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Temporal Measures of Human Finger Tapping: Effects of Age

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COUSINS, M. S., C. CORROW, M. FINN AND J. D. SALAMONE. *Temporal measures of human finger tapping: Effects of age.* PHARMACOL BIOCHEM BEHAV **59**(2) 445–449, 1998.—A computerized finger-tapping test was used in which nonclinical subjects were asked to tap a telegraph key with their index finger as rapidly as possible during five 10-s trials. Comparisons were made between young (mean age = 18 years) and aged (mean age = 75 years) subjects. Consistent with previous findings, aged subjects performed significantly fewer taps than younger subjects. Computerized analysis of finger-tapping patterns in the present study allowed for the determination of novel temporal parameters of tapping responses. Response initiation time was defined as the time from the offset of one finger tap until the onset of the next finger tap. Aged subjects had significant and substantially longer response initiation times than younger subjects. Response duration times also were measured; this parameter was defined as the time from the onset of one finger tap until the offset of the same finger tap. Although the magnitude of the effect was small, aged subjects had significantly longer response duration times than younger subjects. Thus, although the deficit in response rate of a voluntary repetitive response in aged subjects was largely due to impairments in response initiation times, the response duration also contributes to the overall deficit in responding. Using these methods it is possible that greater insight into aging or extrapyramidal motor disorders, such as parkinsonism, may be obtained; it is also possible that these data may be useful as a research tool to aid in drug development and evaluation. © 1998 Elsevier Science Inc.

Human aging Motor Parkinson Initiation Bradykinesia Voluntary movement

TASKS involving hand, arm, and finger usage have been employed for decades to characterize aspects of motor performance. Several variables affect hand and arm motor function, including years of education, gender, and age. A classic motor test for assessing fine motor speed and dexterity is the Finger Oscillation Test developed by Halstead (23), which is now part of the Halstead-Reitan neuropsychological test battery (34) and the Unified Parkinson's Disease Rating Scale (16). It is important to emphasize that although the finger-tapping test of the Unified Parkinson's Disease Rating Scale relies upon subjective observation, it is still used in the diagnosis of Parkinson's disease (3,14). In contrast, in the Halstead-Reitan test subjects are asked to tap a mechanical counter as fast as possible with the index finger during five consecutive 10-s trials (34). Typically, interpretation of the data involve an analysis of the total number of finger taps across the five trials. In general, comparisons between groups of subjects have shown that better performance observed with younger age and in males (2). This test battery has also been used in clinical settings to identify psychostimulants (21,32,40), aid in diagnosis of cerebral dysfunctions or lesions (23,35), epilepsy (13), depression (36), Huntington's disease (24), Alzheimer's disease (31), and Parkinson's disease (41).

Historically, the critical dependent variable in finger-tapping tasks has been obtained by counting the total number of finger taps in a specified period of time. However, the only temporal parameter of finger tapping that this procedure allows one to measure is overall response rate (number of taps divided by time). Specifically, other temporal parameters of responding including the length of time between the offset of a finger tap and the onset of the next finger tap (i.e., response initiation time) and the length of time between the onset and offset of a finger tap (i.e., response duration time) have not previously been considered. Previous work with lever-pressing and other operant tasks in rodents has shown that this type of temporal analysis is highly sensitive to the effects of striatal dopamine depletions, psychomotor stimulants, and antipsychotic drugs (4,6,7,11,17–20). For example, although

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different pharmacological classes of drugs can produce similar effects on overall lever pressing rate in rats, these drugs can be characterized based upon their differential effects on response initiation and duration times (Carriero et al., submitted). In another study, dopamine depletions in the ventrolateral striatum of rats were found to induce profound lever pressing deficits (6–8). This deficit was largely due to increased response initiation times; even animals with mild dopamine depletions (depleted 71%) showed increased initiation times. Of particular interest, though, was the finding that there was an overall increase in response duration times, but only in animals with severe dopamine depletions (depleted 92%). Thus, response initiation and duration times are sensitive to alterations in striatal dopamine levels (6). Taken together, these experiments suggest that measurement of response initiation and duration times may be a useful tool for detecting subtle differences in motor output.

There were three major aims of the present study. The first aim was to develop a computer-based finger-tapping program that could provide quantitative measures of finger-tapping performance as suggested by Ott et al. (31). Because this is the first published account of a computerized finger-tapping task that partitioned finger-tapping rate, the second aim was to demonstrate that the computerized version of this task generates gender- and age-related data that are consistent with previous findings based on mechanical counting devices (2). Finally, due to the limitations of mechanical counting devices, the present methods were designed to measure subtle temporal parameters of finger tapping to more precisely identify the components of the motor behavior that are affected by age. Because finger-tapping tests are widely used in many research settings, it is possible that these temporal analyses of finger tapping may be useful to identify subtle motor impairments observed in extrapyramidal disorders (15,31,39), or as a useful research tool to aid in drug development and evaluation.

