Task-specific performance decline in aging

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ABSTRACT

Decline of motor performance characteristically observed in the aging process has been proposed to be caused by a single factor: deterioration of the central information processing capacity. If so, motor performance in different tasks should decline in a similar way as an individual gets older. In order to test this hypothesis, motor performance of 19- to 73-years-old physical active individuals was studied in eight motor tasks: reaction time, movement time in aiming, handgrip strength, anticipatory timing, force control, repetitive tapping, sequential drawing and sequential fingers movements. The analysis indicated a diversity of performance profiles between tasks across ages, with motor decline at a moderate rate between 20 and 60 years for reaction time, larger performance decline in the transitions between 20 and 40 years in tasks requiring movement speed in simple movements or temporal accuracy, larger decline in the transition between 60 and 70 years for maximum manual strength and graphic skill, and stable performance across ages for manual force control. Therefore, these results are contradictory to the single factor hypothesis, offering support for the alternative hypothesis of task-specific decline of sensorimotor performance as a function of aging.

Keywords: Aging. Motor performance. Specificity.

INTRODUCTION

The study of motor development has a differential regarding the other fields related to human motor behavior, which is represented by the analysis of the variations of performance related to factors associated with time passing, such as maturation; growth and degenerescence. Whenever one has degenerescence as interest focus specifically, it becomes explicit that the study of developmental processes is not restrict to infancy and adolescence, phases in which motricity is more expressively developed; it also deals with the aging process, which is usually characterized by a decline in performance as the individual ages. Lately, there has been a growing interest about understanding the factors associated with the decline of sensorimotor performance during aging, added to a concern in mapping the aspects that deteriorate with age, in the trial to acknowledge the changes in internal mechanisms of motor control. Within this context, it has been observed that the movements of elderly individuals become slower compared with younger individuals[1-3]. This fact is mainly caused by a longer disacceleration during the approaching phase of the hand to a special target[4-5].

Another motor performance aspect that has been observed to consistently decline due to aging is the reaction speed in face of sensory stimulation. In other words, systematic time reaction increase to visual stimulus[6] and reaction time to sound stimulus[7-8] are found with age increase. The work by Teasdale *et al.*[8] particularly, revealed more dramatic auditory reaction time increase in a secondary task (in relation to younger subjects), having as primary task the posture control in relation to different manipulation of sensory information and the pressure center. Having the results comparison with the auditory reaction as single task as the starting point, it became evident that the greatest response latency had as one of the main causes the central processing of information.

Cerella[9] hypothetizes that the decline of performance in the elderly, particularly concerning slowliness of central processes, is due to a generalized decrease of the velocity in which the sensorimotor processes are performed. Such proposition suggests that aging is a destructive process characterized by a random reduction of connections in the neural circuiting, with constant probability overtime. These random losses as an individual ages would supposedly have a broad effect over several distinct functions of information processing, generating hence, a global deterioration of performance in tasks that would need attention resources, among them sensorimotor ones. Such proposition was called *single factor hypothesis*. According to this hypothesis, it was expected that the aging process would lead to a global and relatively uniform decline of performance in sensorimotor tasks of different origins, leading to a process of homogeneous decrease of performance overtime. Conversely to this hypothesis, Krampe and Ericsson[10] presented evidence that the functional loss does not occur for sensorimotor tasks that continue to be practiced during aging. The decline of performance would consequently be selectively determined by the disuse of functions related to the motor control in the daily routine of elder individuals (see also Fisk, Rogers[11]). In that case, differentiated declines would be expected for different movement abilities. In other words, from this concept, the daily experiences of an individual would model the motor decline rate during aging, producing distinct rhythms of performance decrease over the years. In order to contrast such hypothesis, in the present study the results of performance of different age groups were compared, from young adults to elders, in eight motor tasks demanding distinct sensorimotor functions.

METHOD

Participants

Sixty-four physically active individuals voluntarily participated in this study. They were Physical Education college students or regular participants of motor activities programs, from both sexes and with ages between 19 and 73 years. The participants were divided in four groups[1]: 20 (10 men, 10 women, 19-23 years, mean = 20 years), 40 (10 men, 8 women, 36-43 years, mean = 39 years), 60 (8 men, 10 women, 56-63 years, mean = 59 years) and 70 (3 men, 5 women, 68-73 years, mean = 71 years) years of age. The experimental procedures were approved by the local Ethics in Research Committee.

