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PSYCHOMOTOR AGING; RELATIONSHIP BETWEEN NEURAL AND MOTOR COMPONENTS IN TIMED REACTION TASKS

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Abstract: Simple reaction time (SRT) in response to an external visual stimulus was measured in 512 adults aged 13 to 96 years. In addition, a self-initiated movement time (MT) task was measured. Both SRT and MT displayed significant increases with age while the difference (SRT–MT) did not. This pattern is interpreted as evidence that the age-related decline in neuromotor function in humans is primarily due to loss of peripheral neuromotor control rather than to diminished central nervous system function. Comparison with similar studies also indicates that the magnitude of the age-related effect depends upon the degree of involvement of the neuromotor system.

Key words: Psychomotor aging, Neuromotor functions, Simple reaction time, Movement time, Adults, Cansas.

Introduction

Deterioration of psychomotor test performance with age is a well documented phenomenon (e.g. Koga and Mourant, 1923; Pierson and Montoye, 1958; Birren et al., 1980; Spirduso, 1980). The source of this age-related deterioration has, however, been problematical. In a number of studies a classical view is held that the increase in parameters such as simple reaction time (SRT) and discrimination reaction time (DRT) associated with advancing age is attributable to a progressive decline in central nervous system (CNS) function (cf. Welford, 1977; Arenberg, 1978). This view has been supported by at least one investigation of the histochemical changes occurring in muscle cells during the aging process (Larson et al., 1979). However, the more traditional model of CNS aging has been contradicted by several studies in recent years. It has been shown that the *motor* component of both SRT and DRT more closely reflects the overall increase in those parameters than does the CNS component (Spirduso, 1975; Clarkson and Kroll, 1978; Gottsdanker, 1982; Milligan et al., 1984). Moreover, general physical condition and health appear to have a pronounced effect upon both the motor component and the overall times while the CNS component is little affected (Spirduso, 1975; Milligan et al., 1984). Since SRT and DRT display similar training and health effects and since these effects seem to reside primarily in the motor component, it has been suggested that the source of psychomotor slowing with age is to be found in the peripheral aspects of motor outflow and neuromotor control rather than in CNS processing.

In the present paper we address the question of the source of psychomotor slowing using the results of our study of timed reaction tests in 512 adults from Kansas. Our results bear upon this question in several ways as they indicate that (1) simple reaction time (SRT) in response to an external visual stimulus shows a significant increase with age, (2) the peripheral motor component of SRT, as measured by movement time (MT), shows a nearly identical aging pattern, (3) a putative CNS component, taken to be the difference Δ_T = SRT – MT, displays no apparent age effect, and (4) these patterns are consistent regardless of the sex of the subjects. Taken together, our results suggest support for the position the psychomotor slowing with age is due more to changes in the peripheral aspects of motor outflow and neuromotor control.

Subjects and Methods

The 512 adult subjects in this study were aged 13 to 96 years at the time they were tested. The sample was nearly equally divided by sex with 250 male and 262 female subjects. All participants were voluntary members of a general study of aging and longevity conducted amond the Alexanderwohl Mennonite congretions of Kansas and Nebraska (Crawford and Rogers, 1981; Devor et al., 1985b). In particular, the data reported on here were collected in the Goessel, Kansas Mennonite congregation.

Psychomotor tests were administered in the field and the procedures utilised were, therefore, somewhat constrained by considerations of the portability of the testing equipment and the time required to test each participant. Subjects were asked to complete the tests in a single session which lasted about 15 minutes. Two tests were administered, one was a simple reaction time (SRT) task and the second was a separate movement time (MT) task. The SRT task chosen by us consisted of a preferred-hand movement of 46 cm to a stationary microswitch in response to an external visual (light) stimulus. The required movement was made by a seated subject forward and medially the same distance regardless of the hand preferred. A Dekan timer was used to accurately measure the time interval to 0.001 seconds. The separate MT task was the same as the SRT task with the exceptions that a second microswitch was inserted at the start position and the timed interval was self-initiated. In both tests a single untimed trial was permitted following verbal instruction and the tests themselves consisted of three timed repeats. A more detailed description of these tests is provided by Devor et al. (1985a).