METHOD

Subjects

A total of 53 subjects who were not diagnosed as having any motor disorders participated in this experiment. The younger subjects were students at the University of Connecticut fulfilling introductory psychology course requirements [young subjects: 15 females with a mean (±SEM) age = 17.9 ± 0.2, range 17–20 years; 12 males 19.2 ± 0.5 years old, range 17–22 years]. The aged subjects were volunteers from the Mansfield Senior Citizens Center of Connecticut [15 females with a mean (±SEM) age = 74.7 ± 1.6, range 63–88 years; 11 males 75.6 ± 2.4 years old, range 57–85 years]. The younger subjects received credit toward introductory psychology course requirements for participation in this experiment; the older subjects did not receive any compensation for participating in this study.

Behavioral Procedures

Subjects were seated and asked to use their index finger and tap a telegraph key as rapidly as possible using the hand most frequently used for handwriting (23). The wrist of each subject was lightly restrained to the apparatus with a Velcro strap, and each subject was allowed to tap the telegraph key with their index finger until they were comfortable with the movement. Contact closure completed a low-voltage electrical circuit that was connected to a computer interface (Med State, Inc.). The interface was connected to an IBM-type microcomputer running a BASIC program that was used to collect the behavioral data and signal the beginning and end of each trial. There were five 10-s trials, with a 30-s intertrial interval. The computer recorded the total number of finger taps in each 10-s trial. For each response the response initiation time (i.e., the time from the offset of one finger tap to the time until the onset of the next finger tap) and the response duration were recorded (i.e., the time from the onset to the offset of a finger tap) (6,7). Average response initiation times as well as average response duration times were computed for each trial. Subjects were also asked to complete a short questionnaire, which was used to determine the general health and current medications of the subjects.

Statistical Analysis

Overall mean response number, average response initiation time, average response duration time, and percentage contribution of response initiation (see definition below) were analyzed by a $2 \times 2 \times 5$ (age × gender × trial) factorial analysis of variance (ANOVA; using Systat) with repeated measures on the trial factor. Bentley's F-max test was used to test for variability between groups. Factorial ANOVA was used because it is robust against violations of homogeneity of variance (25). Because there was little effect of trial number on performance, all subsequent statistical analyses were conducted on data collapsed across the trials factor. Pearson product-moment correlations were used to establish relations between age and temporal parameters of responding. An aged subject was dropped from statistical analyses because of current neuroleptic treatment (5).

RESULTS

Self-report data indicated that younger subjects were taking allergy medication (two subjects), cholesterol medication [1], and birth control pills [10]; aged subjects indicated taking aspirin [4], nonsteroidal antiinflammatory drugs [4], blood pressure pills [10], insulin [2], a serotonin uptake inhibitor [1], antipsychotics [1], and estrogen [1]. No significant effects of these medications on finger-tapping performance were observed. Data on total response number, response initiation, and response duration are shown in Table 1. ANOVA demonstrated that there was an overall significant effect of age, $F(1, 49) = 30.91$, $p < 0.0001$, and gender, $F(1, 49) = 9.10$, $p < 0.01$, on total number of finger taps. There was not a significant age × gender interaction, $F(1, 49) = 0.69$, NS, nor was there an effect of trials, $F(4, 196) = 0.91$, NS. As shown in Table 1, poorer performance was associated with both the aged and the female subjects. Across both males and females, there was a significant negative correlation between age and finger taps ($r = -0.57$, $p < 0.0001$).

The data on average response initiation times are shown in Table 1. ANOVA showed that there was an overall significant effect of age on average response initiation, $F(1, 49) = 22.27$, $p < 0.0001$, no significant effect of gender, $F(1, 49) = 0.54$, NS, and no age × gender interaction, $F(4, 196) = 1.16$, NS. There was a significant effect of trial, $F(4, 196) = 2.62$, $p < 0.05$. There was a significant positive correlation between age and average response initiation ($r = +0.53$, $p < 0.0001$).

Table 1 also shows the data on average response duration time. There was an overall significant effect of age on average response duration, $F(1, 49) = 4.70$, $p < 0.05$, but no significant effect of gender, $F(1, 49) = 0.47$, NS, no age × gender interaction, $F(1, 49) = 0.002$, NS, and no effect of trial, $F(4, 196) =$

TABLE 1

MEAN (±SEM) NUMBER OF FINGER TAPS (IN 10 s), AVERAGE RESPONSE INITIATION (ms), AVERAGE RESPONSE DURATION (ms), AND THE RELATIVE CONTRIBUTION OF RESPONSE INITIATION TO OVERALL RESPONDING (AVERAGE RESPONSE INITIATION DIVIDED BY THE SUM OF AVERAGE RESPONSE INITIATION AND DURATION TIMES; EXPRESSED AS %) ACROSS TRIALS FOR THE AGE AND GENDER GROUPS

	Young Male Mean (±SEM)	Young Female Mean (±SEM)	Aged Male Mean (±SEM)	Aged Female Mean (±SEM)
Total finger taps	55.03 (0.92)	46.36 (0.98)‡	40.33 (4.50)†	35.49 (1.76)†‡
Avg response initiation	81.4 (3.8)	109.8 (3.4)	172.5 (3.5)†	167.1 (1.9)†
Avg response duration	100.7 (3.8)	107.4 (4.7)	121.0 (17.0)*	126.9 (8.6)*
Contribution of response initiation	44.6 (2.3)	50.6 (1.7)	56.9 (4.0)†	56.7 (1.7)†

*$p < 0.05$, †$p < 0.01$, compared to both groups of young subjects.
‡$p < 0.01$, compared to both groups of male subjects.

