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Successful Aging: Focus on Cognitive and Emotional Health

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Key Words

older adult, elderly, cognitive aging, healthy aging, resilience, stress

Abstract

We review the definitions, predictors, and biobehavioral determinants of successful aging, as well as the evidence for and mechanisms of underlying selected interventions to enhance cognitive and emotional health in older adults. Defining successful aging has proven difficult, with discrepancies seen among biomedical, psychological, and lay perspectives. Although consensus is lacking, a number of studies have examined the genetic, lifestyle, and social determinants of operationalized determinants of successful aging; qualitative examinations of the meaning of the construct have also been conducted. The determinants coincide with fundamental aspects of aging. Recent clinical trials suggest that caloric restriction, physical activity, cognitive intervention, stress reduction, and social programs may enhance cognitive and emotional health in older people.

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INTRODUCTION

As of 2008, there were 506 million people in the world older than 65 years; in 2040, there will be 1.4 billion (Kinsella & He 2009). In the United States, as the baby boom cohort enters older adulthood, the number of people over 65 will rise to 72 million (20% of the population) by 2030 (Greenberg 2008). There is no precedent to this population change, as older adults will outnumber children younger than age 14 for the first time in recorded history (Road to Aging 1996). By and large, older people are healthier than their predecessors of just a few generations ago, as observed in Robert Fogel's Union Army Studies, with mean onset of age-related diseases occurring later in the current cohort of older adults compared to their predecessors (Fogel 2004) and rates of disability declining (Manton 2008). At the same time, there has been a shift in the past 100 years in the cause of mortality, from infectious disease to age-related chronic illnesses as the most common causes of death (e.g., cardiovascular disease, cancer, and stroke). There are some predictions that the gains made in average lifespan may be relinquished owing to obesity trends and the corresponding increases in diabetes (Olshansky et al. 2005). These remarkable and rapidly evolving changes to the age distribution of our species and the emergence of age-related diseases as primary determinants of human morbidity and mortality are cause for the claim that aging is the number one public health issue faced by the developed world (Cutler & Mattson 2006).

Complementary to efforts to differentiate pathological aging from normal aging, a small body of research has attempted to identify the characteristics, determinants, and interventions that promote successful aging. There is remarkable divergence among researchers and laypeople as to what defines successful aging and even as to what descriptor to use (e.g., optimal aging, robust aging, positive aging, healthy aging). Despite the lack of consensus in the construct of successful aging, a number of exciting recent findings have characterized and promoted positive states of health and well-being in older people—particularly in the realm of cognitive and emotional aspects of aging well. In the following review, we describe (*a*) the status of the definitions and components of successful aging, (*b*) hypothetical determinants and mechanisms focusing on cognition and emotion, and (*c*) evidence for the effectiveness of selected interventions to promote successful aging.

DEFINING SUCCESSFUL AGING

History of Successful Aging as a Research Focus

There has long been a dialogue regarding the attainment of healthy aging and longevity that conflicts with popular assumptions about aging and decline. In Cicero's powerful essay *Cato Maior De Senectute* (44 BC), the author refuted prevailing negative stereotypes about aging. Cicero systematically enumerated ways in which positive outcomes could be attained in older age, including adaption of life roles (e.g., fulfilling advisory roles) and the plasticity of the aging mind (e.g., the positive effect of mental exercise on memory).

However, perhaps the earliest specific use of the term "successful aging" in the biomedical literature was in 1961, in an editorial in the first issue of the *Gerontologist*. Drawing from the Kansas City Studies of Adult Life (among the first longitudinal studies aimed at understanding the transition from middle age to older age), Havighurst (1961) described successful aging as "getting a maximum of satisfaction out life," and called upon the young field of gerontology to research and promote successful aging.

