



Advanced Analysis of Finger-Tapping Performance: A Preliminary Study

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ABSTRACT

Background: The finger-tapping test is a commonly employed quantitative assessment tool used to measure motor performance in the upper extremities. This task is a complex motion that is affected by external stimuli, mood and health status. The complexity of this task is difficult to explain with a single average intertap-interval value (time difference between successive tappings) which only provides general information and neglects the temporal effects of the aforementioned factors.

Aims: This study evaluated the time course of average intertap-interval values and the patterns of variation in both the right and left hands of right-handed subjects using a computer-based finger-tapping system.

Study Design: Cross sectional study.

Methods: Thirty eight male individuals aged between 20 and 28 years ($\text{Mean} \pm \text{SD} = 22.24 \pm 1.65$) participated in the study. Participants were asked to perform single-finger-tapping test for 10 seconds of test period. Only the results of right-handed (RH) 35 participants were considered in this study. The test records the time of tapping and saves data as the time difference between successive tappings for further analysis. The average number of tappings and the temporal fluctuation patterns of the intertap-intervals were calculated and compared. The variations in the intertap-interval were evaluated with the best curve fit method.

Results: An average tapping speed or tapping rate can reliably be defined for a single-finger tapping test by analysing the graphically presented data of the number of tappings within the test period. However, a different presentation of the same data, namely the intertap-interval values, shows temporal variation as the number of tapping increases. Curve fitting applications indicate that the variation has a biphasic nature.

Conclusion: The measures obtained in this study reflect the complex nature of the finger-tapping task and are suggested to provide reliable information regarding hand performance. Moreover, the equation reflects both the variations in and the general patterns associated with the task.

Key Words: Finger-tapping test, hand, performance, analysis

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Introduction

The finger-tapping (FT) test has been used for almost a century to evaluate muscle control and motor ability in the upper extremities (1). This task is frequently used to quantitatively evaluate patients with Parkinson's disease (1), ataxia (2), Alzheimer's disease (3), and Korsakoff syndrome (4), as well as in individuals who have suffered an acute stroke (5). Moreover, the finger-tapping test is widely used to evaluate motor function in the upper limbs (6-8) and the relationship between hand preference and hand skill (9) in healthy individuals and to assess hand skill and coordination (10-12) for occupations in which the hands are essential. The finger-tapping test is also used for psychomotor evaluations (13-20).

The movement involved in single-finger tapping is complex and is affected by visual and auditory stimuli, emotional and physical health, and factors that impact the skeletal and nervous systems. The characterisation of finger-tapping by an average tapping interval or by a tapping rate can only provide a limited amount of information. However, constructing a

mathematical function that has the best fit to a series of data points obtained for a complex movement possibly helps to understand the nature of the movement.

Various techniques have been used to record the number of tappings in a certain test period and the average time passed between tappings (intertap-interval) in the finger-tapping test, including a mechanical counter, an electronic switch, a telegraph key, and a computer keyboard associated with word processing software (7, 8). However, the time resolution of these systems is either low or unpredictable. The ability of a system to determine only an average intertap-interval or a tapping speed for a complicated movement results in poor time resolution and carries no information on the time course of the movement. Previous studies on this topic have not considered the temporal changes that occur between consecutive tapping. Therefore, the present study evaluated the time course of average intertap-interval values and the patterns of variation in both the right and left hands of right-handed subjects using the TanTong Finger-Tap system (21, 22).

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Material and Methods

The single-finger-tapping test was conducted on the right and left hands of 38 male university students ranging in age from 20 to 28 years (Mean \pm SD = 22.24 \pm 1.65) using the TanTong Finger-Tapping system. Records of 3 left-handed participants were excluded from data and only the results of 35 right-handed (RH) participants were evaluated. Demographic characteristics of the participants are given in Table 1. Written informed consent was obtained from all participants prior to the initiation of the study. The ethics committee at Bülent Ecevit University in Zonguldak, Turkey, approved the present study.

