Falling down: an insight into the psychomotor slowing.

João Barreiros

Faculdade de Motricidade Humana
Technical University of Lisbon

Aging is a biossocial process of regression. All living beings have several losses in their capacities at different moments of their lives. These depend on some variables: genetic variables, accumulated damage, living conditions and nutritional factors, among others. This decline may begin at different ages for different individuals and the general trend shows extreme individual variations. Despite all these variations, there is general agreement on the evidence of the first signs of decline. Most individuals exhibit a biological decline, following to a peak of maturity at approximately thirty years of age.

This aging phenomenon has been analysed from a scientific perspective, and more studies will be developed as the number of elderly within the world population grows.

Aging after adolescence is deleterious and there are two fundamental reasons for this fact: disuse and degeneration. In a technological society both causes are present. Disuse is a natural consequence of the availability of better tools and the access to long distance information. Better and cheaper machines do limit muscular and energetic participation in work. On the other hand, these new tools demand new perceptual control operations and an increasing participation of sensorial systems and cognitive processes. An obvious observation is that we have reduced our energy expenditure and muscle workload while an increased participation of senses and brain was taking place. The use of technology and other related social and medical benefits has also influenced positively life span. Older biological systems tend to show all kinds of degeneration effects. Degeneration and disuse work together leading to a general weakening and a decline in biological functions and motor performance.

The focus of this paper is on a particular aspect of aging: the psychomotor slowing (Birren, 1959), that is, a general slowing of the body that constitutes a universal phenomenon. This trend is a sort of slowing down of all voluntary responses and of perceptual and cognitive operations. An attempt to associate the psychomotor slowing to the locomotion problems of the elderly will be made, emphasising the perceptual and motor changes of aging.

1. General Age-related changes

Body composition changes over time. Among other changes, there are three main modifications: a water percentage decrease, an increase of fat tissue percentage and a significant reduction of lean body mass; another important change concerns the bone mineral content. These modifications are extremelly important to help us understand some medical problems and both the reduced strength level and the decline in physiological parameters.

Some biological modifications, such as the reduction in cardiac output, increased blood pressure, lowered maximum heart rate or increased peripheral vascular resistance, maybe on the basis of the decline in VO2 max, that is, the general parameter that expresses the work capacity from a cardio-respiratory point of view. Older adults are, therefore, less able to maintain the organism at acceptable adaptation levels, and particularly at extreme effort demands. Other variables contribute to this typical deficit, namely the reduction of ventilatory movements and expiratory volumes. Although “rest” parameters do not seem to be significantly age-dependent, aerobic and anaerobic capacities are clearly affected by aging.

Changes in the nervous system are also worth some comments. It is a well known fact that the brain mass decreases and that the number of brain cells suffers a severe reduction. Other aspects include, for instance, the synaptic excitability and the nerve conduction velocity. These age-related changes have very important consequences in functional aspects, and are partially responsible for the progressive slowing of voluntary movements. Even though cognitive functions were not affected, the degeneration and loss of structural elements of the nervous system will be enough to significantly reduce the natural information flow.

The integrity of the locomotor system is also affected by the deleterious effects of time. Flexibility tests and joint function analysis show consistent decrements in movement amplitude and consequently in the efficiency of fundamental motor patterns like walking or stair climbing. It is also known that muscular parameters like the number of muscle fibers, their size and diameter, or the amplitude and speed of contraction, experience differential decrements which normally strongly affect less used body portions.

All these changes in the muscular structures produce a general decline in muscle contraction, well documented in strength parameters, that can decrease almost to 40% following to the peak of the third decade of life.

The combination of muscular and nervous aging effects are of extreme importance: not only the central and peripheric structures of the nervous system work slower as also the effectors are significantly less efficient. These are two basic arguments to justify the psychomotor slowing. However it is not yet clear what is due to disuse rather than to natural biological aging effects.

2. Sensory and perceptual changes

Sensory devices and perceptual operations are very sensitive to aging effects. This is a critical matter for two reasons: (1) environmental and internal information will be colected in a less precise way, and (2) the rationale for decision-making is weakened, therefore many “wrong” decisions will be executed by the motor system.

