Development and Standardisation of the Computerised Finger Tapping Test: Comparison with other finger tapping instruments

Muriel K. Christianson & Janet M. Leathem
School of Psychology, Massey University, Wellington

The finger-tapping test is a neuropsychological test that assesses motor speed and motor control. The purpose of this study was to obtain normative data for a computerised finger-tapping instrument and to compare it to other traditional finger tapping devices. Eighty-six non-clinical volunteers were tested on the Computer Finger Tapping Test (CFTT), the Western Psychological Services (WPS) digital finger-tapping test (DFTT), and another manual finger tapping test developed by Massey University (MUFTT). Eighty of these participants were also tested on the Halstead-Reitan finger-tapping test (HRFTT). This sample of volunteers was stratified according to gender and age, with four age groups ranging from 16 to 70 years. Correlations between the four tapping tests were high. The CFTT showed similar psychometric properties to those of the other three tapping tests. As expected, higher tapping scores were obtained using the dominant hand, males obtained higher scores than females, and there was a decrease in tapping speed associated with increasing age.

The Finger Tapping Test (FTT), originally developed as part of the Halstead Reitan Battery (HRB) of neuropsychological tests, is a simple measure of motor speed and motor control (Mitrushina, Boone & D'Elia, 1999) and is used in neuropsychology as a sensitive test for brain damage. Although motor functioning in humans is controlled by many areas of the brain, the motor strip rostral to the central sulcus is most important, and the functioning of this area is reflected directly in the FTT (Russell, Neuringer & Goldstein, 1970). As well as direct motor effects, the speed, co-ordination, and pacing requirements of finger tapping can be affected by levels of alertness, impaired ability to focus attention, or slowing of responses. By examining both level of performance and by comparing the two sides of the body, tests of motor performance can be used as reliable indicators of the integrity of brain functions (Dodrill, 1978).

Recent studies have reported impairment of FTT performance in populations with Alzheimer's disease (Wefel, Hoyt & Massama, 1999); traumatic brain injury (Geldmacher & Hills, 1997); and schizophrenia (Flashman, Flaum & Andreason, 1996). The FTT was used in earlier studies to investigate the effects of lithium carbonate in bipolar patients (Shaw, Stokes, Mann & Manevitz, 1987), relapsing-remitting and chronic-progressive multiple sclerosis (Heaton, Nelson & Thompson, 1985), psychiatric disorders in adults (Heaton, Baade & Johnson, 1978), and paint sniffing (Tsushima & Towne, 1977). These studies have shown that both neurological and psychological pathology can impact significantly on motor speed, which may limit performance in other functional areas.

The relationship between age and neuropsychological test performance has long been recognised (Bornstein, Paniak & O'Brien, 1987) and in a study of a number of neuropsychological measures administered to a non-clinical sample, finger tapping gave the strongest correlation with age (Bornstein, 1985). Males tend to perform better than females on tests of strength and fine-motor speed (Leckliter & Matarazzo, 1989). Nicholson & Kimura (1996) observed that men were significantly faster than women at tapping with a single finger, and concluded that the speed advantage in men was related to the relative increase in the amount of fast-twitch muscle at puberty. On average, men experienced no significant decline in finger-tapping speed with increasing age, while women's performance decreased with increasing age (Ruff & Parker, 1993).

The principle of contralateral control operates for both motor and sensory functioning, with representation in the brain opposite the location in the body (Russell et. al., 1970). Generally, performance with the preferred hand is superior to that of the non-preferred hand. Following brain injury performance tends to be worse in the hand contralateral to the lesion (Spreen & Strauss).

Various finger-tapping devices have been developed in order to record finger-tapping speed. The most commonly used device is a tapping lever mounted with a key driven mechanical counter (Mitrushina et. al., 1999). The instrument is available from Psychological Assessment Resources (PAR) Inc., and from the Reitan Neuropsychological Laboratory (parinc.com, 2001). There are also electronic and software versions such as the Digital Tapping Test, available from Western Psychological Services (WPS), which consists of a device with an electronic switch and a digital counter (wpspublish.com, 2001). WPS also have available a software only version where the zero on the number keypad is used as the tapping device. A new device described by Coleman, Moberg, Ragland & Gur (1997) is a Light Beam Finger and Foot Tapper Test (NeuroCognitive Engineering, 1995), which employs photo diodes sensitive to infrared light, placed on top of a tapping board.