Each participant was seated with his forearms resting on a tabletop in front of a computer keyboard during the FT task (21). For the single-finger-tapping (SFT) test, each participant was asked to tap his right index finger on the numeric "1" key and his left index finger on the "Z" key. The participant was instructed to press the keys as consistently and quickly as possible for 10 seconds. The TanTong Finger-Tapping system was previously described in the literature (21, 22). The system records the time of tapping and saves data as the time difference between successive tappings for further off-line analysis.

In order to assess the patterns of temporal fluctuations, the selected mathematical functions were forced to fit to the data points. Linear and polynomial regression analyses were used to determine trends in number of tappings with single finger-tapping. Functions with a strong linear relation to the independent variable are said to be controlled by a simple single factor, whereas a strong polynomial relation suggests multi-factorial complex nature for a function. The complexity of the function is related to the order of the polynomial. Linear and higher-order polynomial equations and related R-squared (R^2) values were obtained and plotted by using the Microsoft® Office Excel curve fitting function routines. Statistical analysis was performed using STATISTICA 8.0 (StatSoft Inc., Tulsa, OK, USA). A p value of less than 0.05 was considered statistically significant for all tests.

Results

The software used in the present study recorded the time difference between consecutive taps at a resolution of 1 ms. The number of tappings in a certain test period and temporal fluctuations in the intertap-intervals are graphically presented in Figures 1-4.

The number of taps within the test period for both the right and left hands are shown in Figure 1 and Figure 2, respectively. The curves depicted in both of the figures fit well to

Table 1. Demographic characteristics of the participants (N=35)

Characteristic	Mean	SD
Age (year)	22.23	1.72
Height (cm)	176.23	6.28
Body Weight (kg)	70.11	7.14
Body Mass Index (kg/m ²)	22.60	2.25

a linear equation ($R^2=0.99$, $F=377307$, $p<0.001$ and $R^2=0.99$, $F=304405$, $p<0.001$) meaning that the tapping rate does not change throughout the test. This graphical presentation suggests that there is a quite steady tapping performance during the 10 seconds of test. Since the reciprocal of the slope of the linear function corresponds to the average intertap-interval for this specific case, this measure for right and left hands are calculated as 164 ms and 183 ms, respectively.

The change in the intertap-interval with respect to the number of tappings for the right hand is shown as a set of three graphics in Figure 3. In contrast to Figures 1 and 2, the intertap-interval data show temporal variation as the number of tappings increases. Furthermore, the data fits poorly to linear function ($R^2=0.21$, $F=20.9$, $p<0.001$). Since finger-tapping performance may be affected by several factors, it is attempted to define the best fitted curve. Three different mathematical functions are forced to fit to the same data in Figure 3, namely linear (a), 2nd order polynomial (b) and 4th order polynomial function. Estimated mathematical functions and corresponding R^2 values are provided in the related graphics. Better fit is achieved by 4th order polynomial function with an R^2 value of 0.74 ($F=52.8$,

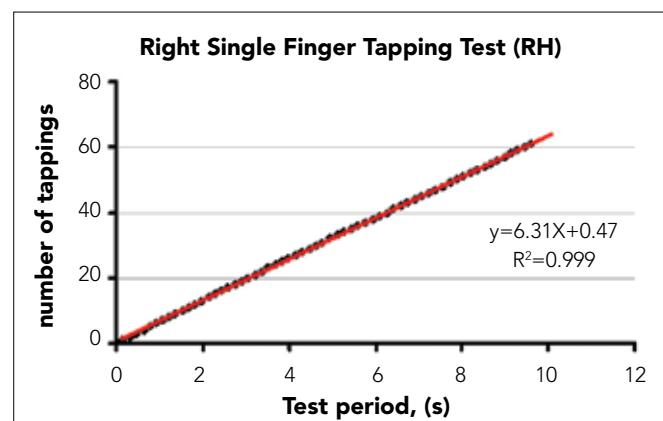


Figure 1. The number of tappings during the test period using right hand single-finger tapping of right-handed (RH) participants. Regression line coefficients and R-squared value of estimated function are given in the inset