Subsequent influential lifespan developmental theories of aging, such as the disengagement theory (Cumming & Henry 1961), activity theory (Lemon et al. 1972), and continuity theory (Atchley 1989, Ryff 1982), integrated data from longitudinal research in order to depict the course of normative late-life development, which had been the subject of far less attention relative to efforts to understand development in younger adults. These theories extended earlier life-stage theories, including that of Erikson (1959), in which successful resolution of earlier conflicts were presumed to lead to better late-life outcomes (e.g., ego integrity) (Erikson 1959). Lifespan developmental theories pointed toward often divergent developmental trends that could account for positive states of health in older age; for example, disengagement theory described late adulthood in terms of the cultural pressures toward reduced involvement with society. Activity theory pointed toward continued engagement and corresponded with the growing number of senior centers. Continuity theory emphasized the general trend for older adults to maintain consistency with earlier life roles and adaptation of activities to sustain such roles.

Despite their differences, underlying the above theories is the assumption that longevity, in and of itself, is an inadequate proxy and that maintaining independence or maximizing well-being were more important constructs in defining positive aging. Fries (1980) described the more optimal of goal of striving for compression of morbidity (COM). COM assumes that the lifespan is relatively finite, and delaying the onset of disability would thus shorten the proportion of life during which an individual experiences disability. The ideal old age would involve living free of disability until death. Healthy aging would be thus be measured by the number of disability-free years (known as the healthspan) rather than chronological years.

Compression of morbidity (COM): delay of the onset of disability relative to age of death

In subsequent seminal works, Rowe & Kahn (1987) and Baltes et al. (1990) addressed the concept of successful aging more explicitly, proposing testable models. Rowe & Kahn (1987) eloquently argued that (*a*) existing research had largely failed to delineate successful and healthy aging, instead focusing on differentiating pathology from normal aging, and that (*b*) successful aging is at the other end of the continuum from pathological aging and is a multidimensional and operationalizable construct that deserved its own rigorous study. Rowe and Kahn's theoretical model of successful aging included three components: (*a*) freedom from disability and disease, (*b*) high cognitive and physical functioning, and (*c*) social engagement (in terms of involvement both in social and productive activities). This model was employed in the MacArthur

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Research Network on Successful Aging, which for nearly a decade followed a cohort of more than 1000 older adults meeting an operationalized definition based on these criteria (Berkman et al. 1993, Rowe & Kahn 1997, Seeman et al. 1994). A complementary theory (Baltes & Smith 2003), selection optimization and compensation (SOC), approached successful aging from the perspective of lifespan development, focusing on psychological and behavioral processes involved in adapting to age-related losses and disabilities and maintaining performance on functional tasks. Baltes and colleagues based this model on the the Berlin Aging Study, which followed older adults between ages 70 and 100 (Baltes & Mayer 1999). Both Rowe and Kahn and the SOC theory were instrumental in subsequent research on successful aging.

Quantitative Studies of Using Definitions of Successful Aging

Since publication of the Rowe & Kahn (1987) paper, the definition, prevalence, and predictors of successful aging have been the focus of a number of quantitative and qualitative studies (see reviews by Depp & Jeste 2006, Peel et al. 2005, and Phelan & Larson 2002). These reviews were aimed at understanding how researchers and laypeople interpreted the successful aging construct as well which variables best separated successful from unsuccessful groups. In a review of 11 studies, Phelan found that seven dimensions of successful aging were used across these studies and noted that definitions of successful aging lacked the perspectives of older people themselves. Building on the Phelan review, Depp & Jeste (2006) reviewed 28 studies published between 1987 and 2006 in English language peer-reviewed journals with sample sizes greater than 100. The majority of these publications derived from large epidemiological investigations, where the main focus was on disease progression (e.g., cardiovascular disease).

The Depp & Jeste (2006) review identified 29 unique definitions of successful aging employed in 28 studies, and the only component of successful aging used in more than half of the studies was physical functioning/disability. Fourteen components appeared in more than one study, including cognitive ability, life satisfaction, social functioning, and absence of disease. Accordingly, the proportion of individuals categorized as aging successfully varied broadly (from 1% to 94%, median 35%) and was negatively associated with the number of components used in the definitions. Thus, among research definitions of successful aging, little consensus exists regarding constituent domains of successful aging other than physical functioning/disability.

