

Normal and Successful Aging: What Happens to Function as We Age

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Focus Points

- The multisystem decline of function described as normal aging closely mimics the effects of inactivity and immobilization. Maintaining daily moderate physical activity and exercise dramatically slows the decline of function.
- While fluid intelligence declines with age, crystallized intelligence is maintained into late life.
- Lifestyle and environment are far more important than genes in predicting the course of late life. The influence of genetic traits declines with advancing age.
- Modifying or reducing risk factors has been shown to reduce the risk of disease, disability, and mortality. This effect is seen even in those >85 years of age.
- Successful aging is more than just avoiding disease and disability and prolonging life. Pursuing challenging cognitive activities, continuing exercise, and maintaining social contacts is the prescription for successful aging.

Abstract

Normal aging is marked by a decline of motor function and mobility and by the impairment of specific cognitive functions. In fact, much of normal aging closely mimics the effects of immobilization and inactivity. A prescription for successful aging, therefore, includes maintaining physical activity and pursuing cognitive challenges. Physiologically, the expected age-related decline in reserves, called homeostenosis, does not necessarily progress to disease and disability. Compliance with medical treatment for existing diseases and lifestyle choices slows progression toward disability and death. This “compression of morbidity” hypothesis allows for physically, cognitively, and socially active individuals to age successfully. The societal expectation of aging is evolving toward a more positive anticipation of maintained cognitive and physical capacity into late life. More than just avoiding disease and disability or prolonging longevity, lifestyle choices and maintained cognitive and physical activity allow for successful aging.

Introduction

According to Rowe and Kahn,¹ when older people are asked about their hopes, aspirations, and goals for their senior years, they simply note that they want to remain independent and continue to take care of themselves. Should one expect to lose one’s faculties and become dependent on others; in effect, to age normally? Or is it possible to try to age successfully? This article attempts to provide some basic understanding of the normal aging process and to provide a script to enhance successful aging.

An Exemplar of Successful Aging

Martin Deutsch, the son of psychiatrists Felix and Helena Deutsch, discovered an elemental form of matter years before he died in 2002 at 85 years of age. When interviewed by *The Boston Globe*² 4 years before his death, Deutsch was still working at his Massachusetts

Institute of Technology (MIT) office several times a week. In reference to work from his youth, Deutsch noted:

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I am a different person from when I was young. But I remember how I thought in those days. I know I had a certain grasp of things. There was a way of looking at the world that I didn't fully understand until I started losing it. ...In 1951 or 1952, I had a great creative outburst that I've never had again. It was a virtuoso performance. I've never had an encore. Since then, I have had periods where I have functioned well and been very satisfied.²

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In regard to his work after that creative surge, Deutsch commented:

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You compensate after that; ...it is true that when I work with people one-fourth my age, I can sometimes see through a problem much faster than they can. I know what mistake they are going to make and can help them avoid it.²

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But he added that he had never again experienced the flashes of paradigm-shifting insights he had enjoyed in his early 30s. He went on to suggest that his "real accomplishment came as an educator," mentoring younger scientists through their leaps of imagination. In addition to the social connection and cognitive challenge of teaching at MIT, Deutsch remained physically active by bicycling and hiking.²

What Does Aging Represent in Society?

One of the images of aging prevalent in society is of cognitive dysfunction, impaired mobility, incontinence, frailty, pain, and death. Yet television images of Senator John Glenn returning from space travel at 76 years of age and the Rolling Stones energetically performing as they turn 60 are beginning to alter the public's perception and expectation of life in later years. Indeed, the market place is launching advertisements appealing to aging "baby boomers," featuring vital seniors cooling off after a vigorous game of tennis or completing a run. Buick's newest commercials declare, "It's not your father's Oldsmobile"; truly, aging will be a different experience for the 76 million baby boomers rapidly approaching retirement than it was and continues to be for the current cohort of people born during the Great Depression now making their way past 65 years of age.

When Does Aging Begin?

Otto von Bismarck established the arbitrary designation of retirement at 65 years of age in late 19th century Germany. At that time, only 2% of the German population lived past 65. Therefore, the social welfare program he proposed for retirees was of minimal cost to the public.³

Recent advances in medical technology and scientific understanding have boosted average life expectancy to unprecedented levels. More than 34 million people in the United States are ≥ 65 years of age, and 4 million are >85 years of age. The extension of life expectancy now recommends the division of 65–75 years of age as "young-old"; those 75–85 years of age are now the "middle age" of the elderly, and "old-old" is reserved for the rapidly expanding group >85 years of age. In fact, those ≥ 85 currently comprise the fastest-growing segment of the population. This group's numbers are expected to double within the next 30 years. Aging may well begin before 65 years of age though: AARP accepts membership as early as 50 years old.⁴ Thus, growing old can be a lifelong process.