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Note

1. Due to the age groups breadth, a transversal approach was applied, while a stricter test to the single factor hypothesis of motor decline with aging would be obtained through a longitudinal approach.

Procedures

Prior to the beginning of the tests session, the participants completed a consent form in which the experimental procedures, duration of experiment and their rights as research's participants were presented. The instructions for the tasks performance were verbally given, with emphasis on the importance of trying to keep the best performance at each try.

Since each of the tests involved specific tasks, they were performed in a single order. The tests were divided in two sessions, performed at different days, with mean duration of thirty-five minutes each. At the first session, tests of touch among fingers (sequential fingers movement); time for drawings completion (sequential drawing); maximal prehension force (handgrip strength) and prehension force control (force control) were performed. At the second session, time tests of single visual reaction (reaction time); movement time; synchronization (anticipatory timing) and repeated touches with a vertical stalk (repetitive tapping) were performed. The tests were performed in the order that they were presented above.

There were familiarization tries followed by main tries of evaluation for all the tasks. The familiarization tries had the aim to introduce the subject to the task in order to provide full comprehension on its objective and attenuate the variability of the initial tries; offering hence, greater representation to the values observed in the tries valid for registration. Different quantities of familiarization tries for each motor task were applied due to the muscular demand of each task: one try for the maximal handgrip strength; five tries for the tasks of touch among fingers, writing movements and repetitive tapping; and in the four remaining tasks (reaction time, movement time, force control and synchronization) ten tries were performed. The main tries were conducted immediately after the familiarization tries, and in all tasks five tries were performed. There was an interval of approximately 10 s between the tries in each task and a longer interval of 2 min between tasks.

Tasks

The following motor tasks were applied in order to obtain a broad sample of different motor skills:

Visual simple reaction time/movement time at aiming – The reaction time/movement time device was applied (Lafayette Instruments Co., model #63017). Such device consists of a control panel, a peripherical which provides preparatory sounds, and two buttons of the teleghaphic type. These buttons were connected to a wooden board so that they were steady, at 55 cm of distance from each other. The subject would initially press one of the buttons at the experimentator's command, a preparatory visual signal would then appear showing that the imperative signal was about to appear. After a period from 2-4 s the imperative signal would sound. The task consisted of reacting and moving as fast as possible to the imperative stimulus, losing contact with the button which was being pressed and pressing the other button of the device with the same hand. The latency for losing contact with the first button (reaction time) and the time spent between this event and the pressing of the second button (movement time) were registered.

Maximal prehension force (handgrip strength) – A digital manual dinamometer (Takei Co.) with grip size regulation was applied for this task. From standing position, with the arm of execution resting along the body, the task consisted of performing the maximal handgrip strength in a fast movement.

Force control – From the same standing position from the previous task and applying the same device, the subject had the aim to perform 50% of the maximal handgrip in the dinamometer. The difference between the criterion value and the value observed in the dynamometer was registered.

Synchronization (anticipatory timing) – The Bassin Anticipation Temporizer (Lafayette Instruments Co., model #50575) was used for this task performance. It consisted of a 152 cm long metal rail, with infrared light-emitting diodes placed along it (LEDs) with spacing of 4,5 cm between them. A controller provides the LEDs sequenced light, giving the impression of dislocation of a light beam, which had a controlled velocity. The task consisted of turning on a manual switch, held by the subject and connected to the rail by a cable which coincides with the end of the light signal dislocation and moved at a 4 m/s velocity. The difference between the perfect synchronization and the real time in which the switch was turned on was registered (error time).

Repeated touches with vertical stalk (repetitive tapping) – Applying a counter of vertical oscillatory movements (Takei Co.), the task consisted of repeatedly touch a 5 cm long vertical metal stalk with a wooden basis with which the stalk is articulated. The stalk was held with the point and index fingers and the thumb (with prehension similar to that applied for writing). The task required alternated flexion and extension movements of the wrist in order to raise and lower the stalk. The contralateral hand pushed the board down so that the main hand's movement was performed as fast as possible without dislocating the device. Each try consisted of 30 touches, with the spent time in each try being registered. The performance was measured with a manual chronometer.