In the Depp & Jeste (2006) review, the strongest predictor of membership in the "successful" category was younger age, defined as close to 60 (observed in 13 of 15 studies). Predictors significantly differentiating successful from unsuccessful groups in more than three articles include absence of arthritis, absence of hearing problems, and lower historical/present smoking. Predictors that were less consistent across studies included higher levels of exercise or physical activity, higher self-rated health, lower systolic blood pressure, fewer medical conditions, and absence of depression. There was limited evidence for higher income, greater education, marriage, and white ethnicity as predictors. It is not surprising that younger age predicted membership groups dichotomized as successful given that most of the definitions of successful included physical functioning and disability.

Qualitative Studies Assessing Lay Perspectives on Successful Aging

A small number of mixed-method and qualitative studies have examined the construct of successful aging from the perspectives of older adults. von Faber et al. (2001) used a mixed-method approach to study 599 adults aged 85 and older. Participants were categorized as successfully aging if they met objective criteria derived from the Rowe & Kahn (1987) model of successful aging, and a subsample of participants were interviewed regarding their

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definition of successful aging. In comparison to the quantitative results, qualitative interview data suggested that interviewed older adults were more likely to (*a*) endorse themselves as aging successfully relative to the proportion that met researcher-defined criteria, and (*b*) depict successful aging in terms of well-being and employ adaptive behaviors to maintain it. In separate studies, Strawbridge et al. (2002) asked older participants in the Alameda County Study to rate whether they were "aging well," and Montross et al. (2006) employed a single-item (1 to 10) subjective rating scale—both studies compared the distribution of subjective ratings of successful aging with that of the proportion meeting criteria for successful aging reported in previous studies. In both studies, significantly more adults rated themselves as aging successfully despite not meeting researcher-defined criteria for successful aging, most often because of the presence of physical disabilities.

Focus groups (Reichstadt et al. 2007), individual interviews (Andrews et al. 2002), and survey instruments (Phelan et al. 2004) have been used to examine the relative importance of individual domains of successful aging. In work with focus groups, Reichstadt et al. (2007) identified four largely psychological constructs discussed in regard to successful aging: (*a*) positive attitude/adaptation, (*b*) emotional security/stability, (*c*) health/wellness, and (*d*) engagement/stimulation. In contrast to the research definitions in which components were equally weighted, participants in the Reichstadt et al. (2007) study depicted successful aging as involving a foundation (e.g., positive attitudes, security) that enabled stimulation/engagement. Knight & Ricciardelli (2003) and Phelan et al. (2004) found that older adults endorsed most research-defined criteria as important to successful aging. However, Phelan et al. (2004) found that the relative importance of components of successful aging differed across Japanese, Japanese American, and European American respondents to a survey: European Americans were more likely to endorse independence as more important, whereas Japanese older adults ranked social belonging as more important. Finally, Bowling & Iliffe (2006) contrasted five definitions of successful aging, including a multidimensional lay-based definition that included more subjective variables than the other four definitions, patterned after research definitions described above. Interestingly, the lay-based definition was a stronger predictor of quality of life than were the biomedical definitions.

Indices of Biological Age/Intermediate Phenotypes

At the other end of the research spectrum from qualitative approaches to uncovering the subjective aspects of successful aging, a number of empirical efforts have been made to develop integrative indices of biological age. Described in depth elsewhere (Karasik et al. 2005, Ravindranath et al. 2002, Wilson 1988), indices of biological age are aimed at tracking the rate of biological aging by combining information from multiple intermediate phenotypes. An index of biological age is validated by its ability to predict functioning and/or mortality better than chronological age or its individual constituents. Ideally, biological age would consist of a set of indicators of basic aging processes that are heritable, not solely related to disease effects, and translatable across species. One could thus define successful biological aging as being biologically younger than one's chronological age. A repeatable biomarker of aging could potentially serve as an outcome of interventions, as well. Allostatic load, for example, combines multiple physiological indicators converging on stress response, and expressed as an index has been shown to predict mortality better than its individual constituents or chronological age (O'Hara et al. 2010).

