Effects of Age and Gender on Discrete and Reciprocal Aiming Movements

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Using a cross-sectional design, this study determined the time course of aging effects on rapid discrete and reciprocal aiming movements in men and women. A total of 80 men and 61 women in good health were classified into six age groups (25, 35, 45, 55, 65, and 75 years). The discrete task required participants to make one discrete aiming movement, whereas the reciprocal task required a series of back-and-forth movements. Results indicated for both aiming tasks that greater age was strongly associated with slower movement times. The significant interaction between age and task indicated that the discrete task showed much larger aging effects (54%) than the reciprocal task (25%). This finding is tentatively interpreted in terms of a reduced efficiency of “on-line” control processes.

Advancing age is accompanied by a reduced ability to execute rapid aimed hand movements (e.g., Goggin & Meeuwsen, 1992; Haaland, Harrington, & Grice, 1993; Pratt, Chasteen, & Abrams, 1994; Warabi, Noda, & Kato, 1986). Notwithstanding the strong support for this claim, it should be recognized that the available evidence is largely based on studies that compare the aiming performance of relatively young research participants, typically between 20 and 25 years of age, with that of relatively old participants, typically between 60 and 80 years of age. Therefore, even though it is clear that old people move more slowly than young people, detailed information on the time course of this slowing effect is sparse (for notable exceptions see Welford, Norris, & Shock, 1969; York & Biederman, 1990). One of our goals in the present study was to provide such a detailed description by examining the aiming performance of six different age groups: 25-, 35-, 45-, 55-, 65-, and 75-year-olds.

Another much neglected aspect in previous studies on age-related changes in movement control concerns the effect of gender. The importance of gender in age-related research has recently been demonstrated by York and Biederman (1990), who showed that on some tasks older men slow down more than older women. This is as one might expect from reports of shorter longevity for men compared with women (York & Biederman, 1990) and suggests that men age biologically faster than do women. Therefore, our second aim in this study was to examine possible sex-related differences in age-related motor slowing.

Most studies on aging effects in the control of rapid aiming movements have used motor tasks that are discrete in nature (e.g., Goggin & Meeuwsen, 1992; Pratt et al., 1994), although continuous, that is, reciprocal, tasks have also been used (e.g., Welford et al., 1969). No single study, however, has investigated aging effects on both types of tasks, even though there is considerable evidence that the underlying control processes are fundamentally different. Keele (1968), for instance, argued that for a repetitive, continuous series of movements, control might shift from reliance on an attention-costly feedback (i.e., closed-loop) mode to a less attention-demanding programmed (i.e., open-loop) mode. In addition, Adam, van der Bruggen, and Bekkering (1993) pointed out that a discrete task requires a movement stop, whereas a reciprocal task requires a movement reversal. It is important to note that stopping a movement and reversing a movement are characterized by different patterns of electromyographic (EMG) activity. A discrete movement typically requires a three-burst EMG pattern of agonist–antagonist–agonist activity, with the last agonist activity damping possible oscillations in order to stop and fixate the limb on the target (Enoka, 1988; Hallett, Shanani, & Young, 1975; Hannaford & Stark, 1985). In a reversal movement, on the other hand, the last component of this three-burst activity pattern is usually absent (Enoka, 1988). In addition, Guiard (1993) argued that cyclicity offers the possibility of saving mechanical energy because of the ability of muscles to store mechanical energy in a potential, elastic form toward the end of each movement to the benefit of the next. Thus, motor control processes underlying discrete and reciprocal tasks are fundamentally different, and examination of both types of tasks in terms of their respective sensitivity to aging therefore seems to be in order.

In sum, we designed the present study to accomplish three goals: first, to determine more precisely the time course of aging...
effects on rapid aimed limb movements; second, to examine possible gender differences in the relationship between aging and aiming performance; and third, to examine these two issues with both a discrete and a reciprocal aiming task in a single study.

Method

Participants

This study was conducted as part of a larger gerontological research project, The Netherlands Memory and Aging Programme, at the University of Limburg. A total of 141 participants served as volunteers. Their ages centered (±1 year) around 25, 35, 45, 55, 65, and 75 years; the numbers of men and women in these age groups were 15 and 10, 16 and 9, 14 and 15, 16 and 10, 13 and 10, and 6 and 7, respectively. Participants were recruited by random selection from a register of patients of general practices in the region of Maastricht, The Netherlands (Metsemakers, Höppener, Knotterus, Kocken, & Limonard, 1992). This register contains all relevant past and current medical morbidity as documented by general practitioners. Because health status may confound outcome measures in cognitive aging research (e.g., Elias, Elias, & Elias, 1990; Houx & Jolles, 1993), we took special precautions to include only physically healthy participants. Exclusion criteria were previous or actual medical conditions with known impact on cognitive or motor functions: overt cerebrovascular disease, chronic neurological pathology (e.g., dementia, epilepsy, and parkinsonism), mental retardation, chronic cardiovascular or pulmonary disease, or psychotropic drug use. All participants had normal or corrected-to-normal vision. Except for 3 participants, they all wrote with their right hands.1 Informed consent was obtained from all participants.