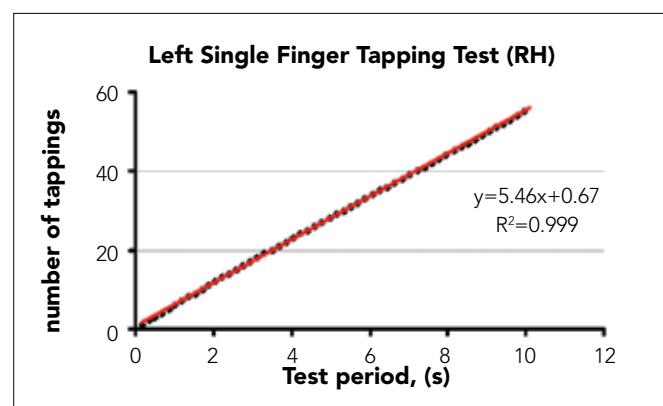


Figure 2. The number of tappings during the test period using left hand single-finger tapping of right-handed (RH) participants. Regression line coefficients and R-squared value of estimated function are given in the inset

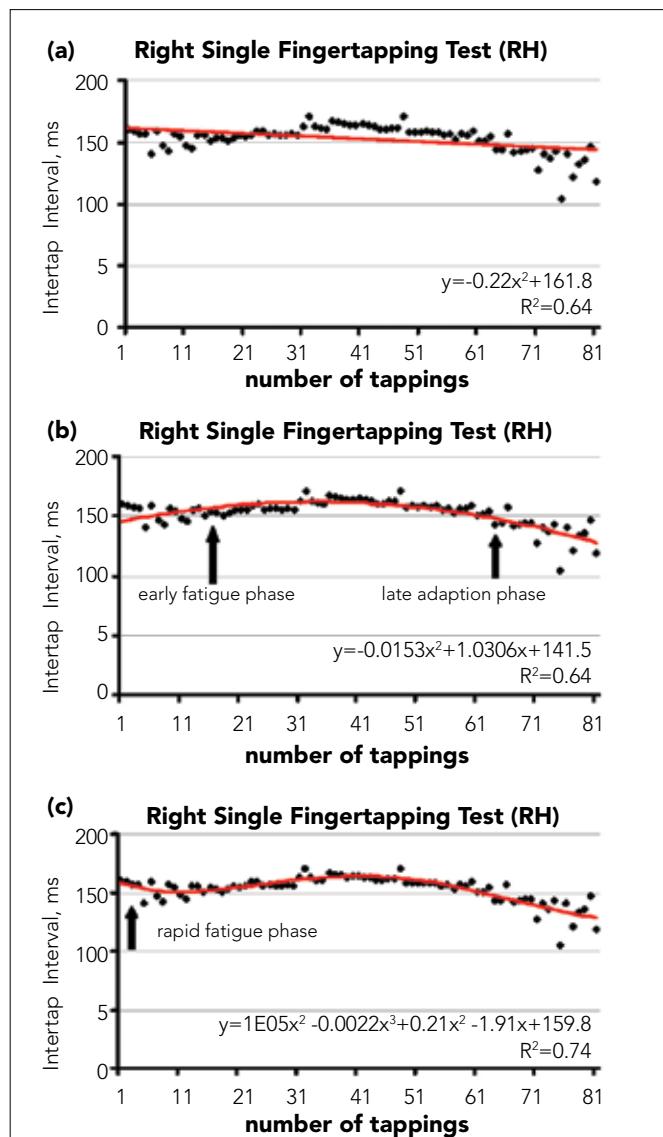


Figure 3. Comparative presentation of three different curve fitting options applied to the same data. Data represent the time course of intertap-interval values of right hand single-finger tapping of right-handed (RH) participants. The coefficients and R-squared values of estimated linear, 2nd and 4th order polynomial equations are given in (a), (b) and (c), respectively.

p<0.001). In contrast to the 2nd order polynomial estimation, the 4th order polynomial curve fit suggests that the finger-tapping pattern is biphasic. Early in the task, the tapping rate was low (tapping intervals: approx. 160 ms) and increased (tapping intervals: approx. 150 ms) within 2 seconds of time. Then, the fatigue period was evident at 4–5 seconds of the task (equal to approx. 30-35 taps). In the present study, the tapping rate increased over time again. However, we have no information on the prognosis of this increased tapping rate since the test period was initially chosen as 10 seconds.