The aim of the current study was to develop and trial a new finger tapping device on a New Zealand population. The new device, the Computer Finger Tapping Test (CFTT), produced locally at fraction of the cost of the devices imported from overseas would be compared to the original manual Halstead-Reitan Finger Tapping Test (HRFTT), the Western Psychological Services Digital Finger Tapping Test (DFTT) and another manual tapping device developed by Massey University (MUFTT). The CFTT would be easy to administer and would be consistent across testers. Concurrent validity for the CFTT would be established by correlating the scores of participants on the CFTT with their scores on each of the other three finger tapping tests. All finger tapping devices, including the CFTT, measure the motor speed of the index finger of each hand by counting and averaging the number of taps that a participant can perform in a ten-second time frame and therefore have construct, content and face validity. As age and gender impact on finger-tapping scores, the study assessed finger-tapping ability in male and female participants ranging in age from 16 to 70 years. Education, which has not been found to impact on finger tapping speed (Finlayson, Johnson & Reitan, 1977; Ruff & Parker, 1993), was not considered in the study.

Specific hypotheses were as follows: there would be a decrease in tapping speed with increasing participant age; males would demonstrate faster tapping speeds than females; and a higher average tapping speed would be obtained with the dominant hand.

Method

Participants

Participants were 86 volunteers (43 men, 43 women) divided into four age groups as follows: 16 – 24 years (13 men, 13 women), 25 – 39 years (7 men, 10 women), 40 – 54 years (11 men, 15 women), and 55 – 70 years (12 men, 5 women). Participants were asked to identify their dominant hand, and where ambiguity occurred, were asked which hand they preferred for writing. Dominant hand was right for 84.4% and left for 15.6% of participants. Participants were asked whether they had any history of Occupational Overuse Syndrome (OOS) with either hand, or a neurological disorder that might affect their ability to tap with the index finger. If these conditions were present, they were excluded from the study. Participants were recruited from the Wellington, Hutt Valley and Horowhenua regions of New Zealand. Letters and information sheets for recruitment of volunteers were sent out to various organisations, including Hutt Valley High School, Massey University (Wellington and Palmerston North), Senior Citizens' groups from Wellington and the Lions' Community group from Eastbourne.

Instruments

All versions of the FTT use a tapping device that records the number of taps performed by a subject over a series of ten-second intervals. The finger tapping score is computed for each hand separately and is the mean of five consecutive 10-second trials (Spreen & Strauss, 1998). The trials included should not differ from each other by more than five taps. Up to ten trials are permitted in order to obtain this average. If this criterion is not met, then the score is the average of the best five trials.

Variations in administration instructions for the FTT, or in devices used, can impact on the interpretation of test results. There can be ambiguity concerning the deletion of deviant trials or the maximum number of permissible trials, which may affect results. There is also a lack of clarity in the manual for the HRB concerning the provision of rest periods following the third trial as to whether these are optional or mandatory (Snow, 1987). Finger tapping speed can vary depending on which instrument is used (Coleman et. al., 1997; Snow, 1987) due to variations in the ease with which a tap may be completed.

Four versions of the FTT were compared in this study, the Halstead-Reitan mechanical Finger Tapping Test (HRFTT), the WPS Digital Finger Tapping Test (DFTT); a mechanical tapping test developed at Massey University (MUFTT) and the Computer Finger Tapping Test (CFTT) which was developed for this study. The HRFTT and MUFTT consist of a rectangular board, on which is mounted a small tapping lever, attached to a rotating counter. This device is used to record the number of taps that occur in a 10-second trial. A stopwatch is used for timing trials. The DFTT consists of a tapping switch mounted on a small rectangular box, which has a digital display. Timing is built into the instrument and commences from the first tap of a trial. Once a trial is completed, the number of taps appears on the digital display. Norms for the HRFTT and DFTT are shown in Table 1.

