

The Forum

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The Gerontologist
Vol. 37, No. 4, 433-440

Substantial increases in the relative and absolute number of older persons in our society pose a challenge for biology, social and behavioral science, and medicine. Successful aging is multidimensional, encompassing the avoidance of disease and disability, the maintenance of high physical and cognitive function, and sustained engagement in social and productive activities. Research has identified factors predictive of success in these critical domains. The stage is set for intervention studies to enhance the proportion of our population aging successfully.

Key Words: Aging, Cognition, Physical function, Engagement, MacArthur Foundation

Successful Aging¹

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In an earlier article (Rowe & Kahn, 1987), we proposed the distinction between usual and successful aging as nonpathologic states. Our purpose in doing so was to counteract the longstanding tendency of gerontology to emphasize only the distinction between the pathologic and nonpathologic, that is, between older people with diseases or disabilities and those suffering from neither. The implicit assumption of that earlier gerontology was that, in the absence of disease and disability, other age-related alterations in physical function (such as increases in blood pressure and blood glucose) and cognitive function (such as modest memory impairment) were "normal," determined by intrinsic aging processes, primarily genetic, and not associated with risk.

We hoped that the distinction between two groups of nondiseased older persons — usual (nonpathologic but high risk) and successful (low risk and high function) — would help to correct those tendencies, stimulate research on the criteria and determinants of successful aging, and identify proper targets for interventions with "normal" elderly. In recent years, "successful aging" has become a familiar term among gerontologists (Abeles, Gift, & Ory, 1994; Baltes & Baltes, 1990; Garfein & Herzog, 1995; Hazzard, 1995) and a considerable body of research has accumulated on its characteristics. Much of this work was supported by the MacArthur Foundation

Research Network on Successful Aging. In this article we summarize the central findings of that work, propose a conceptual framework for successful aging, and consider some pathways or mechanisms that make for successful old age.

Defining Successful Aging

We define successful aging as including three main components: low probability of disease and disease-related disability, high cognitive and physical functional capacity, and active engagement with life. All three terms are relative and the relationship among them (as seen in Figure 1) is to some extent hierarchical. As the figure indicates, successful aging is more than absence of disease, important though that is, and more than the maintenance of functional capacities, important as it is. Both are important components of successful aging, but it is their combination with active engagement with life that represents the concept of successful aging most fully.

Each of the three components of successful aging includes subparts. Low probability of disease refers not only to absence or presence of disease itself, but also to absence, presence, or severity of risk factors for disease. High functional level includes both physical and cognitive components. Physical and cognitive capacities are potentials for activity; they tell us what a person can do, not what he or she does do. Successful aging goes beyond potential; it involves activity. While active engagement with life takes many forms, we are most concerned with two — interpersonal relations and productive activity. Interpersonal relations involve contacts and transactions with others, exchange of information,

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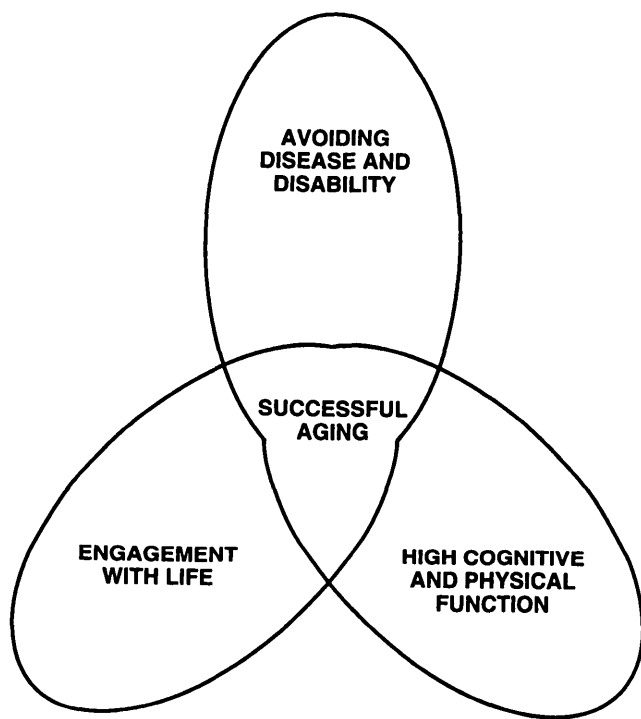


Figure 1. A model of successful aging.

emotional support, and direct assistance. An activity is productive if it creates societal value, whether or not it is reimbursed. Thus, a person who cares for a disabled family member or works as a volunteer in a local church or hospital is being productive, although unpaid (Herzog & Morgan, 1992).

