VALIDATION OF A TRAIL-MAKING TEST DEVELOPED FOR *iPad*

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Introduction

The Trail Making Test (TMT) is a neuropsychological test of visual attention and task switching. It can provide information about visual search speed, scanning, speed of processing, mental flexibility, as well as executive functioning. It is also sensitive to detecting several cognitive impairments such as Alzheimer's Disease and Dementia.

Traditionally, this test is conducted on an A4-sized paper by using a pencil. Participants are asked to connect 25 randomly arranged encircled numbers (Part A) in the correct order. In Part B, the participants have to draw lines alternating between a total of 25 encircled numbers and letters. The TMT is scored by measuring the time for completion of each part and by calculating the difference [Part B – Part A]. The difference between the two parts is often used to remove the speed element from the test evaluation, as a measure of executive function.

We developed an iPad version for the Trail Making Test (Trails).[1] The objective of this study was to investigate the psychometric properties of Trails as a measurement tool.

Methods

Fifty-eight cognitively intact community-dwelling older people, aged 70 years or over, were assessed on the traditional pen-and-paper Trail Making Test (TMT) in conjunction with the developed iPad version of the test (Trails).

All participants were also assessed on the Addenbrooke's Cognitive Examination III (ACE-III), which is a brief cognitive assessment including five domains of cognitive function: attention, memory, verbal fluency, language, and visuospatial abilities.[2] The total score is 100 with higher scores indicating better cognitive functioning. Two components of the Physiological Profile Assessment (PPA) were used to assess simple hand reaction time (ms) and contrast vision sensitivity using the Melbourne Edge Test.[3]

[1] www.neura.edu.au/apps/trails
[2] www.neura.edu.au/frontier/research/test-downloads
[3] www.neura.edu.au/fbrg#The-physiological-assessments

Results

The mean age of participants was 79.2 years (SD 4.1) and 39 (67%) participants were female (Table 1). Participants had on average 12 years (SD 3.5) of education. Participants had a mean Body Mass Index (BMI) of 27 kg/m^2 (SD 4.2) and used just over four medications (SD 2.7). Sixteen (28%) participants reported to have fallen at least once in the previous year.

Table 1. Demographic characteristics of the sample (N=58)

	Mean ± SD or number (%)
Age (years)	79.2 ± 6.1
Women (n)	39 (67%)
Education (years)	12.4 ± 3.5
BMI (kg/m^2)	27.0 ± 4.2
Number of medications (n)	4.4 ± 2.7
Fall history (n)	16 (28%)

Table 2 summarizes scoring of Trail Making Test using the pen-and-paper version and the iPad version. It shows the means and standard deviation, median with range, minimum and maximum scores, and distributions (skewness and kurtosis) for our population. Distributions of both TMT versions were skewed to the right.

Table 2. Times on the trail-making test (TMT) on iPad and paper versions of part A, part B and B minus A

	Min	Max	Mean (SD)		Median (Range)		Skewness (SEM)		Kurtosis (SEM)	
Trail Making Test - Part A										
iPad version (s)	22	102	40.3	(17.7)	36.9	(79.7)	1.85	(0.31)	3.56	(0.62)
Paper version (s)	21	147	47.6	(22.0)	44.3	(126.3)	2.45	(0.31)	7.95	(0.62)
Trail Making Test - Part B										
iPad version (s)	34	320	111.7	(58.9)	99.8	(286.0)	1.54	(0.31)	2.32	(0.62)
Paper version (s)	48	320	126.6	(61.8)	110.2	(271.6)	1.33	(0.31)	1.26	(0.62)
Trail Making Test - B minus A										
iPad version (s)	8	243	71.4	(46.6)	60.1	(235.3)	1.62	(0.31)	3.02	(0.62)
Paper version (s)	3	230	79.0	(51.6)	64.8	(227.0)	1.48	(0.31)	1.79	(0.62)

Correlations between the two TMT versions were all significant at $p<0.001$ and ranged between 0.448 for TMT Part A and 0.826 for TMT Part B (Table 3).

Table 3. Correlations between Trail-making test (TMT) times on iPad and paper versions

		Paper		
		TMT - Part A	**TMT - Part B**	**TMT - B minus A**
iPad	**TMT - Part A**	0.448 (p<0.001)	0.585 (p<0.001)	0.508 (p<0.001)
	TMT - Part B	0.630 (p<0.001)	0.826 (p<0.001)	0.719 (p<0.001)
	TMT - B minus A	0.627 (p<0.001)	0.822 (p<0.001)	0.716 (p<0.001)

Table 4 shows the mean differences between the two versions. There was a mean difference of 7.2 seconds (SD 21.2) on the TMT Part A, in which participants are slower on the pen-and-paper version when compared to the iPad version (p=0.012). Participants were also slower on the TMT Part B using the pen-and-paper version when compared to the iPad (p=0.002), with a mean difference of 14.9 second (SD 35.3). This difference between the two versions was no longer significant when using TMT B minus A (p=0.123).