Since the field conditions under which these tests were administered did not allow us to obtain a large number of trial repetitions for each task and subject, we have chosen to report the fastest time achieved by each subject on each task. While it is clearly better to take a mean time among a larger number of trials, the small sample size within individuals could introduce potentially large individual variances. After noting that there was no significant pattern to the number of the trial in which the fastest time occurred (i.e. no significant training effect), we settled on the fastest time as the reported variable.

Results

Mean times and standard deviations by sex and age-cohort for SRT, MT, and Δ_T = SRT−MT are presented in Fig. 1. It can be seen from the figure that there is a clear increase in SRT with age regardless of sex and that this increase is reflected by a nearly identical pattern in MT. The difference, here called Δ_T, does not display this pattern in either sex. The visual impressions from Fig. 1 are statistically corroborated in two ways. First, Spearman rank correlations of both SRT and MT with age are significant for each sex whereas neither sex showed significant correlations for Δ_T. Among the men in the sample the Spearman rank correlation was $r = 0.623$ for SRT while among the women in the sample the value obtained war $r = 0.543$. Similarly, for the MT task the value of the Spearman rank correlation with age was $r = 0.632$ among the men and $r = 0.555$ among the women. In all four cases these values were highly significant, $p < 0.001$ (Snedecor and Chochran, 1980). For the difference, Δ_T, the correlation values obtained were $r = 0.015$ for men and $r = 0.008$ for women. Clearly, these latter values are statistically non-significant.

In addition to the computation of the correlations each variable was fitted with a polynomial regression in which both linear and non-linear age effects were permitted up to age^4 (Nie et al., 1975). The regressions were performed for each sex independently. Within sexes the relationship between both SRT and MT and age is significantly non-linear as quadratic and even cubic terms in age were included in the optimum repression equations. The final form of the polynomial was obtained by a stepwise procedure with $\alpha = 0.05$ as the criterion for inclusion (Nie et al., 1975). The polynomial regression

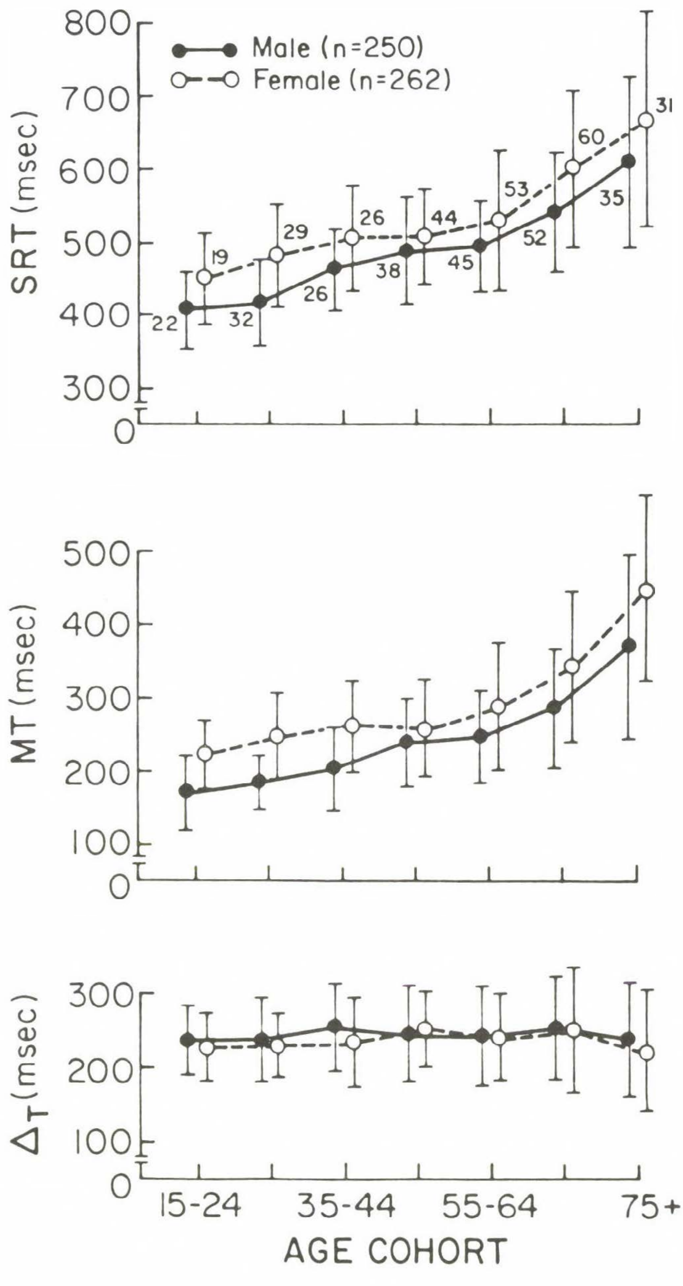

Fig. 1. Mean age–cohort times and one standard deviation unit (in milliseconds) for each age-cohort by sex. Total sample sizes are shown in the top graph along with the sample sizes of each age-cohort.