Time for drawing completion (sequential drawing) – To draw circles with approximately 1 cm of diameter, as fast as possible. The drawings were made on quadrilaterals previously sketched on paper, along a line. The aim was to complete sequences of 10 circles as fast as possible. The performance was measured with a manual chronometer.

Touches among fingers (*sequential fingers movements*) – To alternatively touch the thumb with the point, index, ring and little fingers, in repeated sequences as fast as possible. The task was performed with the subject seated and visualizing the movements. The aim was to complete 10 touch sequences in the shortest time as possible. The performance was measured with a manual chronometer.

Statistical analysis

The inferential analysis was separatedly conducted for each task, comparing the performances of four age groups through analyses of variance of a single factor (age) for independent measures. The later contrasts were conducted with the Newman-Keuls test. In all analyses the minimum significance level adopted was of 5%.

An index based on the proportional decline of performance in the transition for the subsequent age was calculated, with the purpose to compare the mean rate of decline of performance for the different tasks due to aging. The formula applied was the following:

$$[(Mir - Mip) / Mir] \times 100$$

where *Mi*r is the general reference of mean age and *Mi*p is the general mean of the subsequent age. Positive values indicate gain in performance, while negative values show decline in the transition for the following age.

RESULTS

The results analysis indicated significant differences for reaction time [$F(3, 60) = 4{,}67$, $p < 0{,}01$] (figure 1a), movement time at aiming [$F(3, 60) = 12{,}02$, $p < 0{,}001$] (figure 1b), maximal force [$F(3, 60) = 3{,}92$, $p < 0{,}05$] (figure 1c), synchronization [$F(3, 60) = 4{,}40$, $p < 0{,}01$] (figure 1d), touches with stalk [$F(3, 60) = 7{,}94$, $p < 0{,}0005$], touches among fingers [$F(3, 60) = 6{,}01$, $p < 0{,}005$] and difference close to significance for drawings [$F(3, 60) = 2{,}51$, $p = 0{,}07$] (figure 2). The only variable in which no age significant effect was found was force control [$F(3, 60) = 0{,}36$, $p > 0{,}1$] (figure 1e). The following contrasts indicated that for touches among fingers; movement time; synchronization and touches with stalk variables, significant differences were found in the age group of 20 years and the re-

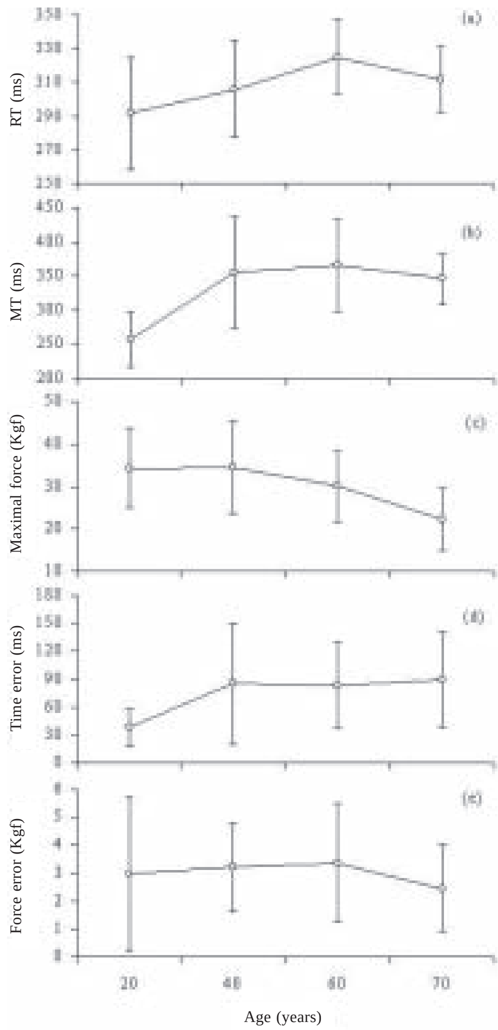

Figure 1 *– Simple visual reaction time* ***(a)****, Movement time at aiming* ***(b)****, Maximal handgrip strength* ***(c)****, Absolute error time in the synchronization task* ***(d)*** *and Absolute error in the force control task concerning age* ***(e)****.*