As is shown in Figure 4, the biphasic behaviour is not valid for the left hand finger-tapping test of right-handed subjects. Second (a) and 4th order (b) polynomial functions both

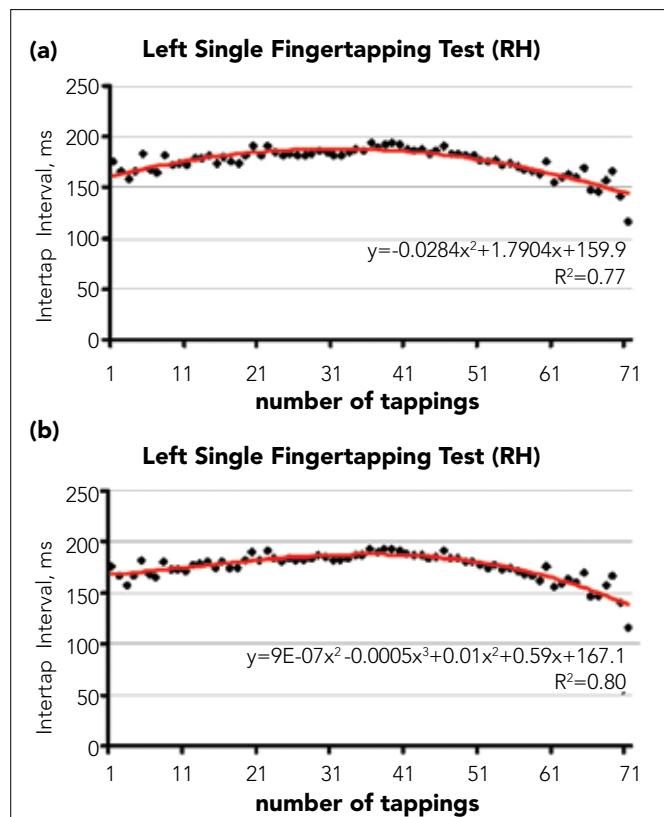


Figure 4. Comparative presentation of two different curve fitting options applied to the same data. Data represent the time course of intertap-interval values of left hand single-finger tapping of right-handed (RH) participants. R-squared values of both 2nd (a) and 4th order (b) polynomial equations are almost identical

represent the data points almost equally ($R^2=0.77$, $F=112.5$, $p<0.001$, and $R^2=0.80$, $F=65.2$, $p<0.001$, respectively).

Discussion

The finger-tapping test provides information about the control and coordination of distal muscle groups in the upper limbs (23, 24). Previous studies have mainly reported the total number of tappings in a certain test period (13-20, 23) and the tapping speed (6, 25). Kauranen et al. (25) compared patients with rheumatoid arthritis (RA) to healthy individuals and found no significant differences in the finger-tapping values of the groups. Significant differences were noted, however, in other measures of motor functioning between these groups. These results are interesting. The authors believed that the failure to detect differences in finger-tapping ability may be due to the fact that the particular finger-tapping movement only involves one joint. Another study by Meyer and Sagvolden (24) reported no significant differences in finger-tapping performance between male and female children. In a study by Brown et al. (23), standard deviation values were greater than those of mean finger-tapping in males and females. However, that study did not suggest the finger-tapping test to be a good choice in the evaluation of hand performance.

Significantly lower finger-tapping scores have been reported in several exposure studies (13, 14, 16, 17, 20). However, significantly higher scores have also been reported (18). Moreover, finger-tapping performance scores were better in males compared with females (12). A significant negative correlation between the finger-tapping scores for the non-dominant hand and the number of physical symptoms in the individuals in an exposure study was reported. The results for the dominant hand, however, were not significant (17). No significant differences were found in finger-tapping performance between the exposure group and controls in other studies (15, 19). Unfortunately, in the previous studies, other parameters that may have impacted the finger-tapping test results were not taken into account. Therefore, the data from the previous studies were only broadly characterised, and alternative interpretations may have resulted if the temporal patterns of the inter-tap-intervals had been assessed.