Staying Healthy: Reducing Risk Factors for Disease and Disability in Late Life

The concept of usual aging as a large subset of those elderly previously considered to be "normal" is depicted in Figure 2 (Rowe, 1990). The curve farthest to the right, labeled "Death," displays the 1980 age-specific mortality experience of the United States. The area to the left of the curve labeled "Disability" estimates that portion of the population without disability, and the envelope between the Death and Disability curves denotes the disabled population. The area to the left of the curve labeled "Disease" represents the nondiseased, nondisabled population. The final curve, labeled "Risk," estimates the portion of the nondiseased population at significant risk for developing disease. The increasing dominance of this population with advancing age reflects emergence of the "usual aging syndrome" associated with risk of chronic disease. The area at the extreme left and bottom of the figure includes the nondiseased population at lowest risk, i.e., those who are aging "successfully" with respect to risk of emergence of disease. While the death, disability, and disease curves traditionally originate at 100%, i.e., with none of the population affected at birth, the risk curve arbitrarily originates at 80% not

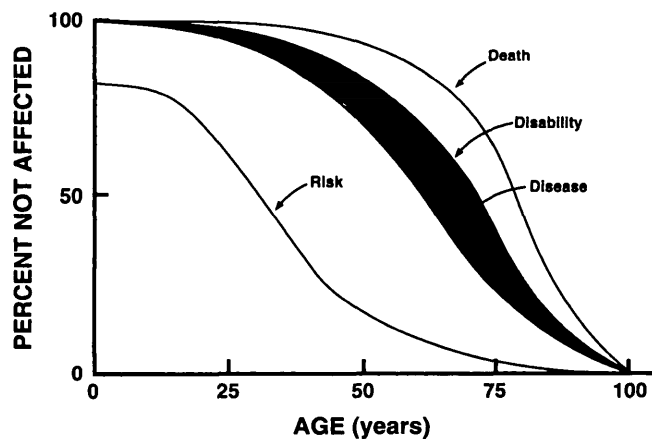


Figure 2. Relation of risk of disease to presence of disease, disability, and death in an aging population.

affected, to reflect the fact that many individuals begin at risk, either because of genetic factors or the psychosocial environment in which they are born.

Heritability, Lifestyle, and Age-related Risk

The previously held view that increased risk of diseases and disability with advancing age results from inevitable, intrinsic aging processes, for the most part genetically determined, is inconsistent with a rapidly developing body of information that many usual aging characteristics are due to lifestyle and other factors that may be age-related (i.e., they increase with age) but are not age-dependent (not caused by aging itself).

A major source of such information is the Swedish Adoption/Twin Study of Aging (SATSA), a subset of the Swedish National Twin Registry that includes over 300 pairs of aging Swedish twins, mean age 66 years old, half of whom were reared together and half who were reared apart. About one third are monozygotic, while two thirds are dizygotic. Comparison of usual aging characteristics in twins of differing zygosity and rearing status enables estimation of the relative contributions of heritable and environmental influences.

SATSA-based studies have determined the heritability coefficients (the proportion of total variance attributable to genetic factors) for major risk factors for cardiovascular and cerebrovascular disease in older persons. These are .66-.70 for body mass index, .28-.78 for individual lipids (total cholesterol, low- and high-density lipoprotein cholesterol, apolipoproteins A-1 and B, and triglycerides), .44 for systolic and .34 for diastolic blood pressure (Heller, deFaire, Pedersen, Dahlén, & McClearn, 1993; Hong, deFaire, Heller, McClearn, & Pedersen, 1994; Stunkard, Harris, Pedersen, & McClearn, 1990).

Heritability trends across decades of advanced age revealed a reduction in the heritability coefficients for apolipoprotein B and triglycerides (see Figure 3) and for systolic blood pressure (.62 for people under 65 years old and .12 for those over 65).

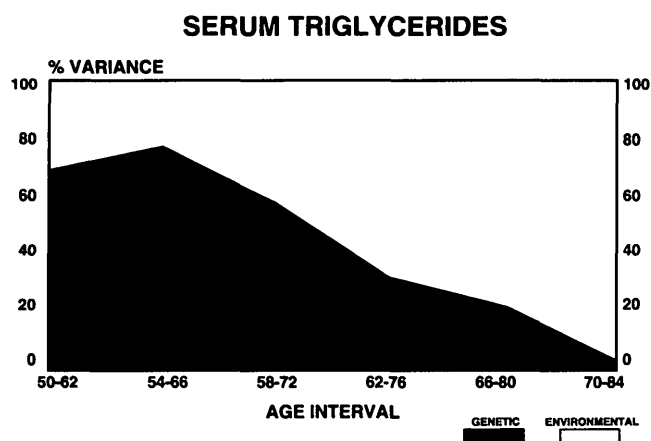
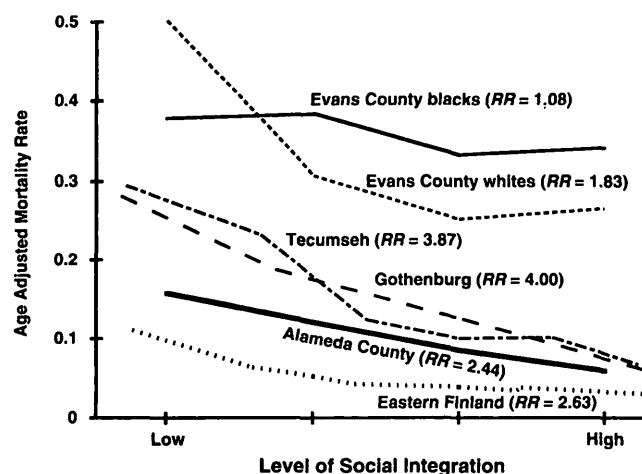


Figure 3. Relative contributions of heredity and environment with advancing age to serum triglycerides in Swedish twins, adapted from Heller, D. et al., 1993.