The computer administered CFTT comprises a tapping switch and red and green indicator lights mounted on a small rectangular box that can be connected to a computer port. Once the test is started, the green indicator light comes on and the participant can commence the tapping trial. Timing starts from the first tap and the software records the number of taps for each trial. A red light and a ringing sound are used to signal when tapping should cease. The green light is then used to show when the second trial can commence. Trials continue until five consecutive trials are obtained that meet the criteria for range restriction, with a maximum of ten trials. The dominant hand is tested first, followed by the non-dominant hand. Provision is made for recording a participant's name, age, gender, dominant hand and relevant information. The software programme provides the mean and standard deviation of the five selected trials. As the CFTT controls rest times and tap counting, standardised administration and accurate scoring across examiners is ensured. This instrument is moderately inexpensive. The software to accompany the instrument is supplied on a disc.

For the purposes of the study, provision was made in the CFTT software programme, for four recording screens, one for each instrument. The number of taps for each trial was recorded on the screen. Once 5 valid trials were recorded for each hand, the screen displayed the average and standard deviation. A 10-second timer, built into the CFTT software programme, was used for timing the HRFTT and MUFTT instruments.

Procedure

The order in which the instruments were tested was randomised for each participant. Participants familiarised themselves with each instrument, making any necessary corrections to technique, prior to commencing testing. It was important to tap with the index finger of each hand, rather than to use a wrist or arm action. The dominant hand was tested first followed by the non-dominant hand. Participants took a brief rest following each trial (10 seconds), with a longer rest period (30 seconds) following every third trial. Recommendations were obtained from a physiotherapist concerning possible fatigue effects with the testing procedure. Participants were encouraged to adjust their posture, stretch their hand and take deep breaths during rest breaks. When using the CFTT instrument, participants' tapping arm was supported on a cushioned pad. With both the CFTT and the DFTT instruments timing was built in to the test. For the two manual instruments the 10-second timer was used. The tester told participants when to start and stop each trial.

Results

Means and standard deviations for the average number of taps in 10 seconds for the 86 participants on the CFTT, DFTT and MUFTT measures and from 80 participants on the HRFTT measure are shown in Table 2.

The normative data from Ruff and Parker (1993) for the HRFTT and the WPS digital finger tapping device (1998), (see Table 1), were compared to the results obtained from this study. For the HRFTT there was a significant difference between the two normative populations. Male participants in this study were faster with the dominant hand (M = 59.1, SD = 7.3) and non-dominant hand (M = 53.4, SD = 6.7), p = 0.01, than males in the Ruff and Parker study (M = 53.4, SD = 6.0), (M = 48.5, SD = 5.2). Female participants in this study were also faster with the dominant hand (M = 53.3, SD = 9.0), p = 0.05, and non-dominant hand (M = 47.6, SD = 7.1), p = 0.01, than females in the Ruff and Parker study (M = 47.8, SD = 5.3), (M = 43.5, SD = 5.4). There was no significant difference between WPS normative data for females, or for males using the dominant hand. However, for males using the non-dominant hand, the normative number of taps for this study (M = 50.6, SD = 6.1) was lower than for the WPS data (M = 54.6, SD = 8.9).

Correlation matrices between all four methods were obtained for each hand. These are given in Table 3. All values were significant to the 0.01 level for a two-tailed test. At the 0.01 level, there was one significant difference between these correlations for the dominant hand, between the DFTT/MUFTT and DFTT/CFTT correlations. For the non-dominant hand, significant differences were found between the DFTT/MUFTT and DFTT/CFTT, MUFTT/HRFTT and MUFTT/DFTT, and CFTT/MUFTT and CFTT/DFTT correlations.

A one-way repeated measures ANOVA comparing scores for the 80 participants who were tested on all four instruments found no significant effect of method for either the dominant or non-dominant hand. For the dominant hand, Wilks' Lambda = 0.974, $F(3, 77)$ = 0.72, multivariate eta squared = 0.26. For the non-dominant hand, Wilks' Lambda = 0.975, $F(3, 77)$ = 0.68, multivariate eta squared = 0.25.

A one-way repeated measures ANOVA, comparing age group, gender and dominant or non-dominant hand,

Table 1. Norms for current finger tapping instruments.