Auditory perception in the elderly is often deteriorated in both the auditory localization and discrimination functions. Hearing sensitivity also decreases with age, specially at high frequency ranges. This auditory “blindness” is also extended to other senses like smell, taste, and particularly, vision.

Visual acuity and focus on objects at close distance show a very intense decay after 40 years of age. Other factors like retinal illuminance, eye lens accomodation and transparancy, and even the number of cells in the retina are not immune to aging effects. Some important consequences are the decline of depth perception and of the visual field sensitivity and amplitude. Old adults are also more sensitive to light conditions: adaptation from dark to light or vice-versa are very slow in the elderly. The changing from one room to another, with different light conditions, may become a serious problem.

Other important changes occur in the proprioceptive information system. Old people are less effective in discriminating limb movements, either in active and in passive movement conditions. The discrimination of passive lower limb movements is very poor, making very difficult do describe whether the limb is being raised or lowered. This inability to recognize limb position, in association with pressure sensitivity deficit, may originate postural control problems, specially in reduced or low vision conditions. The posture, as a whole, instead of being a natural adaptation, becomes a hard problem to solve. This is a valid assumption either in static postures as well as in dynamic conditions.

Walking control demands additional information processing and, of course, much more time. A natural solution for this problem is to walk slowly, a strategy that is often observed in the walking speed of old adults.

Other sensations (cutaneous, vibratory or temperature) are also less differentiated in the elderly. The integration of all these sources of information, i.e., tactile, kinesthetic, vestibular, auditory and visual, is also a delicate problem for a central processor of reduced capacity. In crossing a busy street, for instance, a lot of information, coming from several sources, are used to judge the environment. This judgement must also take into consideration the individual's capacities in order to make the correct decision. Inefficiency either in the perceptual judgement and the motor capacities often lead to wrong decisions. As Welford (1984) has suggested, the major limitations of older adults in the motor domain are their limited capacities to make accurate decisions based on perceptual input and to, subsequently, establish adequate motor programs.

Movement slowing is just a reflection of this sensorial, perceptual and integration decline: a natural consequence of aging.

3. Age-related information-processing changes

As a consequence of the nervous system deterioration, namely the neuronal and synaptic aspects, the operations concerning memory, decision-making, attention and learning, also show the slowing effect. These changes that affect information processing, can be basically explained by a significant loss of neurons and other debilitating changes within neurons themselves (Gabbard,1992).

Attention, and specially attention focus, diminish with age. Dividing attention between tasks can also be a difficult operation for older subjects, and it certainly takes more time. This fact can also be observed in memory functions: short-term and long-term memory capacities show deficits that can also be observed in the transfer of information from the short-term to long term stores (Craik, 1977; Dobbs & Rule, 1989;Poon,1985).

This is partially explained by the misuse of deep elaborate encoding strategies and by the reorganization deficit of information encoding. Therefore all information-processing abilities will demonstrate less flexibility and a clear slowing. Whether or not this is reflected in the learning capacity remains open to discussion. However, it is quite pacific that while old schemata remain stable and available to use, there is a severe reduction of new shemata. This is a natural consequence of the reduction of plasticity of the central nervous system with age. For practical purposes one can state, as a basic and general premisse, that learning becomes increasingly difficult with age, and that the necessary adaptation capacity that all schemata must reveal will exhibit colateral aging effects. As a consequence, even though old schemata do not change significantly, their adaptability is lower, and this maybe a problem in the special case of motor adjustments.

4. Age-related motor-changes.

The rate of the psychomotor slowing is clearly affected by biological variables and by the task demands. Generally, as task complexity increases, processing time and movement time decrease. This is a well known relationship that becomes more intense with aging (Lupinacci et al, 1993). However, motor system areas that continuously keep high activity levels are less sensitive to this deleterious process, allowing quite normal motor standards.

Movement efficiency depends on the good condition of peripheral effectors as well as the integrity of muscle, tendons and joints sensors. These elements work together in order to maintain essential aspects of motor behavior such as posture, balance control, or movement stability.