Critics of biological age are skeptical that a single indicator can provide meaningful summarization of the many causes of aging—thus, one may have multiple biological ages across different systems (McClearn 1997, Wilson 1988). In addition, given that biological age depends on its incremental validity over chronological age, important aspects of aging that

Biological age: index of aging-associated phenotypes that predict mortality/morbidity better than does chronological age

Intermediate phenotypes: traits with greater reliability and less state dependency

Allostatic load: negative physiological effects of chronic exposure to stress

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remain relatively stable over the lifespan are excluded (e.g., emotional function). Nonetheless, some nonage-dependent constructs (e.g., adaptation) could be studied with intermediate phenotypes (e.g., emotional reactivity) that represent more translatable traits that are more closely related to physiological processes.

Summary of Definitions of Successful Aging

Successful aging has yet to attain a consensus definition among researchers and laypersons, with as many definitions as studies (Depp & Jeste 2006). However, there are noteworthy areas of agreement in the literature—it is largely agreed that longevity is necessary but insufficient to define successful aging and that successful aging is a multidimensional construct. Furthermore, among quantitative studies with an operationalized definition of successful aging, physical functioning/disability is included in nearly all definitions, and, on average, a minority of older adults meet criteria for aging successfully, based on these definitions. In contrast to quantitative studies, qualitative approaches find that most older adults believe they are aging successfully, and lay definitions of successful aging are more likely to emphasize psychological adaptation and subjective well-being.

Based on the divergences described above, it would be reasonable to question the utility of the construct of successful aging. It may be particularly challenging to define a positive state of health because some individuals will invariably be excluded from the defined positive state. There is also less of a clinical impetus to attain agreement about successful aging than would be the case in defining a pathological state. However, other multidimensional constructs in aging research have attained consensus, have been subsequently adopted, and have advanced the field (e.g., frailty) (Fried et al. 2001). Policy directives, (Belza & Workgroup 2007, Cent. Disease Control Prev. & Alzheimer's Assoc. 2007, U.S. Dept. Health Human Serv. 2001) mandate investment in health-promotion programs targeting positive states of health, including increasing well-being and optimizing functioning in later life; thus, there is a need to attain consensus so as to define success of these initiatives. Furthermore, it is plausible that predictors and mechanisms of "success" may differ from the lack of risk factors for poor states of health and functioning, necessitating research on the characteristics of the upper end of the continuum of aging (Rowe & Kahn 1987).

A potential compromise is to focus on the determinants of success as individual components and to investigate the extent to which risk factors and interventions impact these components. Another rectifiable issue associated with the reviewed studies of successful aging is the diversity of measures used as indicators of the same construct, as well as the variation in dichotomization schemes. Thus, even if there were agreement in which components to measure, the variation among measures would still introduce variability. Recent trans-National Institutes of Health (NIH) initiatives, such as the Patient-Reported Outcomes Management Information System (PROMIS) (Fries et al. 2005) and the NIH Toolbox initiative (Baughman et al. 2006), are aimed at increasing the consistency among biobehavioral studies by identifying core sets of measures validated for different populations (including older adults). These initiatives may aid in increasing consensus around definitions of successful aging.

Increasing the Focus on Cognitive and Emotional Aging

A prominent deficit in the quantitative literature is the comparative lack of focus on cognitive and emotional components of successful aging relative to physical functioning/disability. One reason for this may be that many of the quantitative studies reviewed drew from investigations of physical disease (e.g., cardiovascular illnesses). For example, measures used to delineate states of cognitive health were designed to rule out dementia or depression and thus may have limited sensitivity in distinguishing between normal and successful aging. Psychological constructs described by older adults as central to successful aging, such as resilience, were frequently omitted, in part because there are few well-accepted measures of such constructs.