Consistent with these age-related reductions in heritability are mortality data from a 26-year follow-up of the entire Swedish Twin Registry, 21,004 twins born between 1886 and 1925 (Marenberg, Risch, Berkman, Floderus, & deFaire, 1994). Among male identical twins, the risk of death from coronary heart disease (CHD) was eightfold greater for those whose twin died before age 55 than for those whose twin did not die before age 55, and among male nonidentical twins the corresponding risk was nearly four times greater. When one female identical twin died before the age of 65, the risk of death for the other twin was 15 times greater than if one's twin did not die before the age of 65, and 2.6 times greater in the case of female nonidentical twins. Overall, the magnitude of the risk associated with one's twin dying of CHD decreased as the age at which the twin died increased, independent of gender and zygosity.

Beyond twin studies, other evidence indicates the importance of lifestyle factors in the emergence of risk in old age. For instance, advancing age is associated with progressive impairment in carbohydrate tolerance, insufficient to meet diagnostic criteria for diabetes mellitus but characterized by increases in basal and post-glucose challenge levels of blood sugar and insulin. The hyperglycemia of aging carries increased risk for coronary heart disease (Donahue, Abbott, Reed, & Yano, 1987) and stroke (Abbott, 1987), with progressive increases in the usual aging range associated with increasing risk. Similarly, the hyperinsulinemia associated with aging is an independent risk factor for coronary heart disease (Pyorala, 1979; Foster, 1989). Several studies have now demonstrated that the dominant determinants of this risk are age-related but potentially avoidable factors, such as the amount and distribution of body fat (Elahi, Muller, Tzankoff, Andres, & Tobin, 1982; Kohrt, Staten, Kirwan, Wojta, & Holloszy, 1990) and reduced physical activity and dietary factors (Zavaroni et al., 1986).

Substantial and growing evidence supports the contention that established risk factors for the



Note: RR indicates the relative risk ratio of mortality at the lowest versus highest level of social integration

Figure 4. Relation of level of social integration to age-adjusted mortality in five prospective studies, adapted from House, J. et al., 1988.

emergence of diseases in older populations, such as cardiovascular and cerebrovascular disease, can be substantially modified (Hazzard & Bierman, 1990; Sticht & Hazzard, 1995). In a study demonstrating the modifiability of "usual aging," Katznel and colleagues (Katznel, Bleecker, Colman, Rogus, & Sorokin, 1995) conducted a randomized, controlled, prospective trial comparing the effects of a 9-month diet-induced weight loss (approximately 10% of body weight) to the effects of a constant-weight aerobic exercise program and a control program on a well characterized group of middle-aged and older men at risk for cardiovascular disease. The study participants were nondiabetic and were obese (body mass index 30 kg/m²), with increased waist-hip ratios and modest increases in blood pressure, blood glucose, insulin, and an atherogenic lipid profile. Compared to controls, the reduced-energy intake diet resulted in statistically significant reductions in weight, waist-hip ratio, fasting and postprandial glucose and insulin levels, blood pressure and plasma levels of triglycerides, low-density lipoprotein/cholesterol, and increases in high-density lipoprotein/cholesterol. While the older weight loss subjects (over 60 years old) lost less weight than the middle-aged subjects and had more modest improvements in carbohydrate tolerance, they participated fully in the reductions in other risk factors. In general, the weight loss intervention had greater effects than the constant-weight aerobic exercise intervention.

Taken together, these reports reveal three consistent findings. First, intrinsic factors alone, while highly significant, do not dominate the determination of risk in advancing age. Extrinsic environmental factors, including elements of lifestyle, play a very important role in determining risk for disease. Second, with advancing age the relative contribution of genetic factors decreases and the force of

nongenetic factors increases. Third, usual aging characteristics are modifiable. These findings underline the importance of environmental and behavioral factors in determining the risk of disease late in life.

Intra-Individual Variability: A Newly Identified Risk Factor in Older Persons

The traditional repertoire of risk factors identified in studies of young and middle-aged populations may not include some additional risk factors unique to, or more easily identified in, elderly populations. In this regard, the MacArthur Foundation's Studies of Successful Aging point to a previously unrecognized risk factor — altered within-individual variability in physiologic functions — which may be important in determining the usual aging syndrome.

Most gerontological research, and indeed research in all age groups, is not geared to the measurement of short-term variations and changes. Study designs generally focus on the absolute level of a variable, perhaps comparing levels at two or more time points that may be separated by months or years. Nesselroade and colleagues (Kim, Nesselroade, & Featherman, 1996), reasoned that short-term variability in a number of physiological or perhaps psychological characteristics might reflect a loss of underlying physiological reserve and represent a risk factor for emergence of disease or disability. To study the impact of short-term variability, they examined between-person differences in similarly aged residents of a retirement community. They assessed various aspects of biomedical, cognitive, and physical functioning every week for 25 weeks in a group of 31 individuals and a matched group of 30 assessed only at the outset and the end of the 25-week period, and they followed the subjects for several years to ascertain the relationship between within-person variability and its risk.

Within-person variability of a joint index of physical performance and physiological measures (gait, balance, and blood pressure) was an excellent predictor of mortality five years later ($R = 0.70$, $R^2 = 0.49$). Variability of the composite measure was a better predictor of mortality than mean level, which did not represent a statistically significant risk factor (Nesselroade, Featherman, Agen, & Rowe, 1996). A similar pattern of findings held for the psychological attributes of perceived control and efficacy, for which average level was not a significant predictor of mortality but intra-individual variability scores predicted 30% of the variance in mortality (Eizenman, Nesselroade, Featherman, & Rowe, in press).