Reaction time follows an intense decline curve. The time needed to perform a simple reaction time task maybe around 300 msec at 80-years-old, representing a 1500% increase of the normal reaction time of a young adult, and of course it constitutes an important source of danger for daily activities.

There is also a significant performance decrease in fast movements or in tasks where action speed is a major or critical factor. In movement sequences strongly dependent of perceptual information, and specially of external information, the planning operations will be delayed. In complex movement sequences, with important time constraints, the neural and motor delay is obvious; on the other hand, in slow actions that have been intensively practiced there is a reasonable performance level in old subjects.

Balance is a good example of the correlation of very different factors. Balance loss in the elderly is the consequence of the cumulative changes in sensory organs, central mechanisms and motor output integrity. The balance problem may be understood as a specific type of postural deterioration: muscular weakness and limited motion range come together with delayed reaction time, motor control deficit and sensory integration. This balance loss is of a great importance for locomotor actions and other upright activities.

The techniques used to investigate balance include force platforms and other devices that can assess postural sway in different conditions. The sway magnitude follows a U-shaped curve, with highly increased values after the age of 30 (Era & Heikkinen, 1985). Compensation strategies for this augmented sway involve postural adaptations and the search for wider support basis. Nevertheless, muscular strength loss, and movement time decrement, create the conditions for a high probability of falls and accidents which constitute a serious damage and an obvious limitation of comfort and quality of life.

Some other factors must be considered in the "balance problem". Older adults often present inefficient or even dangerous movement patterns, such as in walking and stair climbing. While walking, many old adults move while holding on to furniture, that may not be completely stable or in the expected location. Foot raise is very reduced and falls may occur in the presence of unexpected objects or adherence modifications of the ground.

Changes in walking pattern with age have been identified (Craik, 1989), and generally they include a walking speed decrease, shorter steps, reduction of pelvic rotation and ankle extension, variations in rhythm and reduction of step height.

In what concerns stair climbing, and after the age of 70, subjects can climb up and down a 10 or 20 cm step, making use of a handrail, when needed. However, about 15% of the subjects are unable to climb a 40 cm step, even with the use of the handrail (Lundgren-Lindquist, Aniansson & Rundgren, 1983).

The reasons why old people fall are of two kinds: the environment conditions that promote the loss of balance, and the inability or the excessive time that is necessary to correct the loss of balance.

The risk of falling increases with age, with significant changes from 65 to 80 years (Derber, 1950). Falls constitute an additional serious risk for health because bone density has dramatically changed in the elderly.

5. Three directions for the problem.

It has been pointed out that, with advancing age, the motor output registers a general slowing down. This effect is a negative consequence of a biological decline in sensory, perceptual, cognitive and motor functions, aggravated by the movement reduction that arises with aging.

Many authors have shown that the best antidote to prevent deleterious aging affects is to keep active life patterns and a continuous engagement in daily activities. Therefore, three directions must be taken into consideration:

1. To promote the engagement in physical activity programs, especially designed for the elderly, that is, taking into consideration the physiological and functional capacities, the set of motivations and the emotional structure of the elderly. A most common mistake is to adapt adult common activities, like sports, by merely reducing the volume or the intensity of the workload. As I have explained before, many other variables do change, like the movement time or the central programming of actions. There is also a specific framework for motivations at this age that demands the search for specific physical activities, often of ancestral origin. This is the case of the majority of free open space activities commonly practiced in China and Macau.

2. To encourage the participation of the elderly in daily activities such as cooking, walking, shopping, and taking care of other persons. Once again the chinese grand mother is a good example. To keep active habits will reduce the biological decline of aging. It is well documented the fact that less used body parts are more sensitive to function loss. The stimulation deficit of sedentary people is a consequence of the misuse of senses, and, as I tried to explain, perceptual decline provokes a chain reaction that involves the brain and the movements.

3. To adjust environment configuration to the specific needs of the elderly. The psychomotor slowing requires some environment adjustments, in order to prevent accidents and other damages. This may include aspects such as streets design, the timing and the brightness of lights at intersections, additional information involving different perceptual systems, stairs design, handrail access, illumination of public areas, noise control, the use of colours that enhance visual contrast and identification of obstacles, the quality of the pavements or the delimitation of slippery surfaces.