There is reason to increase the focus on cognitive and emotional health in relation to successful aging. First, in comparison to physical-functioning-based approaches to studying successful aging, cognitive and emotional phenotypes may become more relevant in the future because neurodegenerative illnesses are less amenable to treatment than many other chronic physical illnesses at the present time (e.g., Alzheimer's disease is now the sixth leading cause of death, surpassing diabetes) (Alzheimer's Assoc. 2009). Second, cognitive and emotional processes mediate health behaviors that impact physical health, and health behaviors are the foundation for most health-promotion programs in later life. Third, nearly all older adults will experience a chronic disease; very few centenarians have escaped these illnesses (Evert et al. 2003). Thus, although avoiding chronic illness in late life is probably not a feasible goal, cognitive and emotional adaptation to these illnesses may well be attainable. Fourth, the phenotypes of successful aging described by older adults are largely psychological constructs rather than physical ones—Bowling & Iliffe (2006) showed that multidimensional lay-perspective-based definitions in comparison with other definitions may in fact be more predictive of later quality of life.

There is recent public health emphasis on increasing cognitive and emotional health in older age, as evidenced by several recent U.S. initiatives. In 2001, three Institutes of the NIH, the National Institute on Aging, the National Institutes of Mental Health (NIMH), and the National Institute of Neurological Disease and Stroke (NINDS), formed the Cognitive and Emotional Health Project (CEHP) (Hendrie et al. 2006, 2010). The Centers for Disease Control together with the Alzheimer Association have also recently published a report, "The Healthy Brain Initiative: A National Public Health Road Map to Maintaining Cognitive Health" (Cent. Disease Control Prev. & Alzheimer's Assoc. 2007). These initiatives demonstrate the emerging interest in promoting states of cognitive and emotional health in older adults as complements to disease-focused initiatives.

Resilience: physical and/or emotional capacity to recover from stress or adversity

CEHP: the NIH Cognitive and Emotional Health Project

DETERMINANTS OF COGNITIVE AND EMOTIONAL HEALTH

In this section, we describe several putative determinants of successful aging, focusing on factors associated with positive effects on cognitive and emotional phenotypes in older age. We do not restrict this review to the identified determinants of the quantitative definitions of successful aging described above (see Depp & Jeste 2006, Peel et al. 2005). Instead, we take a broad approach to describing some the key mechanisms in selected positive constructs in cognitive and emotional aging.

Genetic Determinants

Although many studies have investigated the heritability of longevity (estimated to be approximately 20% to 40%; Christensen et al. 2006), fewer studies have investigated the heritability of other phenotypes related to successful aging (e.g., cognitive ability, functioning) and fewer still the genetic contribution to multidimensional definitions of successful aging such as those reviewed above. Uncovering the genetics of longevity has proven quite challenging (Christensen et al. 2006), and assessing the genetic contribution to successful aging is made perhaps even more complex by the late age of onset, postreproduction (*late penetrance*) of many phenotypes in older age, along with a multitude of indirect and direct influences of genes on disease and adaptive processes over the life course (Jazwinski 1996). Nevertheless, a number of studies have found that later age of parental death is associated with better functional performance and cognitive ability in the offspring, suggesting that positive outcomes in aging may be heritable (Vaillant & Mukamal 2001). In a twin study, Gurland et al. (2004) estimated the heritability of 10 indices of

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HPA: hypothalamic-pituitary-adrenal

functioning in a sample of more than 2600 twin pairs. Estimates of heritability across these measures of functioning varied between 20% and 25%, slightly lower than heritability associated with longevity. It is conceivable that some traits related to successful aging occur in single-gene autosomal dominant fashion, such as in families with exceptional longevity (Perls et al. 2002).