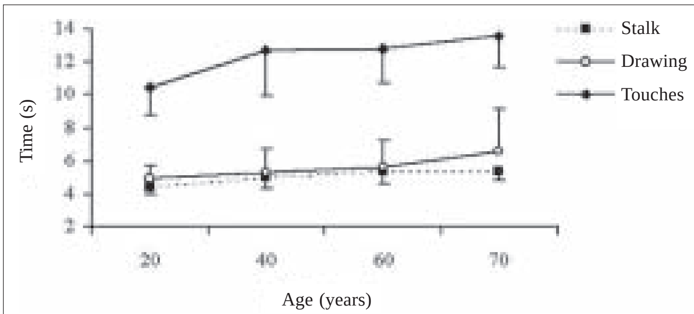

Figure 2 *– Completion time for the repetitive tapping tasks with vertical stalk (stalk), circles drawing (drawing), and sequential fingers movements (touches) concerning age*

maining ones, without indication of significant effects in the comparisons in the other ages. The tendency of more expressive decline of performance after the 20 years of age for reaction time was kept; nevertheless, significant difference was only found between the 20 and 60 years groups. This tendency was inverted for maximal force, once significant difference was identified only between the 70 years of age and the remaining ones, showing a more expressive decline in performance in the passage from 60 to 70 years of age. The value close to the significance borderline for the drawings task shows a tendency of higher decline of performance between the 60 and 70 years of age, with less expressive variations among the previous ages. The mean values of the decline of performance indices among ages are presented in table 1. From these results on, it becomes clear that different patterns of decline in the motor tasks are observed with aging.

TABLE 1
Decline in performance Index in the transition in age groups for each motor task

	Age transition		
	20-40	**40-60**	**60-70**
RT	–4,88	–6,34	4,15
MT	–38,20	–2,78	5,31
Stalk	–12,81	–7,57	1,11
Drawing	–8,37	–6,03	–17,30
Touches	–21,60	–0,49	–6,03
Force	0,52	–12,77	–25,75
Force control	–8,05	–4,21	27,11
Synchro	–123,94	1,76	–7,47

DISCUSSION

Generally speaking, the results initially show that the decline in performance is not proportional to aging. The results here presented showed linear tendency up to 60 years of age for visual reaction time, with a break in this tendency in the passage from the 60 to the 70 years of age, though. The eldest population presented visual reaction time values without significant increase in relation to the previous age (see Wilkinson, Allison[6], for similar results). Other important breaks in the tendency of gradual deterioration of performance due to aging were found for movement velocity, as shown in the movement time; touches among fingers and touches with stalk analysis. Significant difference was only found between the 20 years of age and the following age groups in these tasks, which represents relative performance stability from the 40 to the 70 years of age. Although the differences between ages did not reach the minimum significance, for the drawing tasks, the results showed tendency of more expressive decline between the 60 and 70 years of age. Therefore, although these tasks require movement velocity as main element, specific patterns of alteration of performance during aging were found, which is also understood from the analysis of the indices of decline of performance.

In previous investigations reporting decline of movement velocity with age, the strategy of comparing how an age group develops with subjects in the age group 20-30 years has been usually adopted (p.e., Pratt *et al.*[5]). Such studies only allow us to know that there is a decline of performance when one reaches ages relatively advanced. However, they do not indicate how this process occurs over the years. An exception is found in the work by York and Biederman[3], in which the movement time in a task of reciprocal touches was studied in populations from 20 to 89 years of age. The results were somehow similar to the ones reported in this study, once the most expressive decline of performance occurred in the passage from the 30's to the 40's, as observed here in three out of four tasks involving movement velocity in the passagefrom 20 to 40 years of age: touches among fingers; movement time and touches with stalk.

Concerning the force production, the results here reported corroborated findings of previous investigations (see Booth *et al.*[12], for review) when revealing progressive decline of maximal handgrip strength from 40 years of age, with more expressive decline in more advanced ages. Proportionally speaking, a decline of approximately 13% was observed in the passage from 40 to 60 years of age; and an additional decrease of 25% in the transition between 60 and 70 years of age was observed. Once the studied population was of physically active subjects, the muscular strength seems to be a motricity aspect inexorably harmed by aging. Such characteristic has been proposed to be the result of an atrophy process of the muscular system, which can be related with alterations of muscular cells and motoneurones, which occur during aging[12].