Homeostenosis

At no other time has the medical community had so much to offer with regard to improving the quality of life of older people. As advanced as medicine is, the diseases of old age still become increasingly prevalent as all bodily systems undergo a progressive

involutional process. Homeostenosis is the normal restriction of efficacy or reserve of organ function that occurs with age. It implies a decreased resistance to overall system insult. That is to say, physiologic reserves are spent with advancing age. This “normal aging” affects all systems of the body including the brain. Some of these expected changes include decreases in bone density, muscle mass, respiratory capacity, and immune function. Other common physiologic changes with aging include modest increases in blood sugar, abdominal fat, and blood pressure. Yet these changes do not constitute a disease or cause immediate disability. When the elderly person with this normal constellation of changes is challenged with an infection, trauma, or other insult; however, they will have much greater difficulty recovering. For example, a 21-year-old woman with a urinary tract infection may experience pain addressed by medications, while her 81-year-old grandmother may require hospital admission to treat delirium and sepsis resulting from the bacterial infection.

As homeostenosis progresses, the impact of risk factors (eg, progressive weight gain, decreased physical activity, increased blood pressure) on quality of life increases. However, modifying risk factors through diet, exercise, and compliance with medication regimens, can lead to decreased risk of advancement toward disease. As an example, compliance with a medication regimen to reduce systolic blood pressure over a period of 4.5 years reduced the incidence of stroke by 36% and myocardial infarctions by 27% in a sample group. Benefits were even seen in those >80 years of age.⁵

Compression of Morbidity

Decline in function is inevitable with aging. Nearly 40% of those ≥85 report some difficulty with walking, while <15% of those 64–75 years of age report the same difficulty.⁶ An increase in life expectancy does not necessarily mean more years of disability later in life, though. Indeed, the number of disabled Americans has remained static over 10 years despite a growing population.⁷ This is attributed in part to an expanding population of healthy elders. Presented in terms of the individual, the chance of an 85-year-old staying healthy over the next 2 years improved from 60.5% to 67.5% (from the period 1982–1984 to 1984–1989).⁷

The delay in onset of initial disability and the reduction of the cumulative period of lifetime morbidity is described as the “compression of morbidity.”⁸ The ultimate manifestation of the compression of morbidity would be a physically active, socially integrated, cognitively intact individual dying soon after the initial onset of disease and disability. This would represent both successful aging and perhaps successful dying. Certainly, Deutsch maintained his rigorous physical and cognitive activity into his early 80s and died while still productive at 85.

Genes Versus Environment and Lifestyle

Age is not the best predictor of life expectancy. Environment and lifestyle are likely far more important than genes in regard to aging. Because these factors are modifiable, opportunities for change are abundant. Even with a strong genetic predisposition toward a particular risk factor or disease (eg, high cholesterol or coronary artery disease) lifestyle can modify genetic susceptibility. For example, at 54–66 years of age, >75% of the variance in serum triglycerides is due to genetic factors, while by 70–84 years of age, nearly 100% of the variance is from environmental or lifestyle factors.⁹ In general, genetic influences on health decline with advancing age, while the influence of environmental factors increases.

Physical Functioning and Exercise

Early in life, function and independence are gained with advancing development and maturity. But by the fourth decade of life, muscle strength and bone mass begin to decline as physical reserves likewise decline. In general, function and independence decrease when the demands of the task outstrip the individual’s reserves. As an example, a sedentary individual 75–85 years of age would require more than half of their reserve strength simply to shower. An active older individual who maintains a higher baseline of functional reserve will more easily maintain functional independence.¹⁰

For example, Deutsch was an anomaly in that he rode his bicycle to MIT several times per week up until his death and that he often hiked in the hills of Italy. Most older people, though, can easily become fatigued or experience pain when they try to bicycle or are just unable to do what they used to be able to do. Yet, this decline in functional capacity is not related to the aging process alone. It is critical to note that the expected decline in function experienced by most of the population, including decreased muscle mass, declining respiratory capacity, restricted range of motion, and decreased strength, closely mimics the results of physical inactivity or immobilization. Presumably, the sedentary nature of most Americans of all ages may explain a significant portion of decreased function

often attributed to aging.

In reality, only a fraction of the normal decline in physical functioning is directly related to chronological aging. Control subjects in their seventh decade studied over 10 years were found to have maximal oxygen consumption declines of 12% over the decade. On the other hand, age-matched runners showed declines of only 5.5%.¹¹

The benefits of exercise extend to more than just an improvement in the body's ability to extract oxygen: regular resistive and cardiovascular exercise helps reduce high blood pressure, decrease tendency toward diabetes, improve osteoporosis, and decrease risk of falls. Moreover, regular moderate exercise helps correct other risk factors for heart disease including obesity, smoking, and high blood lipids.