Device Publisher	Age Group	Males n	Preferred Hand *M*	*SD*	Non-preferred Hand *M*	*SD*	Females n	Preferred Hand *M*	*SD*	Non-preferred Hand *M*	*SD*
Mechanical Tapping Test:	16-24	45	52.9	5.2	48.2	4.4.	45	49.5	5.1	45.6	5.1
Halstead-Reitan	25-39	44	52.7	6.8	48.7	5.7	45	49.0	4.1	44.6	4.6
(Ruff & Parker, 1993)	40-54	45	54.3	5.7	48.9	5.8	44	47.0	5.6	43.5	5.2
(HRFTT)	55-70	45	53.5	6.4	48.3	5.0	45	45.7	5.5	40.4	5.2
	Total	179	53.4	6.0	48.5	5.2	179	47.8	5.3	43.5	5.4
Electronic Tapping Test	16-19	24	44.1	3.6	43.2	2.0	120	44.4	2.6	42.5	3.4
(WPS)	20-29	59	57.2	8.5	54.4	8.6	44	54.4	9.8	52.3	11.0
(DFTT)	30-39	59	57.6	6.2	57.3	8.4	24	55.6	7.0	51.9	9.1
	40-59	37	59.4	6.3	59.6	5.0	12	53.8	5.9	52.0	8.3
	60+	5	51.1	8.9	44.3	7.4	24	46.4	7.8	42.2	6.7
	Total	184	55.9	8.3	54.6	8.9	114	52.0	8.9	49.2	10.0

Note: HRFTT – Halstead-Reitan Finger Tapping Test; WPS – Western Psychological Services; DFTT – Digital Finger Tapping Test.

Table 2 New Zealand Normative Data for the HRFTT, DFTT, MUFTT, CFTT.

Test	Age Groups	n	Males Preferred Hand M	Males Preferred Hand SD	Males Non-preferred Hand M	Males Non-preferred Hand SD	n	Females Preferred Hand M	Females Preferred Hand SD	Females Non-preferred Hand M	Females Non-preferred Hand SD
HRFTT	16-24	12	56.6	4.8	54.3	4.9	13	53.1	7.0	47.6	6.2
	25-39	5	62.8	2.9	59.0	5.1	9	56.0	10.2	49.8	6.6
	40-54	10	62.9	9.4	56.1	6.4	14	54.8	5.0	48.9	5.5
	55-70	12	57.0	7.4	47.9	5.7	5	44.4	15.9	40.2	10.6
	Total	39	59.1	7.3	53.4	6.7	41	53.3	9.0	47.6	7.1
DFTT	16-24	13	56.4	5.5	51.6	3.3	13	55.8	7.4	49.4	7.6
	25-39	7	61.6	6.9	55.6	5.8	10	57.6	8.1	50.0	5.3
	40-54	11	59.2	10.4	49.9	8.0	15	54.5	6.3	48.5	3.4
	55-70	12	56.4	5.5	47.5	4.9	5	47.9	7.2	45.1	9.2
	Total	43	58.0	7.3	50.6	6.1	43	54.8	7.5	48.7	6.0
MUFTT	16-24	13	58.2	4.1	55.0	4.6	13	54.3	6.9	48.7	5.3
	25-39	7	59.7	7.3	54.3	8.2	10	57.4	5.6	50.4	5.8
	40-54	11	61.9	9.7	52.6	7.1	15	54.2	6.7	48.0	5.0
	55-70	12	58.8	8.3	49.4	6.4	5	46.4	5.6	38.1	9.6
	Total	43	59.6	7.4	52.7	6.6	43	54.1	6.9	47.6	6.7
CFTT	16-24	13	58.2	6.2	51.6	5.2	13	54.7	7.6	48.3	5.7
	25-39	7	60.4	6.2	54.3	5.5	10	57.2	7.5	50.1	4.6
	40-54	11	56.8	8.7	49.9	4.3	15	54.4	5.3	48.7	4.2
	55-70	12	54.9	6.9	48.0	6.3	5	49.4	6.8	45.3	5.4
	Total	43	57.3	7.1	50.6	5.6	43	54.6	6.8	48.5	4.9

Note: CFTT – Computer Finger Tapping Test; MUFTT – Massey University Finger Tapping Test.

found that 3 groups had a significant effect of method, with higher tapping scores obtained with the HRFTT and MUFTT instruments. This occurred for males in the 16 – 24 year age group, using the non-dominant hand, Wilks' Lambda = 0.268, $F(3, 7) = 8.19$, multivariate eta squared = 0.732, $p = 0.006$, and for males in the 40 – 54 year age group, using the dominant hand; Wilks' Lambda = 0.234, $F(3, 7) = 7.62$, $p = 0.013$, multivariate eta squared = 0.766 and non-dominant hand; Wilks' Lambda = 0.248, $F(3, 7) = 7.09$, $p = 0.016$, multivariate eta squared = 0.752.