It should be emphasized that some functions are highly variable under normal conditions and others much less so. The significant aspect of intra-individual variability as a potential measure of decreased capacity and increased risk must be a change from the normal variability, regardless of whether the change is an increase or decrease. For example, a decline in beat-to-beat variability in heart rate has been shown to be a predictor of mortality in patients

who have previously suffered a myocardial infarction. While in the physiological measurement used in this study, an increase in variability was associated with increased risk; in other highly regulated systems, a decrease in variability may be detrimental and represent decreased reserve and increased risk.

Maximizing Cognitive and Physical Function in Late Life

A second essential component of successful aging is maximization of functional status. One common concern of older people relates to cognitive function, especially learning and short-term memory. Another functional area of major interest is physical performance. Modest reductions in the capacity to easily perform common physical functions may prevent full participation in productive and recreational activities of daily life.

The MacArthur Foundation Research Network on Successful Aging conducted a longitudinal study of older persons to identify those physical, psychological, social, and biomedical characteristics predictive of the maintenance of high function in late life. The 1,189 subjects in this three-site longitudinal study were 70–79 years old at initial evaluation and were functionally in the upper one third of the general aging population. Smaller age- and sex-matched samples (80 subjects in the medium functioning group and 82 subjects in the low functioning group) were selected to represent the middle and lowest tertiles. Initial data included detailed assessments of physical and cognitive performance, health status, and social and psychological characteristics (the MacArthur battery), as well as the collection of blood and urine samples. After a 2.0–2.5 year interval, 1,115 subjects were re-evaluated, providing a 91% follow-up rate for the study.

Predictors of Cognitive Function

Cognitive ability was assessed with neuropsychological tests of language, nonverbal memory, verbal memory, conceptualization, and visual spatial ability. In the initially high functioning group, four variables — education, strenuous activity in and around the home, peak pulmonary flow rate, and self-efficacy — were found to be direct predictors of change or maintenance of cognitive function, together explaining 40% of the variance in cognitive test performance. Education was the strongest predictor, with greater years of schooling increasing the likelihood of maintaining high cognitive function (Albert et al., 1995). This finding is consistent with several cross-sectional studies, which identify education as a major protective factor against reductions in cognitive function. Since all the subjects had high cognitive function at first evaluation, it is unlikely that the observed effect merely reflected ability to perform well on cognitive tests or was the result of individuals with greater innate intelligence having received more education. Instead, the results suggest either or both of two explanatory mechanisms: a direct beneficial effect of education

early in life on brain circuitry and function, and the possibility that education is a proxy for life-long intellectual activities (reading, crossword puzzles, etc.) which might serve to maintain cognitive function late in life.

Pulmonary peak expiratory flow rate was the second strongest predictor of maintenance of cognitive function. In previous studies, this function was a predictor of total and cardiovascular mortality and a correlate of cognitive and physical function in elderly populations (Cook et al., 1989).

A surprising finding of this study was that the amount of strenuous physical activity at and around the home was an important predictor of maintaining cognitive function. In a follow-up study to evaluate a possible mechanism of this effect, Neeper, Gomez-Pinilla, Choi, and Cotman (1995) measured the effect of exercise on central nervous system levels of brain-derived neurotrophic factor (BDNF) in adult rats. These investigators found that increasing exercise was associated with very substantial "dose-related" increases in BDNF in the hippocampus and neocortex, brain areas known to be highly responsive to environmental stimuli. These data provide a potential mechanism whereby exercise might enhance central nervous system function, particularly memory function.

A personality measure, perceived self-efficacy, was also predictive of maintaining cognitive function in old age. The concept of self-efficacy developed by Bandura is defined as "people's beliefs in their capabilities to organize and execute the courses of action required to deal with prospective situations" (Bandura, 1995). In students and young adults, self-efficacy influences persistence in solving cognitive problems (Brown & Inouye, 1978), heart rate during performance of cognitive tasks (Bandura, Cioffi, Taylor, & Brouillard, 1988), mathematical performance (Collins, 1982), and mastery of computer software procedures (Gist, Schwoerer, & Rosen, 1989). Lachman and colleagues have proposed a role for self-efficacy beliefs in maintenance of cognitive function among older people (Lachman, & Leff, 1989; Lachman, Weaver, Bandura, Elliott, & Lewkowicz, 1992).

In addition to these findings of predictors of maintenance of cognitive function, evidence is accumulating to indicate that it can be enhanced in old age. For example, older people who showed a clear age-related pattern of decline in fluid intelligence (inductive reasoning and spatial orientation) showed substantial improvement after five training sessions that stressed ways of approaching such problems and provided practice in solving them (Schaie & Willis, 1986). Moreover, repeated measurement indicated that the improvements were maintained. Studies from the Max Planck Institute in Berlin confirm the finding that cognitive losses among healthy older people are reversible by means of training, although they also show a substantial age-related training effect in favor of younger subjects (Kliegl, Smith, & Baltes, 1989). There is a double message in these findings: first, and most important, the capacity for positive change, sometimes called plasticity, persists

in old age; appropriate interventions can often bring older people back to (or above) some earlier level of function. Second, the same interventions may be still more effective with younger subjects, which suggests an age-related reduction in reserve functional capacity. These demonstrations of plasticity in old age are encouraging in their own right and tell us that positive change is possible.