Data for IQ were collected for all but 2 participants. IQ was measured by means of a standard Dutch intelligence test (Luteijn & van der Ploeg, 1983). The different age groups were not reliably different in terms of IQ, F(5, 127) = 2.25, MSE = 180.43, p > .05. Men scored higher on IQ than women (115.0 vs. 109.9, respectively), F(1, 127) = 6.21, MSE = 180.43, p < .05. Inclusion of the IQ score as a covariate in the analyses of variance reported in the Results section did not alter the outcomes in any meaningful way.

Apparatus and Tasks

A black, synthetic 30- × 60-cm box was mounted on an 85-cm-high table. For each movement condition, a specific target plate was constructed that contained two circular copper targets. This target plate was placed on top of the box. The copper targets had diameters of 4, 12, or 32 mm. A distance of 8 cm separated the centers of the two targets. Targets and stylus were connected to an MS-DOS AT computer that recorded movement times, error rates, and dwell times (time spent on the target). Sampling rate was 1000 Hz.

Participants had to perform a discrete (single) aiming task and a reciprocal (back-and-forth) aiming task. The discrete aiming task required them to move the stylus from the right target (diameter of 4 mm) to the left target (diameters of 4, 12, or 32 mm). The reciprocal task required them to move the stylus, starting from the right target, repetitively between the two equally sized circular targets (diameters of 4, 12, or 32 mm) for a duration of 15 s.2

Procedure

For both the discrete and reciprocal aiming tasks, participants stood facing a table on which the aiming apparatus was mounted. They were asked to hold a stylus with their preferred hand in a pen-grip fashion and to position themselves such that their body midline was biased toward the center of the left target. Performance instructions required participants to move as quickly and accurately as possible. In particular, it was stressed that they move quickly but make sure that the target was hit each time. With these instructions we attempted to minimize the occurrence of errors in order to obtain comparable estimations of movement time across participants. Manipulation of target size (diameters of 32, 12, and 4 mm) resulted in three movement conditions reflecting levels of increasing movement complexity.3 These three movement conditions were counterbalanced within age groups. For the discrete aiming task, each movement condition consisted of two practice and three test trials; for the reciprocal aiming task, each movement condition consisted of one practice and two test trials. The order of the reciprocal and discrete aiming tasks was counterbalanced within age groups.

Analysis

Movement time was the interval between departure and arrival of the stylus on the targets. Dwell time was the amount of time the stylus was in physical contact with the target. Movements that did not come into contact with the target were recorded as errors. For each condition of the reciprocal aiming task, movement time, dwell time, and percentage errors were formed from the average of movements to both left and right targets in both test trials. For each condition of the discrete aiming task, movement time and percentage errors were formed from the average of the three test trials. Unweighted means analyses of variance to control for the unequal numbers of participants in the different conditions (Keppel, 1982) were conducted. Whenever appropriate, the tests involving the within-subject factor(s) were adjusted for heterogeneity of variance and covariances using the Huynh-Feldt corrected significance values.

Results

Participant means for the independent variables of movement time and percentage of errors were submitted to separate four-way analyses of variance with the factors of age (25, 35, 45, 55, 65, or 75 years), gender (female or male), task (discrete or reciprocal), and target size (4, 12, or 32 mm), with repeated measures on the last two factors.4

Movement Time

The main effect of task, F(1, 129) = 42.56, MSE = 7,314, p < .001, reflected the overall shorter movement times in the reciprocal task, but it was qualified by several two-way interactions: Age × Task, F(5, 129) = 5.47, MSE = 7,314, p < .001; Gender × Task, F(1, 129) = 11.15, MSE = 7,314, p < .001; and Target Size × Task, F(2, 258) = 22.24, MSE = 2,678, p < .001. The interaction between age and task demonstrated a greater aging effect for the discrete task than for the reciprocal