In a study by Aoki et al. (26), the average intertap-interval was shorter in musicians compared with controls. This suggests that hand performance is better in individuals who have occupations that require more frequent finger movements. The finger-tapping test appears to be influenced by daily activities, activity patterns, and occupation. Moreover, gender, age, education, emotional state, and external stimuli can affect the results of the finger-tapping test. Besides, there are also some other factors that may have positive or negative effects on tapping performance during the test. It is possible to improve the finger-tapping movements through repetition, which may affect the results of the task (1).

The results of this preliminary study suggest that the temporal variations may be correlated with internal and external factors. Furthermore, the impacts of these factors may be graphically demonstrated and even parametrically defined.

As the number of tappings within a certain test period is assessed in a number of studies, or more specifically tapping speed, this provides a single number defining the average tapping performance. It is logical to define such a single number to a complex movement if the movement does not change significantly during the test period. Data given in Figure 1 and 2 fit well to linear functions ($R^2=0.99$, $F=377307$, $p<0.001$ and $R^2=0.99$, $F=304405$, $p<0.001$ respectively) suggesting that there was a quite steady tapping performance during the 10 seconds of the test. The only apparent difference between the two graphics is the slopes of the regression lines. These only suggest that tapping speed of right hand is higher than that of left hand for right-handed subjects (6.31 taps/sec and 5.46 taps/sec, respectively).

In Figure 3a, however, the same data are re-plotted after a simple numerical manipulation. The change in intertap-interval with respect to the tapping count shows fluctuations and fits poorly to a linear function ($R^2=0.21$, $F=20.9$, $p<0.001$). Although there is a poor linear relation, we may broadly estimate that tapping performance has an increasing trend.

Exploring the best-fit mathematical function may help to understand the temporal pattern of tapping performance more specifically. Figure 3b and 3c clearly suggest that finger-tapping is not a monotonous steady movement. On the

contrary, it may have several acceleration and deceleration phases. Although the 2nd order polynomial curve fitting is also poor ($R^2=0.64$, $F=69.8$, $p<0.001$), it may be roughly estimated again that the pattern of tapping performance has at least two phases: *early fatigue phase* and *late adaptation phase*.

In addition to the better representation ($R^2=0.74$, $F=52.8$, $p<0.001$), the higher order (4th order) polynomial curve fitting gives further graphical detail to the fatigue phase (Figure 3c). It may be suggested that fatigue phase may be composed of two sub-phases. During the first 2 seconds the tapping rate gradually increased and then started to decrease. The first 2 seconds of the gradually increasing phase of the test can be treated and named as the *rapid adaptation phase* and may be attributed to the positional interaction between hands, fingers and the keyboard/keypad. Therefore, it may be suggested that at least the first 5 tappings (corresponds to 2 sec of tapping) may be excluded from the data series. Repeatability of this finding is assessed in the repeat test data and found to be still valid (data not shown). The prognosis of the late adaptation phase is not predictable due to the short test period. Therefore, choosing the best finger-tapping test period is an important issue and might be chosen in accordance with the proposed study.

As presented in Figure 4b the biphasic behaviour does not work for the left hand finger-tapping test of right-handed subjects. This is to be further investigated with an extended number of participants in future studies. Our future studies will also include an extended test period in order to assess the performance trend beyond 10 sec.

The current study has several limitations. First, this study was limited by its small number of participants for broad generalisations. Second, the test duration needs to be extended, as stated above.

The present study suggests that the assessment of patterns of temporal variation in the intertap-interval would provide more reliable results in studies that evaluate the effects of working conditions, working hours, and exposure to various agents on motor coordination and hand performance. Moreover, in future studies, the finger-tapping test should be applied in an isolated testing environment where factors that may impact movements can be controlled.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Bülent Ecevit University.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

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