Appendix 1 - General age-related changes

Brain mass	10-15% reduction form 30 to 90
Brain cells	Up to 70% reduction
Spinal cord axons	About 40% loss
New axon growth	Delayed
Number of central synapses	Decrease
Synaptic function	Biochemical changes
Central synapses excitability	Reduction
Latency of stretch reflexes	Increased latency time
Motor nerve conduction velocity	0,5 m/sec/decade decrease; signific. decrease > 50
Sensory nerve conduction velocity	1,2 m/sec/decade; ; significant decrease > 21
Nerve conduction velocity	10 – 15% decrease
Elasticity of the arteries	Decreases
Terminal circulation	Efficiency loss
Cardiac efficiency	Decline of stroke volume and max.heart rate
Blood pressure	Increase
Cerebral circulation	Significant reduction
Respiratory function	About 40 % loss in vital capacity between 30 - 70
Oxygen transport capacity	Decrease
Oxygen extraction capacity	Decrease
Anaerobic Power	About 40 % decline by age 70
Isometric strength	15% loss at 65; more rapid decrease >65
Dynamic strength	General Loss; great variability
Grip Strenght	20% decrement
Flexibility (sit-and-reach)	10 to 20 cm decrement
Flexibility	General loss; great variability
Joint function	Decreasing mobility
Muscle mass	About 25% decrease between 30 – 70
Number of Muscle fibers, size and diameter	Decrease; differential decrement (higher in leg-trunk than arm-hand)
Muscular speed of contraction	Decrease
Contractile proteins	Decrease
Oxidative and glycolitic enzimes	Decrease
Body composition	Consistent changes
Water percentage	Decrease
Fat tissue	Increase of fat percentage
Lean body mass	10 – 15 % reduction
Bone mineral content	Change
Oxygen consumption	30 % decline between 30 – 70
Ventilatory movements	Decrease

Information gathered from: Vieira e Fragoso (1993), Williams (1990), Gabbard (1992), Eckert (1987), Asmussen (1968), Shepard (1972), Rikli e Busch (1986).

Appendix 2 - Age-related sensory and perceptual changes

Hearing sensitivity	Loss with age
Auditory Perception	Loss with age
Auditory localization	Loss with age
Auditory discriimination	Loss with age
Hearing (high frequency range)	Significant loss
Vestibular efficiency	6% decrease; decrement > 40
Smell and taste	Decrease
Visual acuity	Decrement >40; more intense >60
Focus on objects at close distance	Strong reduction >40
Depth perception	Evident loss >60
Retinal illuminance	70% reduction at 60
Contrast sensitivity	Declines with age
Eye lens accomodation and transparency	Reduction
Macula neuron population	50% reduction from 20 to 80
Peripheral retina	Subtle but progressive change
Visual field sensitivity (central and peripheral)	Reduction >60
Visual field amplitude	Narrowing
Dark to light adaptation	Dramatic decrease >60
Adaptation to darkness	More than 500% reduction from adolescence to 80
Cutaneous sensitivity	Decrease with age
Vibratory sensitivity	Greatest decline >80
Temperature sensitivity	Greatest decline >80
Pain sensitivity	Greatest decline >80
Touch/pressure	Greatest decline >80
Weight discrimination	Greatest decline >80
Discrimination of passive lower limb movements	Decrease with age
Kinesthetic acuity	Decrease with age
Sensory acuity	Loss
Passive limb position	Decrease in ability to tell if limb is passively raised or lowered
	Significant increase (100%) of thresholds for hip, knee and ankle
Active joint-movement sensation	No major changes

Information gathered from:Brocklehurst et al (1982), Williams (1990), Kenshalo (1977), Kleemeier (1959), Gabbard (1992), Eckert (1987).