Thus, those maintaining higher levels of muscle strength, flexibility, and aerobic capacity not only live longer but are able to preserve their independent function longer and pursue more of their daily activities. In that regard, their aging is "slowed." In a comparison of runners to a non-running control group over a period of 8 years beginning at an average age of 59, exercisers developed only 25% as many disabilities as sedentary subjects.¹²

When individuals are no longer able to reliably generate enough strength to perform basic activities of daily living, including transfers to and from a toilet, rising unassisted from a chair, or walking short distances around the home, their function falls below a threshold and assistance must be sought. Help can be sought from modification of the environment (eg, grab-bars in the bath, a cane or walker for balance, or assistance from an individual such as a family member or healthcare assistant). With extreme declines in function, the individual's safety is best ensured by replacing their home environment with an assisted living facility or nursing home.

Cognitive Function

As individuals age, a series of anatomic, biochemical, physiologic, pharmacologic, and support system changes underlie the progressive degradation of the nervous system and the development of cognitive inefficiencies. Both Davidoff¹³ and Albert¹⁴ provide a review of the nature of these changes in the context of normal aging. In brief, the brain of a healthy elder differs from that of a healthy young adult. By young adulthood, a person has generated all of the neurons that he or she will ever have. Over the course of a lifetime, 50,000–100,000 neurons are lost each day and the body has no natural mechanism to replace them, although some newer animal studies suggest that neurogenesis can occur in adulthood.¹⁵ As a result, brain atrophy can occur over time, resulting in a 10% loss of brain volume between early adulthood and old age.¹³ As neurons are lost over the years, protein deposits and other cell debris simultaneously begin to accumulate and levels of neurotransmitters, especially acetylcholine, decline. Though this inevitable decline of function occurs with age, activity slows this precipitous descent. The process of dendritic arborization and synaptogenesis proceed throughout life, resulting in an increasingly complex neural network.¹⁶

Given the changes that occur in the aging brain, it is not surprising to note that some predictable cognitive changes occur concomitantly. These normal changes in cognitive efficiency typically include mild memory difficulties (often referred to as "benign senescent forgetfulness"), inefficiencies of executive functions (eg, difficulties in problem solving, multitasking, selective attention, and flexible thinking), and slowed motor processing speed. Nevertheless, Powell, in his review of previous studies,¹⁷ notes that measurable changes in cognitive efficiency do not appear until after 50 years of age. Similarly, overall intelligence does not decline significantly until the seventh decade of life.

Powell does add, however, that different mental functions appear to "peak" at different times of life.¹⁷ The ability to pursue more abstract endeavors, such as mathematics and physics, appears to reach its creative apex at relatively young ages, usually in the 30s (eg, Deutsch's self-noted creative outburst). Less abstract sciences, such as biology or geology, appear to peak later and other pursuits, such as literature and music, seem to be considerably more age tolerant. Some language-based abilities seem to improve into the seventh decade of life.

The concepts of "crystallized" intelligence and "fluid" intelligence are useful in capturing the nature of these cognitive changes. Crystallized intelligence relies on the use of previously stored information manipulated in familiar ways. It appears to remain relatively stable (or even improves slightly) throughout the life span until the eighth decade.¹⁷ In contrast, fluid intelligence, which requires the manipulation of novel material in unfamiliar and/or complex ways, begins to deteriorate as early as the fifth decade of life.^{13,17-19} Furthermore, this increasing inefficiency is exacerbated by slowed mental processing speed. The point at which these changes intrude

on everyday life, and the actual magnitude and rate of the change, vary on an individual basis and with the particular cognitive domains. Hence, cognitive dysfunction in the healthy elder does not arise uniformly and is subject to a wide range of individual variation. In other words, individuals are more likely to be able to “think outside the box” when they are younger. Personality and social skills are not grossly affected by aging, although prior traits may be accentuated. Familiar facts and procedures are retained and continue to be utilized well. Although older people may require more time to master information, they are still able to do so.

The finding that fluid intelligence declines with age compared to the relative stability of crystallized intelligence helps to explain the arc of Deutsch’s remarkable career. Such considerations also allow us to understand how Monet was able to continue his creative career into his 80s, why Picasso continued to impress the art world into his 90s, and how Casals could still stun an audience at Carnegie Hall when he was 91. The stability of crystallized intelligence also helps us to understand the longevity of the careers of such writers as John Updike and Henry Roth. Their novels only become more satisfying as the authors age and become more adept at translating the wealth of their experiences to their art.