In tasks that depend more on precision than strength or velocity, such as in synchronization and force control, a singular pattern of performance alteration during aging was not found. Significant differences for force control were not found in any of the comparisons in ages, which is an indication of the weak influence of aging in this variable. Such results do not agree with previous findings by Cole[13] and Lazarus and Haynes[14], which showed a reduced capacity of the elderly to regulate the handgrip strength in pinching movements. The discrepancy between previous results and these here reported may be a consequence of the kind of task applied, once the handgrip strength used in order to start the dinamometer may have inhibited the appearance of subtle differences in the quality of motor control within age groups, which is more evident in abilities requiring strength fine control. However, what the results here presented show is that the deterioration in the force control is not a characteristic that mandatorily follows aging (see Cole[15]).

An expressive decline of performance in the passage of 20 to 40 years of age for the synchronization task was observed, with subsequent stabilization of performance in the following ages. In this task, the main aspects for good performance is the ability to integrate visual information with movements control in order to obtain a good response contemporization. Within this context, the deterioration of sensorimotor functions which are associated to aging do not seem to affect performance in the task. Hypothetically, such decline of performance is more related to the reduction of motor experiences quantity in interceptative actions than to the structural deterioration of the neuromuscular system. Once previous investigations have shown the anticipation of coincidence as a transferable function in motor tasks[16-18], the decrease of practical experiences in sports tasks involving synchronization of movements to environmental events, usually observed when individuals leave the young adults stage, may be related with this significant decrease of performance. In this flow of thinking, the transfer of intertask learning could be responsible for the observed advantage of the participants of 20 years of age.

At the end of the performance analysis of different age groups in the motor tasks here applied, we reach to the conclusion that there was not a single pattern of decline of performance. The performance profile in each motor task seems to have its particular characteristics during aging, with decline at a moderate rate between 20 and 60 years of age for reaction time; more severe declines of performance in the transition between 20 and 40 years of age in tasks requiring execution velocity of simple movements or time precision; more dramatic decline in the transition between 60 and 70 years of age for maximal strength and graphic ability; and maintenance of the performance ability with aging for handgrip strength. Therefore, these results are contradictory with the single factor hypothesis[9]. Alternatively, Krampe and Ericsson[10] propose that the decline of performance during aging is task-specific, being selectively determined by the disuse of sensorimotor functions, while those that continue to be practiced as age progresses are relatively kept. Studies in which the effect of regular motor activities for elderly individuals was shown reinforce this interpretation. Zizi *et al.*[19], for instance, demonstrated that after a program in motor activities, elder individuals presented performance improvement in the tasks regularly practiced. Moreover, Salhouse[20], Walker *et al.*[21] and more recently Silva *et al.*[22] reported not having found significant difference between the performance of young and elder individuals in tasks similar to those the latter are used to practice, while in non-habitual activities the young subjects are usually in advantage. Thus, both evidence sources related to oriented motor activities programs or daily activities show that systematic motor activities may delay the aging effects for the specifically practiced tasks. The expected effect of this factor on motricity is a diversity of decline of performance rates due to the specific motor experiences of the individuals in their daily lives.

An aspect that could be mentioned as an intervenient factor in the results is the quantity of daily activities of the participants. Since this is one of the factors that has been shown to modulate the capacity of motor performance of elder individuals (see Spirduso[23]), it could be a variable aspect among groups together with age. Nonetheless, as all participants of the study regularly practiced oriented motor activities, it is not probable that the quantity of physical activity had significantly varied among groups.

Therefore, the results here presented show a diversity of motor decline rates among the distinct motor tasks. The fact that the performance in certain motor tasks was very similar to that observed in young individuals is of special interest in applied terms, as well as the existance of certain critical ages for specific variables. The first aspect shows a broad preservation capacity of performance observed in young adults during aging of physically active individuals. The second aspect has implications in the selection of more relevant tasks for each age in motor activities programs oriented to maintenance of motricity for individuals in aging process.

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