Predictors of Physical Function

In the MacArthur studies, maintenance of high physical performance, including hand, trunk, and lower extremity movements and integrated movements of balance and gait, was predicted by both socio-demographic and health status characteristics. Being older and having an income of less than \$10,000 a year increased the likelihood of a decline in physical performance, as did higher body mass index (greater fat), high blood pressure, and lower initial cognitive performance. Behavioral predictors of maintenance of physical function included moderate and/or strenuous leisure activity and emotional support from family and friends. Moderate levels of exercise activity (e.g., walking leisurely) appeared in these studies to convey similar advantages to more strenuous exercise (e.g., brisk walking).

Continuing Engagement with Life

The third component of successful aging, engagement with life, has two major elements: maintenance of interpersonal relations and of productive activities.

Social Relations

At least since Durkheim's classic study of suicide (Durkheim, 1951), isolation and lack of connectedness to others have been recognized as predictors of morbidity and mortality. Five prospective studies of substantial populations have now demonstrated causality throughout the life course in such associations: being part of a social network is a significant determinant of longevity, especially for men (see Figure 4; House, Landis, & Umberson, 1988).

Research on the health protective aspect of network membership has emphasized two kinds of supportive transactions: socio-emotional (expressions of affection, respect and the like) and instrumental (direct assistance, such as giving physical help, doing chores, providing transportation, or giving money (Cassel, 1976; Cobb, 1976; House, Kahn, McLeod, & Williams, 1985; Kahn, & Antonucci, 1981; Kahn & Byosiore, 1992).

The three-community MacArthur study tested both instrumental and emotional support as predictors of neuroendocrine function and physical performance. Neuroendocrine measures were also studied as possible mediators of the effects of support. Over a three-year period, marital status (being married), presumably a source of emotional support, protected against reduction in productive activity (Glass, Seeman, Herzog, Kahn, & Berkman, 1995). Men with higher emotional support had sig-

nificantly lower urine excretion of norepinephrine, epinephrine, and cortisol, and for both men and women, emotional support was a positive predictor of physical performance. Instrumental support, on the other hand, had few significant neuroendocrine relations for men, none for women, and was associated with lower physical performance, probably as an effect rather than a cause (Seeman, Berkman, Blazer, & Rowe, 1994; Seeman, Berkman, Charpentier, Blazer, Albert, & Tinetti, 1995).

These varying effects of social support are consistent with research relating the effect of support to the specific situation in which it is offered. For example, instrumental support rather than emotional support influenced the promptness with which older people who experienced cancer-suspicious symptoms actually saw a physician (Antonucci, Kahn, & Akiyama, 1989). Opposite results came from a nursing home experiment, however: socio-emotional support (verbal encouragement) had positive performance effects, whereas instrumental support (direct assistance) had negative effects on performance (Avorn & Langer, 1982).

Several conclusions seem warranted regarding the properties of social relations and their effects:

- a. Isolation (lack of social ties), is a risk factor for health.
- b. Social support, both emotional and instrumental, can have positive health-relevant effects.
- c. No single type of support is uniformly effective; effectiveness depends on the appropriateness of the supportive acts to the requirements of the situation and the person.

Productive Activities

Older people are not considered "old" by their families and friends, nor do they think of themselves as "old," so long as they remain active and productive in some meaningful sense (Kaufman, 1986). In legislative policy, Congressional discussion as to whether the nation can "afford" its older people is as much a debate about their productivity as their requirements for service, especially medical care.

Part of the confusion stems from lack of clarity about what constitutes a productive activity. Our national statistics define Gross Domestic Product (GDP) in terms of activities that are paid for, and exclude all unpaid activities, however valuable. Several current studies (ACL, MacArthur, HRS) utilize a broader definition that includes all activities, paid or unpaid, that create goods or services of economic value (Kahn, 1986), and these studies have generated age-related patterns very different from those for paid employment alone (Herzog, Antonucci, Jackson, Kahn, & Morgan, 1987; Herzog, Kahn, Morgan, Jackson, & Antonucci, 1989).

The nationwide Americans Changing Lives (ACL) study found that, contrary to the stereotype of unproductive old age, most older people make productive contributions of some kind, more as informal help-giving and unpaid volunteer work than paid employment. When all forms of productive ac-

tivity are combined, the amount of work done by older men and women is substantial. Among those aged 60 or more, 39% reported at least 1500 hours of productive activity during the preceding year; 41% reported 500–1499 hours, and 18% reported 1–499 hours. The relationship between age and productive activity depends on the activity. While hours of paid work drop sharply after age 55, hours of volunteer work in organizations peak in the middle years (ages 35–55), and informal help to friends and relatives peaks still later (ages 55–64) and remains significant to age 75 and beyond.

Both the ACL and MacArthur studies address the question of what factors enable sustained productivity in old age. Both include longitudinal as well as cross-sectional data, and in some respects the studies are complementary — national representativeness over the full adult age range in the ACL survey, biomedical and performance measures as well as self-report in the MacArthur research. Three factors emerge as predictors of productive activity: functional capacity, education, and self-efficacy.

Functional Capacity. — Men and women high in cognitive and physical function are three times as likely to be doing some paid work and more than twice as likely to be doing volunteer work. Moreover, for all forms of productive work except child care, functional status also predicts the amount of such work. Indicators of functional decrement, such as limitations with vision and number of bed days during the three months preceding the data collection, predict lesser productive activity.