Appendix 3 - Age-related information-processing changes

Attention	Declines
Short-term memory	Strong decrease >60
Storage capacity	Increased deficit
Information-processing abilities	Less flexible
Information encoding	Reorganization deficit
Memory recall	General deficit
Attention focus	Dividing attention becomes more difficult
Sensory storage	Little decline
Sensory storage/STM	Information is lost
Short-term memory	Declines slightly
STM/LTM	Transfer deficit
Long-term memory	Declines
Encoding strategies	Misuse of deep elaborate encoding strategies
Information-Processing speed	Decline
Decision making	Slows when based on perceptual information
Programming of movement sequences	Decline; increased amount of error in fast actions; no significant changes in slow movements
Learning capacity	Slows
Old schemata	Remain stable
New schemata	Diminishes with age

Information gathered from: Gabbard (1992), Dobbs & Rule (1989), Perlmutter (1983), Foss (1983), Craik (1983), Lupinacci et al (1993), Wellford (1984), Moore et al (1984), Wiliams (1990), Haaland et al (1993).

Appendix 4 - Age-related motor changes

Movement speed in simple discrete arm/hand movements	More than 32% decrement between 50-90
Complex sequential arm/hand/finger movements	65% decrement between 50-90
Balance	General decrease >young adults;
Postural control	General decrease
Postural sway	Increase >30
Walking gait	Deterioration >60
Walking speed	20% slower >70
Movement speed	Decrease; greater decline in trunk and legs
Cyclical finger movements	About 50% decrease form 20 to 70
Hand rotation velocity	About 70 % decrease from 20 to 80
Reaction time	Decrease (more than 50% from 20 to 80)
Repetitive hand movement	About 30% decrease
Hand mobility	Decreases >40
Arm/hand steadiness	Nearly 80% decrease from 50 to 90
Reflexes	Increased latency of stretch and polysynaptic reflex
Bilateral coordination	General decrease, more intense in non-prerred hand
Movement precision	General decrease with age
Writing words	About 70 % decrease from 30 to 80

Information gathered from: Rikli & Busch (1986), Lupinacci et al (1993), Hodgkins (1962), Haaland (1993), Light & Spirduso (1990), Williams (1990),
Barreiros (1994).

References:

Asmussen, E. (1968). The Neuromuscular System and Exercise. In H. Falls (Ed.), *Exercise Physiology*. New York: Academic Press.

Barreiros, J. (1994). Standing on one foot on a balance board. Data from 4 to 70 years-old. Unpublished data. FMH: Lisboa.

Birren, J.E. (1959). *Handbook of Aging and the Individual*. Chicago: The University of Chicago Press.

Brocklehurst, J.C., Roberton, D. & James-Groom, P. (1982). Clinical Correlates of Sway in Old-age – Sensory Modalities. *Age and Ageing*, *11*, 1-10.

Cerella, J. (1990). Aging and Information-processing Rate. In In J.E. Birren and K.W. Schaie (Eds.), *Handbook of the Psychology of Aging* (3rd ed.). New York: Van Nostrand Reinhold.

Craik, F.I.M. & Simon, E. (1980). Age Differences in Memory: the Roles of Attention and the Depth of Processing. In L.W Poon, J.L. Fozard, L.S. Cermak, D. Arenberg and L.W. Thompson (Eds.), *New directions in Memory and Aging*. Hillsdale, NJ: Erlbaum.

Craik, F.I.M. (1977). Age Differences in Human Memory: In In J.E. Birren and K.W. Schaie (Eds.), *Handbook of the Psychology of Aging*. New York: Van Nostrand Reinhold.

Craik, R. (1989). Changes in Locomotion in the Aging Adult. In M.H. Woolacott and A. Shumway-Cook (Ed.), *Development of Posture and Gait Across the Life Span*. Columbia: University of South Carolina Press.

Derber, M. (1950). *The Aged and Society*. Champaign, ILL: Industrial Relations Research Association.

Dobbs, A.T. & Rule, B.G. (1989). Adult Age Differences in Working Memory. *Psychology and Aging*, *4*, 500-503.

Eckert, H.M. (1987). *Motor Development* (3rd ed.). Indianapolis: Benchmark.

Era, P. & Heikkinen, E. (1985). Postural Sway During Standing and Unexpected Disturbance of Men of Different Ages. *Journal of Gerontology*, *40*, 287-295.