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1 This rather low percentage (2.1%) of left-handers is probably related to the fact that until quite recently the Dutch educational system actively encouraged left-handers to write with their right hands.
2 Task requirements for the left-handed participants were the other way round.
3 Expressed in terms of Fitts's (1954) index of difficulty, ID = \log_{2}(2A/W), where A = amplitude and W = target width or target size, these three movement conditions resulted in 2.32, 3.73, and 5.32 bits/response.
4 A separate analysis including the order of the discrete and reciprocal tasks as an additional, between-subjects variable yielded no significant effects involving the factor of order.
task (see Figure 1). Age effects in each task, however, were significant \((p < .001)\). The interaction between gender and task indicated that in the discrete aiming task male participants moved faster than female participants but that in the reciprocal task both sexes moved almost equally fast. The interaction between target size and task reflected the increasingly shorter movement times with increasing target size for the reciprocal task compared with the discrete task.

**Error Rate**

Only the main effects of task, \(F(1, 129) = 13.96, \text{MSE} = 18.52, p < .001\), and target size, \(F(2, 258) = 13.96, \text{MSE} = 14.30, p < .01\), were significant, reflecting, respectively, more errors in the reciprocal task than the discrete task (2.2% versus 0.94%) and an increasing number of errors with smaller targets.

**Discussion**

This study examined the effects of age on the movements of men and women in a discrete and a reciprocal aiming task. Contrary to most previous studies, we provided a detailed analysis of the time course of aging effects by investigating age-related motor slowing in each age decade from the 20s to the 70s. The most important result was that advancing age progressively slowed discrete responses more than reciprocal responses. That is, as a function of advancing age, increments in movement time were relatively small in the reciprocal task but rather large in the discrete task, with a maximal slowing down of 25% and 54%, in 75-year-olds compared with 25-year-olds, for reciprocal and discrete tasks, respectively (see Figure 1). This outcome is consistent with the results of other studies that also suggested larger aging effects for discrete than for reciprocal tasks. For a discrete aiming task, Goggin and Meeuwsen (1992) reported an increment in movement time of 62%, while increments of 25% and 21% have been reported for reciprocal tasks by York and Biederman (1990) and Welford (1969, cited in Welford, 1977), respectively.

It is possible to consider an alternative interpretation of the present age effects. This interpretation focuses on the limited number of trials, for both tasks, that were administered to the participants. According to such an account, older adults may adopt to novel situations more slowly than do younger adults and consequently may need more practice in order to reach a stable performance level. Thus, according to the practice hypothesis, the presumed age effects may simply be due to age-related differences in practice effects. Several considerations argue against such an interpretation. First, the present aiming tasks were very simple in nature and can hardly be considered to confront participants with an unfamiliar situation because many daily-life activities require people to make accurate aimed hand movements (e.g., picking up objects). Second, Goggin and Meeuwsen (1992) studied discrete aiming performance as a function of practice by using five blocks of 42 test trials (7 trials at each of 6 movement conditions). There was no trial block effect and, as mentioned before, the reported increment in movement time was similar to that reported in the present study.

In addition, two possible confounds should be mentioned regarding the differential pattern of aging effects for the discrete and reciprocal tasks. The first focuses on the large difference in number of responses between both types of tasks. However, as argued before, individual movements in the reciprocal task cannot be considered equivalents to their discrete counterparts. As Guiard (1993) has shown, a series of fast reciprocal movements cannot be viewed as a serial concatenation of individual discrete movements. The second possible confound points to the difference in error rate between the reciprocal and discrete tasks. That is, slightly more errors were made in the reciprocal task than in the discrete task (2.2% and 0.94%, respectively). However, it should be noted that (a) error rates were very low in both conditions, and (b) the crucial interaction between age and task was evident only for movement time, not for error rate.

There is a growing body of evidence indicating that older people are less efficient at processing feedback information and producing corrective submovements than younger people (Pratt et al., 1994; Proteau, Charest, & Chaput, 1994; Warabi et al., 1986). In light of evidence that discrete movements more than reciprocal movements rely on attention-costly, central feedback control, the larger aging effect for discrete movements may perhaps be understood in terms of a failing or an impaired efficiency of “on-line” control processes. This conclusion, however, should be viewed with some caution given (a) the importance of open-loop and closed-loop processes for both types of tasks, and (b) the exclusive reliance in this study on movement time as the dependent variable. Those conducting research in the future, therefore, should investigate more directly the control mechanisms of discrete and reciprocal aiming movements by using kinematic and EMG analyses.

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5 These percentages are based on a comparison of movement times of participants in their 20s and 70s.
References


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