Glatt et al. (2007) reviewed available molecular genetic studies examining the association of candidate genes with multidimensional definitions of successful aging. Of 29 studies reviewed that examined candidate genes, Glatt and colleagues found that the modal study compared "cases" who were free of cognitive impairment, without physical disabilities, and free of significant chronic disease, with "controls" who did not meet these criteria. Candidate genes in these studies were selected a priori, often because of their established relevance to age-related disease, and therefore the contribution of less well studied genes in relation to aging is unclear. Nevertheless, there were six genes with significant associations in two or more studies: APOE, GSTT1, IL6, IL10, PON1, and SIRT3. Interestingly, each of these genes is involved in fundamental aging processes, including inflammation (IL6, IL10), cell cycling and signaling (SIRT3), cardiovascular health (PON1), neuronal degradation (APOE), and metabolism (GSTT1).

Genome-wide association studies of successful aging are rare but have been undertaken (Lunetta et al. 2007, Seshadri et al. 2007, Zubenko et al. 2002). For example, in the Framingham Cohort, 1345 members were assessed for walking speed, achieving age of 65 without chronic illness, and biological age based on an osseographic index; again, several age-related genes, including PON1, were identified (Rana 2010). Genome-wide approaches may be particularly valuable in assessing genetic association in the traits of the oldest-old (e.g., nonagenarians) who have preserved capabilities (Christensen et al. 2006, Jeremy et al. 2008). Therefore, plausible association can be seen between these candidate genes and positive outcomes in aging, operating via fundamental mechanisms involved in aging (described in the next section).

Basic Biological Determinants

The theories of biological aging are beyond the scope of this article and are reviewed in depth elsewhere (Armbrecht 2001, Hayflick 1985). Central mechanisms of aging that are particularly relevant to the brain health include apoptosis, neurotoxicity, oxidative stress, and dysregulation of inflammatory processes (Bodles & Barger 2004, Lin & Beal 2006). These processes are implicated in the etiology of specific neurodegenerative pathologies (e.g., Alzheimer's disease) and are probably are decelerated in successful aging. Among the best-studied physiological process in aging is the effect of stress. Recent studies have yielded fascinating insights into maintaining brain health, with research linking environmental and behavioral variables with physiological indicators of health.

A substantial body of research indicates that there are age-related increases in responsivity to stress in the hypothalamic-pituitary-adrenal (HPA) axis (McEwen 2003a, Sapolsky et al. 1985). Chronic overactivation of the HPA leads to secretion of glucocorticoids, such as cortisol, which can lead to damage to brain structures such as the hippocampus. Indeed, HPA dysregulation is associated with decreases in cognitive function and increases in anxiety and depression (McEwen 2003b). Stress may negatively influence the brain through inflammation and diminishing immune responses, with research relating proinflammatory cytokines, such as interleukin 1(IL-1), 2, and 6 to oxidative stress (Black 2006), and anti-inflammatory cytokines IL-4 and IL-10 to resilience to stress and immunoprotection (Di Iorio et al. 2003). Cellular biomarkers of aging (e.g., the telomere; a region of the chromosome that protects against cell death) also appear to be altered by chronic stress (Epel et al. 2004).

Using clinical measures, allostatic load has been operationalized as an index of dysregulation of stress-related systems, and a longitudinal epidemiological study in the MacArthur

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successful aging cohort suggests that greater allostatic load predicts faster functional decline (Arun et al. 2002). In turn, reduction of allostatic load was associated with reduced risk of mortality in the same sample (Karlamangla et al. 2006).

The above studies generally refer to severe and chronic stress, but interestingly, low levels of stress may actually produce positive changes in the aging brain (Prolla & Mattson 2001, Rattan 2004). Hormesis refers to a biological process in which exposures to mild levels of stress results in changes that reduce vulnerability to stress. Hormesis may explain why physical activity, for example, which produces cellular stress, results in reduced vulnerability and improved function—somewhat analogous to the body's response to vaccines (Mattson et al. 2002, 2010). Neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), are activated by the mild stress associated with physical activity, caloric restriction, and cognitive stimulation, and are implicated in the evidence that aging brains retain the capacity for neuroplasticity. As these biological pathways to brain vulnerability and protection are being described, models for interventions to promote successful aging may be optimized. The fascinating evidence for a nonmonotonic relationship between stress and aging outcomes provides additional proof of the complexity of aging.