Foss, P.W. (1989). Adult Age Differences in Working Memory. *Psychology and Aging*, *4*, 3, 269-275.

Gabbard, C.P. (1992). *Lifelong Motor Development*. Dubuque: Wm.C. Brown.

Haaland, K.Y., Harrington, D.L.. & Grice, J.W. (1993). Processing Speed and Aging. *Psychology and Aging*, *8*, 4, 617-632.

Hasselkus, B.R. & Shambes, G.M. (1975). Aging and Postural Sway in Women. *Journal of Gerontology*, *30*, 661-667.

Himwick, H.E. (1959). Biochemistry of the Nervous System in Relation to the Process of Aging. In J. E. Birren (Ed.), *The Process of Aging in the Nervous System*. Springfield, ILL:C.C. Thomas.

Hodgkins, J. (1962). Influence of age on the speed of reaction and movement in females. *Journal of Gerontology*, *17*, 385-389.

Kenshalo, D.R. (1977). Age Changes in Touch, Vibration, Temperature, Kinesthesis, and Pain Sensitivity. In J.E. Birren and K.W. Schaie (Eds.), *Handbook of the Psychology of Aging* (pp. 562-579). New York: Van Nostrand Reinhold.

Kleemeier, R.W. (1959). Behavior and the Organization of the Bodily and the External Environment. In J.E. Birren (Ed.), *Handbook of Aging and the Individual*. Chicago: The University of Chicago Press.

Light, K.L. & Spirduso, W.W. (1990). Effects of adult aging on the movement complexity factor or response programming. *Journal of Gerontology*, *45*, 107-109.

Lundgren-Lindquist, B., Aniansson, A. & Rundgren, A. (1983). Functional Studies in the 79-years-olds. III. Walking Performance and Climbing Ability. *Scandinavian Journal of Rehabilitation Medicine*, *15*, 125-131.

Lupinacci, N.S., Rikli, R.E., Jones, J. & Ross, D. (1993). Age and Physical Activity Effects on Reaction Time and Digit Symbol Substitution Performance in Cognitively Active Adults. *Research Quarterly for Exercise and Sport*, *64*, 2, 144-150.

Moore, T.E., Richards, B. & Hood, J. (1984). Aging and the Coding of Spatial Information. *Journal of Gerontology*, *39*, 210-212.

Perlmutter, M. (1983) Learning and Memory through Adulthood. In M.W. Riley, B.B. Hess and K. Bond (Eds.), *Aging and Society: Selected Reviews of Recent Research*. Hillsdale, NJ: Erlbaum.

Poon, L.W. (1985). Differences in Human Memory with Aging: Nature, Causes, and Clinical Implications. In In J.E. Birren and K.W. Schaie (Eds.), *Handbook of the Psychology of Aging (2nd ed.)*. New York: Van Nostrand Reinhold.

Rikli, R. & Busch, S. (1986). Motor Performance of Women as a Function of age and Physical Activity Level. *Journal of Gerontology*, *41*, 645-649.

Shepard, R. J. (1972). *Alive Man*. Springfield, ILL: cC.C. Thomas.

Shock, N.W. (1962). The Psychology of Aging. *Scientific American*, *206*, 1, 100-110.

Vieira, M.. & Fragoso, I. (1993). Alterações Morfológicas da População Idosa Portuguesa. In A. Marques, J.M. Constantino, P. Vogelaere and R. Ersham (Eds.), *International Conference of Physical Activity and Health in the Elderly* (p.53). C.M.Oeiras, Portugal.

Welford, A.T. (1984). Between Bodily Changes and Performance: Some Possible Reasons for Slowing with Age. *Experimental Aging Research*, *10*, 73-88.

Williams, H.G. (1990). Aging and Eye-hand Coordination. In H.G. Williams (Ed.) , *Development of Eye-hand Coordination*. Columbia: University of South Carolina Press.

Wright, R.E. (1981). Aging, Divided Attention and Processing Capacity. *Journal of Gerontology*, *36*, 605-614.