It is important to note, however, that cognitive changes in older persons can become more noticeable as a result of concurrent psychosocial changes. Elderly individuals often become more cautious; more rigid, ie, unable to accept multiple solutions to a problem; and experience a reduction in social interactions and a shrinking of their social network.¹³ Each of these changes can accelerate the appearance of cognitive deterioration. It is also important to note that as cognitive flexibility declines, the individual’s ability to function becomes more susceptible to the demand characteristics (ie, complexity) of his or her particular environment. Additional factors that might influence the appearance of cognitive decline include social isolation due to the death of friends and relatives, financial isolation due to retirement from employment, and physical isolation due to illness and declining physical abilities.

There are also data that suggest that the degree and extent of cognitive decline in an elder may be inversely proportional to the amount of “cognitive reserve” that the individual has built up throughout his or her life. In other words, individuals with relatively poor education, poor linguistic abilities, and unchallenging jobs are at greater risk for cognitive decline in old age than individuals whose lives involve continual learning and stimulation.²⁰ Some studies even suggest that lower levels of education result in a greater susceptibility to dementia.²¹ Mechanisms to explain these findings remain theoretical in that they are derived from animal studies that demonstrate ongoing synaptogenesis in response to the intensity and complexity of stimuli in the animal’s environment regardless of the age of the animal.^{22,23} By extension, it is possible that Martin Deutsch’s ongoing cognitive vigor throughout his life was directly a function of his immersion in cognitively challenging environments.

Evidence that normal age-related decline of cognitive functioning can be reversed was first provided by Schaie and Willis,²⁴ who reported the improvements in a group of elders on tasks of reasoning, spatial ability, and attention following five 1-hour training sessions. Of even greater significance is the fact that these gains were maintained even at a 6-month follow-up. Since the seminal work of Schaie and Willis, a variety of other studies suggested that keeping oneself cognitively active in the later decades can, at the very least, compensate for many of the normal age-related changes in cognitive functioning.²⁵⁻²⁷

A Prescription for Successful Aging

While no one has yet developed an elixir that would allow older persons to remain completely healthy and cognitively intact until death, research clearly provides a template for maximizing the likelihood of successful aging. The concepts of homeostenosis and compression of morbidity indicate that good physical health in old age depends on proper and prompt management of medically compromising comorbidities in the context of a regular exercise program. Furthermore, physical exercise may have a direct salutary effect on cognitive function as well.^{28,29} Clearly, proactive management of medical risk factors, such as hypertension, atherosclerosis, and diabetes, that are associated with cognitive decline will also help preserve cognitive function as aging progresses.

Our current understanding of aging in relation to cognitive function also provides some guidelines to maximize said function. As mentioned earlier, it is likely that an environment that is cognitively and socially challenging without being overwhelming would facilitate enhanced cognitive performance. An environment that provides little stimulation results in boredom and cognitive decline, while an environment that is overstimulating causes anxiety and cognitive withdrawal. Hence, the demand characteristics of a particular environment must balance the extremes. Social interactions and social networks challenge the individual to communicate, utilizing their cognitive abilities to apprehend both verbal and nonverbal communication,³⁰ and hence help to maintain cognitive abilities in old age.

As it did with Deutsch, engagement in cognitively challenging work in old age serves to preserve cognition. Often such work also provides a social network and an increased sense of self-efficacy, which helps to avoid depression and maintain function. Levinson³¹

suggests that retirement become the opportunity for a second career and that such engagement both tends to the neglected self and helps maximize quality of life.

Specific cognitive training has been demonstrated to have only limited value, resulting in temporarily enhanced function for particular abilities. This may result from the narrow cognitive focus and limited time frame of such regimens. Rather, a rich, challenging environment appears to convey longer lasting benefits on the individual.

The progressive involution of all bodily systems with age also suggest the importance of attending to such factors as sleep, nutrition, sensory impairment, patterns of drug usage, and levels of stress. Small perturbations of such factors may have disastrous consequences in terms of cognitive decline. Careful management of such issues can only help to maintain a context for successful aging.

Common wisdom ultimately suggests that it is imperative to maintain a healthy mind in a healthy body. Current research indicates some methods and factors that need to be considered in order to follow this adage; simply heeding these may be all that is necessary for aging as successfully as Deutsch did.

Conclusion

The age-related progressive decline of physiologic, cognitive, and physical functions—though considered normal aging—is not optimal. The description of and prescription for successful aging includes continuing cognitive challenges, maintaining social involvement, and pursuing regular physical exercise. Furthermore, lifestyle changes and appropriate medical treatments should be pursued to address diseases and risk factors for diseases. The ultimate goal is not immortality but rather living a more functional, healthier, and perhaps longer life with less disease and disability. *PP*

References

1. Rowe JW, Kahn RL. *Successful Aging*. New York, NY: Pantheon Books; 1998: 42.
2. Yamma J. Old mind, young heart. *Boston Globe Sunday Magazine*. May 3,1998:4.

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Disclosure: Dr. Phillips is a consultant for MedTrak Technologies, Inc. Dr. Davidoff has received honorarium from Eli Lilly.

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