equations obtained are: SRT (men) = $0.398 + 3\text{x}10^{-3}$ (age^2), $R^2 = 0.390$; SRT (women) = $0.460 + 4\text{x}10^{-5}$ (age^3), $R^2 = 0.315$; MT (men) = $0.156 + 3\text{x}10^{-3}$ (age^2), $R^2 = 0.332$; and MT (women) = $0.217 + 4\text{x}10^{-5}$. (age^3), $R^2 = 0.358$. On the other hand, no regression equation in age could be obtained for the difference, Δ_T, in either sex even with only linear terms.

Another important aspect of the data shown in Fig. 1 is an increase in the within-age- cohort variance over time for SRT and MT in both sexes. However, though this trend toward higher within- age- cohort variance is there in the data, only MT (men) reveals significant heteroscedasticity over the age- cohorts as measured by Bartlett's Test (χ^2 = 14.495, d.f. = 6, $p < 0.05$). Other values were only suggestive such as SRT (men) with $\chi^2 = 9.614$ (d.f. = 6, $0.25 < p < 0.10$), and MT (women) with $\chi^2 = 10.595$ (d.f. = 6, $0.25 < p < 0.10$). Values for the difference, Δ_T, were clearly not significant with $\chi^2 = 2.515$ (d.f. = 6, $0.90 < p < 0.75$) obtained for men and $\chi^2 = 7.611$ (d.f. = 6, $0.50 < p < 0.25$) obtained for women on the same test statistic (Snedecor and Cochran, 1980).

Discussion

The data presented here show that simple reaction time (SRT) tends to increase with advancing age. Moreover, this increase is significantly non-linear in both sexes. Thus, as with a number of measures of neuromotor function observed by us (Devor et al., 1985a) and by a long run of other investigators (e.g. Miles, 1931; Bellis, 1933; Ruch, 1934; Hodgkins, 1963), diminished ability to respond to a stimulus accelerates as we age. This accelerating pattern of decline is also clearly present in the self-initiated peripheral motor component, MT. If, as has been suggested by Spirduso (1980), the difference Δ_T = SRT − MT can be assumed to be at least a rough measure of CNS function with regard to stimulus recognition and signal processing, then the lack of a similar aging pattern in this component may be taken as evidence that the source of the decline in overall SRT is not to be found in the CNS but, rather, in the peripheral aspects of motor outflow and neuromotor control.

Naturally, we do not mean to suggest here that there is such a clean-cut division of labor in the nervous system that the source of diminished function can so easily be dichotomized. Perhaps, a more realistic conclusion might be that, on the basis of our data, the source of decline in overall SRT with age is predominantly in the peripheral aspects of motor outflow and neuromotor control. Support for this conclusion may be seen not only in the present results but in those reported by Nebes (1978). Nebes (1978) found that age-related differences in reaction times depended to a large degree upon the type of required response. When the response required of his subjects was verbal there was no significant difference between the mean response times of the younger and older cohorts. However, when the subjects were required to make a manual response similar to the one required of our subjects (Nebes used two telegraph keys 35 cm apart), a significant decrement in response speed was observed in both sexes. Moreover, it appears that the magnitude of the observed decrement in manual response speed depends upon the nature of the task involved. For example, losses of response speed on the order of 80 msec. or more were observed in our sample. Nebes (1978) observed losses on the order of 35 msec between 20 and 70 year olds on his similar manual task. By contrast, Gottsdanker (1982) required a much reduced manual response of his subjects by asking them to simply press a button on which their finger already rested and, while statistically significant, the loss in speed he observed was less than 10 msec. Such results suggest that not only will the effects of advancing age be most obvious in the peripheral motor system but also in tasks that require the most involvement of parts of that system. That is to say, the more of the peripheral neuromotor system that is involved, the more pronounced will be the effects of age.

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