A two-way between-groups analysis of variance was conducted, with data divided according to hand, to determine the impact of age on the average number of taps as measured by the FTT. There was a statistically significant main effect of age [$F(3, 322) = 6.23$, $p = 0.000$], eta squared = 0.07. Post-hoc comparisons using the Tukey HSD test indicated that for the dominant hand, the mean score for the 25 – 39 age range ($M = 58.6$, $SD = 7.3$) was significantly different from the 55 – 70 age range ($M = 53.9$, $SD = 8.9$). For the non-dominant hand, post-hoc comparisons showed that the 16 – 24 age range ($M = 50.8$, $SD = 5.9$), the 25 – 39 age range ($M = 52.3$, $SD = 6.3$) and the 40 – 54 age range ($M = 50.0$, $SD = 5.8$) were significantly different to the 55 – 70 year age group ($M = 46.4$, $SD = 7.2$).

A two-way analysis of variance was conducted to explore the impact of age and dominant or non-dominant hand on tapping speed with the CFTT. There was a statistically significant main effect for age [$F(3, 168) = 3.93$, $p = 0.004$] with effect size, eta squared = 0.085. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for the 25 – 39 age group ($M = 55.2$, $SD = 7.0$) was significantly different from the 55 – 70 age group ($M = 50.3$, $SD = 7.2$). There was also a statistically significant effect for dominant hand [$F(1, 168) = 39.05$, $p = 0.000$], with effect size eta squared = 0.187. The interaction effect between age and dominant hand did not reach statistical significance.

To investigate the impact of age and gender on tapping speed with the CFTT, the data were divided into tests with the dominant and non-dominant hands. For both hands and with all age groups,

Table 3. Pearson Correlations for Finger Tapping Instruments.

		Pearson Correlation HRFTT	DFTT	MFTT	CFTT
HRFTT	Dominant Hand	1			
	Non-dominant Hand N	1			
		80			
DFTT	Dominant Hand	0.557	1		
	Non-dominant Hand N	0.505	1		
		80	86		
MFTT	Dominant Hand	0.678	0.543	1	
	Non-dominant Hand N	0.721	0.366	1	
		80	86	86	
CFTT	Dominant Hand	0.606	0.770	0.569	1
	Non-dominant Hand N	0.568	0.756	0.529	1
		80	86	86	86

Note: All correlations were significant at the 0.01 level.

males were faster than females with the difference particularly pronounced for the 55 –70 age group with the dominant hand. The decrease in tapping speed with age, for the CFTT was more noticeable for the non-dominant hand with both males and females. A two-way between-groups analysis of variance found no significant main effect of age for the dominant hand [$F(1, 78) = 2.40$, $p = 0.06$], but a significant main effect of gender [$F(1, 78) = 6.20$, $p = 0.02$], eta squared = 0.07. The age X gender interaction effect did not reach statistical significance. For the non-dominant hand there was a significant effect of age [$F(1, 78) = 4.01$, $p = 0.02$], eta squared = 0.14. There was also a significant effect of gender for the non-dominant hand [$F(1, 78) = 4.01$, $p = 0.05$], eta squared = 0.05. The age X gender interaction effect did not reach statistical significance. There was a decrease in tapping speed for females in the 55 – 70 age range with the dominant hand, an effect that was not observed with the non-dominant hand.

Discussion

Participants for this study were non-clinical volunteers recruited from the Wellington, Hutt Valley and Horowhenua regions of New Zealand, with ages ranging from 16 to 70 years. Although a wide range of ages for both males and females was represented in this study, the female 55 – 70 year age group was small in number. The sample was recruited predominantly from urban areas. 84.4% of the participants identified as preferring the right hand, with 15.6% preferring the left. Prospective participants with a severe condition such as OOS or a neurological disorder that impaired their ability to tap with the index finger of each hand were excluded from the study.