Education. — Educational level is a well established predictor of sustained productive behavior, paid and unpaid (Chambre, 1987; Cutler & Hendricks, 1990; Harris & Associates, 1981; Herzog, Franks, Markus, & Holmberg, 1996; Herzog & Morgan, 1993; Lawton, 1983; Morgan, 1986). The possible mechanisms of this effect include the role of education as a major determinant of occupation and income, both of which are major influences on the life course, the selective process in education that probably includes genetic elements and certainly includes parental socioeconomic status, and the tendency of education to inculcate values and establish habits that express themselves in later life as higher functional status and engagement in productive behavior.

Self-Efficacy. — Self-efficacy and the related concepts of mastery and control are consistent predictors of sustained activity in old age. The ACL study, in addition to identifying a positive relationship between self-efficacy and productive activity, found that two other variables, labeled vulnerability and fatalism, essentially inversions of self-efficacy, were negatively related to productivity. Consistent with these findings, in the MacArthur sample only one factor — mastery — emerged as relevant for both increases and decreases in productivity; increases in mastery led to increased productivity; decreases in mastery had the opposite effect.

Response to Stress

If we had continuous rather than occasional measurement of successful aging, we would expect to find that even older people who are aging successfully have not met the criteria at every moment in the past. They have moved "in and out of success," just as healthy people can be said to move in and out of illness. Under the most fortunate circumstances, aging brings with it some repetitive experience of chronic or recurrent stresses, the "daily hassles" of life (Lazarus & Folkman, 1984) and their cumulative effects. Most older people have also experienced more acute episodes, the "stressful life events" that have been much-studied (Dohrenwend & Dohrenwend, 1974; Holmes & Rahe, 1967). For example, older men and women may have been seriously ill, temporarily disabled by accident or injury, disoriented after a stroke, or depressed by the death of a spouse. Apart from such crises of illness and bereavement, but similarly stressful, are the experiences of forced retirement, sudden reduction in income, mugging, and burglary.

We propose the concept of *resilience* to describe the rapidity and completeness with which people recover from such episodes and return to meeting the criteria of success. Determination of resilience in dealing with a specific stressful event would require assessment of relevant functions before the stressing challenge is encountered and subsequent monitoring to observe the initial decremental effect, the time required to regain stability of function, and the level of function regained. While no research has yet robustly evaluated resilience, a number of studies are relevant to it. The work by Nesselrode and his colleagues, described earlier, demonstrated the importance of short term variability in physical function and blood pressure as a predictor of mortality among elderly subjects. We may interpret low variability in blood pressure as an indicator of resilience, but the interpretation must be tentative; we do not know the challenges or stressors to which these subjects were responding.

Conclusion

Recent and projected substantial increases in the relative and absolute number of older persons in our society pose a significant challenge for biology, social and behavioral science, and medicine. Gerontology is broadening its perspective from a prior preoccupation with disease and disability to a more robust view that includes successful aging. As conceptual and empiric research in this area accelerates, successful aging is seen as multidimensional, encompassing three distinct domains: avoidance of disease and disability, maintenance of high physical and cognitive function, and sustained engagement in social and productive activities. For each of these domains, an interdisciplinary database is coalescing that relates to both reducing the risk of adverse events and enhancing resilience in their presence. Many of the predictors of risk and of both functional and activity levels

appear to be potentially modifiable, either by individuals or by changes in their immediate environments. The stage is thus set for intervention studies to identify effective strategies that enhance the proportion of our older population that ages successfully.