0.46, NS. There was not a significant correlation between age and average response duration ($r = +0.26$, NS).

The relative contribution of average response initiation to overall responding was calculated by dividing average response initiation by the average interresponse time. The average interresponse time is the sum of average response initiation and duration times, and this value represents the reciprocal of the response rate. As shown in Table 1, ANOVA showed that there was an overall significant effect of age on this measure, $F(1, 49) = 19.05$, $p < 0.0001$, but no significant effect of gender, $F(1, 49) = 1.92$, NS, no age × gender interaction, $F(1, 49) = 2.19$, NS, and no effect of trial, $F(4, 196) = 2.35$, NS. This demonstrates that significantly more of the interresponse time was taken up by the initiation time, rather than the duration time, in older subjects as compared to younger subjects.

DISCUSSION

Consistent with previous reports, there were significant effects of age (2,9,29) and gender (2,12) on finger-tapping performance. There were substantial age-related effects on finger tapping when the data were analyzed in terms of group differences between young and aged subjects. Moreover, correlational analyses showed a negative correlation between age and response rate in both male and female subjects. The reliability of these age-related declines in finger-tapping performance is supported by the observation that the average number of finger taps in males and females in the present study do not differ from the normative data of Bornstein (2) by more than 0.5 standard deviations. The present findings also are generally consistent with other data showing that motor slowing is a hallmark of aging (1,2,9,22,28,29,33). Mortimer (29) determined that speed of arm movements and gait were negatively correlated with age. Reaction times have also been shown to increase with age (10,26,38). Electromyographic methods have shown that older subjects require more time for muscle contractions (30). Thus, the present results are consistent with those reports indicating that finger-tapping rate in older subjects is slower than that of younger subjects [(2), but see also (28)].

Although previous studies have measured the total number of finger taps, the present work was unique in that computerized data collection allowed for the determination of detailed temporal parameters of responding. Examination of average response initiation time revealed that aged subjects took longer between each finger tap. Age-related effects also were reflected by the positive significant correlation between age and average response initiation. There was a significant increase in average response duration with age. This could be due to the longer time required for muscle contractions, slower neuronal conduction times, motivational differences, and orthopedic or medication-related difficulties in aged subjects. Although speculative at this point, the longer average response duration exhibited by the aged subjects may reflect the fact that they have greater difficulty switching response sets than younger subjects. To perform a finger tap, a subject needs to press down the finger with one group of muscles and then relax that set as the antagonistic set of muscles lifts the finger. It is possible that the response duration deficit exists in older subjects because of the greater time to make the transition between individual movements (37). Indeed, it has been suggested that response duration may be related to the bradykinesia that is observed in Parkinson's disease (17,20). Regardless of the processes underlying the response initiation and duration time effects, these temporal measures were found to be useful for characterizing age-related effects on the finger-tapping task.

Although it is evident that both response initiation and response duration contribute to the overall response slowing shown in aged subjects, evidence suggests that these measures do not do so equally. First, the aged subjects have an average response initiation time that is approximately 44% greater (or, 72.2 ms) than that of younger subjects, but have an average response duration time that is only 17% greater (or, 20.0 ms) than younger subjects. Thus, the relative increase in average response initiation in aged subjects represents more than twice the increase in average response duration. Second, analysis of the contribution of response initiation relative to response duration showed that response initiation time contributed more to the total interresponse time in older subjects than in younger subjects. Therefore, when considering the contribution of response initiation and duration times to the slower finger tapping observed in the aged subjects, it is evident that the increase in response initiation time accounts for a greater proportion of the overall response deficit than the increase in response duration time.

In addition to observing age-related deficits in finger tapping, the present study also found significant gender differences. Females in the present study performed significantly fewer finger taps than males. The data for males and females obtained in the present study were very similar to previous research (i.e., within 0.27 standard deviations of the normative

data reported by (2)). These data suggest that gender differences in finger-tapping performance are relatively reliable across laboratories. However, analysis of the response initiation and duration times did not show a significant gender effect. Thus, gender differences in numbers of finger taps were not attributable to a highly specific effect on any particular parameter of movement. Instead, it appears that some females had longer initiation times, while others had longer duration times, and both tendencies contributed to the reduced overall number of responses.

CONCLUSIONS

Consistent with previous studies, aged subjects performed fewer total finger taps than younger subjects. This age-related effect extends beyond the measurement of total number of finger taps, and is also evident in analyses of response initiation and duration times. Increases in response initiation time contributed more than increases in response duration to the overall effect of age on finger tapping. In conclusion, it is possible that greater insight into extrapyramidal motor disorders may be obtained by using computerized temporal measures of movement in addition to clinical rating scales (15,27,31,39); in addition, methods such as these may be a useful research tool to aid in drug development and evaluation (21,32,40).

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