Normative values have been obtained for the CFTT and MUFTT instruments. Normative values for the HRFTT in the current study were higher than those obtained by Ruff and Parker (1993). While both studies contained participants with a similar age range there was a difference in sample size (Ruff and Parker: 16 – 70 years, N =358; CFTT: 16 – 70 years, N = 86). In comparing the tapping speeds for participants of the current DFTT study and those from the WPS sample, differences were found only for males using the non-dominant hand.

Males were faster than females for all age groups and across all methods, confirming the findings of Ruff and Parker (1993) and Leckliter and Matarazzo (1989) that males perform better than females on tests of fine motor speed. The dominant hand was faster than the non-dominant hand for both males and females, across all age groups, and methods. For both hands, tapping speed reached the highest level with the 25 – 39 age group. Tapping speed decreased with increasing age, particularly with the 55 – 70 age groups. As for other methods, with the CFTT, higher tapping scores were obtained by males, and by the dominant hand. There was a decrease in tapping speed with age, particularly with females. This decrease was more pronounced with the non-dominant hand. These results supported the hypotheses that tapping speed was higher with the dominant hand, that males were faster than females and that as age increased, tapping speed would decline, providing further confirmation that the CFTT has comparable properties to the FTT tests already in use.

High correlations were found between the tapping scores of all 4 instruments, providing confirmation of the construct validity of the CFTT, in that the instrument may effectively be used to assess motor speed. Correlations between the two electronic instruments or the two mechanical instruments were higher than those between electronic and mechanical instruments. Combined results show that the mean tapping speeds of all 4 instruments were very similar and there was no significant effect of method on tapping speed. As hypothesised, the CFTT demonstrated comparable properties to the DFTT, HRFTT and MFTT tapping instruments.

Because the CFTT is administered through a software programme, inter-tester variation is eliminated. With the FTT, ambiguity can arise concerning the deletion of deviant trials, or the maximum number of trials (Snow 1987). With the CFTT, once the 5 trials have been successfully completed, it is not possible to delete trials or extend the number of trials above 10. Timing errors for trials and rest periods are eliminated, and the programme calculates test averages. The CFTT may be used with a laptop computer and the tapping device would fit in most computer cases. The time required for administration of the test is approximately six minutes including rest breaks, which makes it suitable for use with brain injured and older clients.

One of the limitations of the current research was the small number of participants in the older age groups. Initially, some participants in the 70+-age range were tested on the tapping devices, however, the numbers were very small, so the results for this age range have not been included in this description of the study. Having larger numbers of participants in these older age groups would increase confidence in the finding that tapping speed declines with increasing age. It was noted that older participants found the CFTT to be a comfortable device to use. Another limitation was that hand dominance was determined by asking participants which was their preferred hand. Some participants noted that they used both hands, depending on the task being performed, but expressed a preference of one hand for writing. This was not recorded for the study, and might have had an impact on dominant and non-dominant tapping speeds. Using a more comprehensive method, such as that used by Ruff and Parker (1993), would increase the validity of the normative data. The participants for this study were drawn from a non-clinical population. Future research could determine whether the CFTT distinguishes between brain damaged and non-brain damaged participants.

In summary, the CFTT has demonstrated concurrent validity (high correlations with test scores obtained from the widely used HRFTT and WPS DFTT devices and also with the Massey manual finger-tapping device). It also shows that males tap faster than females, the dominant hand is faster than the non-dominant hand, and there is a decrease in tapping speed with increasing age, especially for females. The CFTT has content and face validity in that it records the number of taps in a ten-second interval, which is a clearly defined method of measuring motor speed.

Normative values have been determined across a range of age groups, for males and females and for the dominant and non-dominant hand. These normative values were obtained from a New Zealand population. Further research could investigate whether the CFTT distinguishes between brain damaged and non-brain damaged populations. Determining test-retest reliability would be another topic for future research.

The CFTT appears to have positive features in that it standardises administration of the FTT; it is portable and easy to use as it may be used with a laptop computer. The time required for administration of the test is brief as the test may be completed in about 6 minutes. The CFTT shows promise as both a clinical and research tool.

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Address for correspondence:

Janet M. Leathem (PhD)
School of Psychology
Massey University
P.O. Box 756
Wellington, New Zealand
Phone (6) 801 2794
Fax (6) 801 2796

Email: J.M.Leathem@massey.ac.nz