References

- Abbott, R. D. (1987). Diabetes and the risk of stroke. The Honolulu Heart Program. *Journal of the American Medical Association*, 257, 949-952.
- Abeles, R. P., Gift, H. G., & Ory, M. G. (Eds.). (1994). *Aging and quality of life*. New York: Springer.
- Albert, M. S., Savage, C. R., Jones, K., Berkman, L., Seeman, T., Blazer, D., & Rowe, J. W. (1995). Predictors of cognitive change in older persons: MacArthur Studies of Successful Aging. *Psychology and Aging*, 10, 578-589.
- Antonucci, T. C., Kahn, R. L., & Akiyama, H. (1989). Psychosocial factors and the response to cancer symptoms. In R. Yancik & J. W. Yates (Eds.), *Cancer in the elderly: Approaches to early detection and treatment* (pp. 40-52). New York: Springer.
- Avron, J., & Langer, E. J. (1982). Induced disability in nursing home patients: A controlled trial. *Journal of the American Geriatric Society*, 30, 397-400.
- Baltes, P. B., & Baltes, M. M. (1990). *Successful aging: Perspectives from the behavioral sciences*. Cambridge, U.K.: Cambridge University Press.
- Bandura, A. (1995). *Self-efficacy in changing societies*. New York: Cambridge University.
- Bandura, A., Cioffi, D., Taylor, C. B., & Brouillard, M. E. (1988). Perceived self-efficacy in coping with cognitive stressors and opioid activities. *Journal of Personality and Social Psychology*, 55, 479-488.
- Brown, Jr., I., & Inouye, D. K. (1978). Learned helplessness through modeling. *Journal of Personality and Social Psychology*, 36, 900-908.
- Cassel, J. (1976). The contribution of the social environment to host resistance: the fourth Wade Hampton Frost Lecture. *American Journal of Epidemiology*, 104, 107-123.
- Chambre, S. M. (1987). *Good deeds in old age: Volunteering by the new leisure class*. Lexington, MA: Lexington Books.
- Cobb, S. (1976). Social support as a moderator of life stress. *Psychosomatic Medicine*, 3, 300-314.
- Collins, J. L. (1982, March). *Self-efficacy and ability in achievement behavior*. Paper presented at the annual meeting of the American Educational Research Association, New York, NY.
- Cook, N. R., Evans, D. A., Scherr, P. A., Speizer, F. E., Vedral, S., Branch, L. G., Huntley, J. C., Hennekens, C. H., Taylor, J. O. (1989). Peak expiratory flow rate and 5-6 year mortality in an elderly population. *American Journal of Epidemiology*, 130, 66-78.
- Cutler, S. J., & Hendricks, J. (1990). Leisure and time use across the life course. In R. H. Binstock & L. K. George (Eds.), *Handbook of aging and the social sciences* (3rd ed., pp. 169-185). San Diego: Academic Press.
- Dohrenwend, B. S., & Dohrenwend, B. P. (1974). *Stressful life events: Their nature and effects*. New York: Wiley.
- Donahue, R. P., Abbott, R. D., Reed, D. M., & Yano, K. (1987). Post-challenge glucose concentration and coronary heart disease in men of Japanese ancestry: Honolulu Heart Program. *Diabetes*, 36, 689-692.
- Durkheim, E. (1951). *Suicide*. Glencoe, IL: Free Press. (Original work published in 1897).
- Eizenman, D. R., Nesselrode, J. R., Featherman, D. L., & Rowe, J. W. (in press). Intraindividual variability in perceived control in an older sample: The MacArthur Successful Aging Studies. *Psychology and Aging*.
- Elahi, D., Muller, D. C., Tzankoff, S. P., Andres, R., Tobin, J. D. (1982). Effect of age and obesity on fasting levels of glucose, insulin, glucagon and growth hormone in man. *Journal of Gerontology*, 37, 485-491.
- Foster, D. W. (1989). Insulin resistance — A secret killer [Editorial]. *New England Journal of Medicine*, 320, 733-734.
- Garfein, A. J., & Herzog, A. R. (1995). Robust aging among the young-old, old-old, and oldest-old. *Journal of Gerontology: Social Sciences*, 50B, S77-S87.
- Gist, M. E., Schwoerer, C., & Rosen, B. (1989). Effects of alternative training methods on self-efficacy and performance in computer software training. *Journal of Applied Psychology*, 74, 884-891.
- Glass, T. A., Seeman, T. E., Herzog, A. R., Kahn, R. L., & Berkman, L. F. (1995). Change in productive activity in late adulthood: MacArthur Studies of Successful Aging. *Journal of Gerontology: Social Sciences*, 50B, S65-S76.
- Harris, L., & Associates (1981). *Aging in the eighties: Americans in transition*. Washington, D.C.: National Council on the Aging.
- Hazzard, W. R. (1995). Weight control and exercise: Cardinal features of successful preventive gerontology [Editorial]. *Journal of the American Medical Association*, 274, 1964-1965.
- Hazzard, W. R., & Bierman, E. L. (1990). Preventative gerontology: Strategies for attenuation of the chronic disease of aging. In W. Hazzard, R. Andres, E. Bierman, & J. Blass (Eds.), *Principles of geriatric medicine and gerontology* (2nd ed., pp. 167-171). New York: McGraw Hill.
- Heller, D., deFaire, U., Pedersen, N., Dahlén, G., & McClearn, G. (1993). Genetic and environmental influences on serum lipid levels in twins. *New England Journal of Medicine*, 328, 1150-1156.

