. (1991). Lateralized brain damage and performance on trail making A and B, digit span forward and backward, and TPT memory and location. *Archives of Clinical Neuropsychology, 6*(4), 251-258.

Lezak, M. D. (2004). *Neuropsychological asessment 4 Ed*: Oxford university press.

Matarazzo, J. D., Wiens, A. N., Matarazzo, R. G., & Goldstein, S. G. (1974). Psychometric and clinical test-retest reliability of the Halstead Impairment Index in a sample of healthy, young, normal men. *The Journal of nervous and mental disease, 158*(1), 37-49.

Sanchez-Cubillo, I., Perianez, J., Adrover-Roig, D., Rodriguez-Sanchez, J., Rios-Lago, M., Tirapu, J., & Barcelo, F. (2009). Construct validity of the Trail Making Test: role of task-switching, working memory, inhibition/interference control, and visuomotor abilities. *Journal of the International Neuropsychological Society, 15*(3), 438.

Strauss, E. H. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary*: Oxford University Press.

Wilde, E. A., Whiteneck, G. G., Bogner, J., Bushnik, T., Cifu, D. X., Dikmen, S., . . . Malec, J. F. (2010). Recommendations for the use of common outcome measures in traumatic brain injury research. *Archives of Physical Medicine and Rehabilitation, 91*(11), 1650-1660. e1617.