Table 4. Differences (Mean, SD) between Trail-making test (TMT) times on paper versus iPad versions of TMT part A, part B and B minus A

	Mean	SD	95% CI	t	p
TMT - Part A (s)	7.3	21.2	1.7 – 12.8	2.6	0.012
TMT - Part B (s)	14.9	35.7	5.5 – 24.3	3.2	0.002
TMT - B minus A (s)	7.7	37.3	-2.1 – 17.5	1.6	0.123

Note: Participants are slower using the TMT pen-and-paper version when compared to the iPad version

Finally, good discriminant validity was confirmed relating to cognitive performance, simple hand reaction time and contrast vision sensitivity (Table 5). TMT scores were significantly higher in participants who score worse on the global cognitive function (ACE-III) and its subdomains of attention, fluency and visuospatial. These between-group differences were similar for both the traditional pen-and-paper version of the TMT and the iPad version. There were no between-group differences based on contrast vision sensitivity.

Conclusion

This initial validation study showed that the Trail-Making Test for iPad (Trails) has excellent psychometric properties and is congruent with the traditional pen-and-paper version. Significant attributes of Trails are that it automates the process of collecting results, timing and error checking facilitating quicker and more accurate testing of participants. Results are exported in the easy-to-read comma separated value format. The summary files are natively supported by Microsoft Excel, SPSS Matlab and many other data analysis programs.

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Table 5. Mean and Standard Deviation (SD) of Trail-making test (TMT) times on paper versus iPad versions of TMT part A, part B and B minus A for Subgroups Based on cognitive performance, simple hand reaction time (HRT) and contrast vision sensitivity (median split)

		Measure		TMT-A (iPad)		TMT-A (paper)		TMT-B (iPad)		TMT-B (paper)		TMT-B-A (iPad)		TMT-B-A (paper)	
		Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
Ace-III total (0 to 100)	*worse*	84.6	(6.4)	46.8	(21.6)	56.7	(26.7)	141.0	(67.1)	152.7	(68.0)	94.1	(52.7)	96.0	(57.5)
	better	94.8	(2.2)	33.8	(9.0)***	38.4	(10.2)***	82.4	(28.1)***	100.5	(41.7)***	48.6	(24.0)***	62.1	(39.0)**
Attention (0 to 100)	*worse*	87.0	(7.0)	46.4	(21.5)	52.7	(27.2)	135.6	(64.5)	146.8	(70.7)	89.2	(49.6)	94.1	(59.8)
	better	96.7	(16.7)	34.2	(9.6)**	42.4	(14.0)^	87.8	(41.5)**	106.4	(43.9)*	53.6	(36.1)**	64.0	(37.2)*
Memory (0 to 100)	*worse*	83.6	(11.0)	42.2	(19.7)	46.3	(16.9)	108.6	(55.4)	127.7	(59.3)	66.4	(41.2)	81.4	(53.5)
	better	97.7	(2.0)	37.0	(13.1)	49.9	(29.4)	117.2	(65.7)	124.7	(67.4)	80.2	(54.9)	74.9	(49.1)
Fluency (0 to 100)	*worse*	66.3	(14.0)	43.9	(19.6)	53.9	(23.9)	127.0	(63.5)	142.7	(62.4)	83.1	(50.3)	88.8	(52.2)
	better	91.2	(4.6)	33.0	(9.6)**	34.6	(8.1)**	80.3	(30.7)**	93.5	(46.4)**	47.4	(25.1)**	58.9	(45.4)*
Language (0 to 100)	*worse*	91.9	(5.8)	43.1	(19.3)	48.1	(25.0)	120.0	(65.5)	131.5	(66.6)	76.9	(52.0)	83.4	(52.5)
	better	100.0	(0.0)	33.7	(10.5)^	46.3	(12.7)	91.8	(32.2)^	114.9	(48.1)	58.0	(26.6)^	68.5	(49.3)
Visuospatial (0 to 100)	*worse*	86.8	(11.1)	46.8	(20.8)	54.6	(26.2)	135.7	(66.3)	146.0	(67.8)	88.9	(52.7)	91.4	(59.2)
	better	100.0	(0.0)	32.3	(7.2)***	39.0	(10.8)**	82.1	(28.6)***	102.8	(44.0)**	49.8	(25.3)***	63.8	(36.0)*
HRT (ms)	*worse*	200.6	(13.9)	36.7	(16.5)	43.5	(22.6)	103.1	(58.6)	108.7	(59.5)	66.4	(46.9)	65.2	(47.9)
	better	265.2	(51.0)	43.9	(18.3)	51.6	(21.1)	120.3	(59.0)	144.5	(59.8)*	76.4	(46.6)	92.9	(52.3)*
Contrast vision (dB)	*worse*	20.4	(1.3)	37.1	(13.6)	43.4	(11.9)	108.6	(54.6)	125.1	(62.5)	71.5	(46.0)	81.7	(58.6)
	better	23.1	(0.4)	44.9	(21.6)	53.5	(30.6)	116.1	(65.5)	128.8	(62.1)	71.2	(48.4)	75.3	(40.6)

*Note: *** p≤0.001; ** p≤0.010; * p≤0.050; ^ p≤0.100*