- Herzog, A. R., Antonucci, T. C., Jackson, J. S., Kahn, R. L., & Morgan, J. N. (1987, February). *Productive activities and health over the life course*. Paper presented at the Annual Meeting of the American Association for the Advancement of Science, Chicago, IL.
- Herzog, A. R., Franks, M. M., Markus, H. R., & Holmberg, D. (1996). Productive activities and agency in old age. In M. Baltes & L. Montada (Eds.), *Produktives Leben im Alter* [Productive living in old age]. Frankfurt/New York: Campus Verlag.
- Herzog, A. R., Kahn, R. L., Morgan, J. N., Jackson, J. S., & Antonucci, T. C. (1989). Age differences in productive activities. *Journal of Gerontology: Social Sciences*, *44*, S129–S138.
- Herzog, A. R., & Morgan, J. N. (1992). Age and gender differences in the value of productive activities: Four different approaches. *Research on Aging*, *14*, 169–198.
- Herzog, A. R., & Morgan, J. N. (1993). Formal volunteer work among older Americans. In S. Bass, F. Caro, & Y. P. Chen (Eds.), *Achieving a productive aging society*. Westport, CT: Greenwood.
- Holmes, T. H., & Rahe, R. H. (1967). The social readjustment rating scale. *Journal of Psychosomatic Research*, *11*, 213–218.
- Hong, Y., deFaire, U., Heller, D., McClearn, G., & Pedersen, N. (1994). Genetic and environmental influences on blood pressure in elderly twins. *Hypertension*, *24*, 663–670.
- House, J. S., Kahn, R. L., with McLeod, J., & Williams, D. (1985). Measures and concepts of social support. In S. Cohen & S. L. Syme (Eds.), *Social support and health* (pp. 83–108). Orlando, FL: Academic Press.
- House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science*, *241*, 540–545.
- Kahn, R. L. (1986, November). *Productive activities and well-being*. Paper presented at the meeting of the Gerontological Society of America, Chicago, IL.
- Kahn, R. L., & Antonucci, T. C. (1981). Convoys of social support: A life-course approach. In S. B. Kiesler, J. N. Morgan, & V. K. Oppenheimer (Eds.), *Aging: Social change* (pp. 383–405). New York: Academic Press.
- Kahn, R. L., & Byosiere, P. (1992). Stress in organizations. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of industrial and organizational psychology, Vol. 3* (2nd ed., pp. 571–650). Palo Alto, CA: Consulting Psychologists Press.
- Katzel, L. I., Bleecker, E. R., Colman, E. G., Rogus, E. M., & Sorkin, J. D. (1995). Effects of weight loss vs aerobic exercise training on risk factors for coronary disease in healthy, obese, middle-aged and older men: A randomized controlled trial. *Journal of the American Medical Association*, *274*, 1915–1921.
- Kaufman, S. R. (1986). *The ageless self: Sources of meaning in late life*. Madison, WI: University of Wisconsin Press.
- Kim, M., Nesselroade, J., & Featherman, D. (1996). The state component in self-reported world views and religious beliefs of older adults: The MacArthur Successful Aging Studies. *Psychology and Aging*, *11*, 396–407.
- Kliegl, R., Smith, J., & Baltes, P. B. (1989). Testing-the-limits and the study of adult age differences in cognitive plasticity of a mnemonic skill. *Developmental Psychology*, *25*, 247–256.
- Kohrt, W. M., Staten, M. A., Kirwan, J. P., Wojta, D. M., & Holloszy, J. O. (1990). Insulin resistance of aging is related to body composition. *The Gerontologist*, *30* [Special Issue], 38A.
- Lachman, M. E., & Leff, R. (1989). Perceived control and intellectual functioning in the elderly. *Psychology and Aging*, *2*, 266–271.
- Lachman, M. E., Weaver, S. L., Bandura, M. M., Elliott, E., & Lewkowicz, C. J. (1992). Improving memory and control beliefs through cognitive restructuring and self-generated strategies. *Journal of Gerontology: Psychological Sciences*, *47*, 293–299.
- Lawton, M. P. (1983). Time, space, and activity. In G. D. Rowles & R. J. Ohta (Eds.), *Aging and milieu: Environmental perspectives on growing old* (pp. 41–61). New York: Academic Press.
- Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. New York: Springer.
- Marenberg, M., Risch, N., Berkman, L., Floderus, B., & deFaire, U. (1994). Genetic susceptibility to death from coronary heart disease in a study of twins. *New England Journal of Medicine*, *330*, 1041–1046.
- Morgan, J. N. (1986). Unpaid productive activity over the life course. In Institute of Medicine/National Research Council (Eds.), *America's aging: Productive roles in an older society*. Washington, DC: National Academy Press.
- Neeper, S. A., Gomez-Pinilla, F., Choi, J., & Cotman, C. (1995). Exercise and brain neurotrophins. *Nature*, *373*, 109.
- Nesselroade, J. R., Featherman, D. L., Ager, S. H., & Rowe, J. W. (1996). *Short-term variability in physical performance and physiological attributes in older adults: MacArthur Successful Aging Studies*. Submitted for publication.
- Pyorala, K. (1979). Relationship of glucose tolerance and plasma insulin to the incidence of coronary heart disease: Results from two population studies in Finland. *Diabetes Care*, *2*, 131–141.
- Rowe, J. W. (1990). Toward successful aging: Limitation of the morbidity associated with "normal" aging. In *Principles of geriatric medicine and gerontology* (2nd ed., pp. 138–141). New York: McGraw Hill.
- Rowe, J. W., & Kahn, R. L. (1987). Human aging: Usual and successful. *Science*, *237*, 143–149.
- Schaie, K. W., & Willis, S. L. (1986). Can adult intellectual decline be reversed? *Developmental Psychology*, *22*, 223–232.
- Seeman, T. E., Berkman, L. F., Blazer, D., & Rowe, J. W. (1994). Social ties and support and neuroendocrine function: The MacArthur Studies of Successful Aging. *Annals of Behavioral Medicine*, *16*, 95–106.
- Seeman, T. E., Berkman, L. F., Charpentier, P. A., Blazer, D. G., Albert, M. S., & Tinetti, M. E. (1995). Behavioral and psychosocial predictors of physical performance: MacArthur Studies of Successful Aging. *Journal of Gerontology: Medical Sciences*, *50A*, M177–M183.
- Sticht, J. P., & Hazzard, W. R. (1995). Weight control and exercise: Cardinal features of successful preventative gerontology [Editorial]. *Journal of the American Medical Association*, *274*, 1964–1965.
- Stunkard, A., Harris, J., Pedersen, N., & McClearn, G. (1990). The body-mass index of twins who have been reared apart. *New England Journal of Medicine*, *322*, 1483–1487.
- Zavaroni, I., Dall'Aglio, E., Bruschi, F., Bonora, E., Alpi, O., Pezzarossa, A., & Butturini, U. (1986). Effect of age and environmental factors on glucose tolerance and insulin secretion in a worker population. *Journal of the American Geriatrics Society*, *34*, 271–275.

Received October 30, 1996
Accepted November 10, 1996