Neurobiological Determinants

Cognitive abilities were included as a component in about one-third of the quantitative studies of successful aging reviewed by Depp & Jeste (2006) and constitute a domain in the Rowe and Kahn model of successful aging. Most of the quantitative studies relied upon screening measures to separate groups into impaired and unimpaired samples; which cognitive abilities were examined and how these abilities are maintained was not well described. Karasik et al. (2005) characterized cognitive abilities as an intermediate phenotype of biological age because cognitive ability, in aggregate, reliably declines with age, and a greater decline in cognitive function predicts mortality and morbidity better than does chronological age. Cognitive aging is the subject of a large body of research with comprehensive reviews (Brown & Park 2003, Park & Schwarz 2000, Schaie 2004).

Challenges in defining and predicting cognitive health include interindividual differences in baseline and peak levels of ability—i.e., an individual with a previously high level of functioning may experience decline that may be incompatible with cognitive health yet may still allow the individual to function better than age peers. In addition, there is a well-known dispersion of cognitive performance with age, with increasing between-person variability. Determining cognitive health also depends on which brain regions are altered with age (West 1996), when these declines begin (Salthouse 2009), which cognitive abilities are modifiable (Ball et al. 2002), and which, if modifiable, could enhance functioning and well-being the most. In addition to more traditional neuropsychological foci (e.g., memory, executive function), more esoteric constructs such as sense of purpose or wisdom fall under the umbrella of cognitive health. Problem solving and decision making are related cognitive constructs that are closer to the functional aspects of everyday life and integrate cognitive processes with emotional abilities (Blanchard-Fields et al. 2007).

One preliminary definition of cognitive health from the NIH CEHP project is an "ongoing sense of purpose, and the abilities to function independently, to permit functional recovery from illness or injury, and to cope with residual functional deficits" (Hendrie et al. 2006). Closely aligned with this definition of cognitive health are brain reserve and cognitive reserve (Stern 2002). Brain reserve refers to the amount of damage to neural tissue that can be withstood while preserving function, analogous to the brain's "hardware." Brain reserve is likely heritable, with twin studies indicating heritability of diverse cognitive functions (Finkel et al. 1995). In contrast, cognitive reserve refers to the brain's ability to adapt to damage, such as via compensation and recruitment of alternate

Hormesis: favorable or strengthening response to mild stressor

BDNF: brain-derived neurotrophic factor

Brain reserve: capacity to withstand neuropathological damage before crossing threshold of impairment

Cognitive reserve: capacity to maintain performance in the presence of neuropathological damage by efficiency

HAROLD: Hemispheric Asymmetry Reduction in OLDer Adults

brain regions to perform tasks (Brickman et al. 2010). Cognitive reserve may theoretically explain, for example, why some individuals retain cognitive function despite significant neuropathology postmortem (Snowdon 2003). Cognitive reserve is believed to be more modifiable than is brain reserve, akin to the "software" of the brain, and thus perhaps is a better target for intervention. Higher education levels, participating in mentally demanding occupations, cognitively stimulating activities, and lifestyle factors theoretically contribute to cognitive reserve (Fratiglioni et al. 2004).

Although somewhat controversial, compensatory processes are evident in functional neuroimaging studies of older adults (Hedden & Gabrieli 2004, Heuninckx et al. 2008). Greater bilaterality of brain-activation patterns has been seen in older adults who perform well on cognitive tasks, leading some researchers to formulate a model of decreased hemispheric asymmetry with age (HAROLD: Hemispheric Asymmetry Reduction in OLDer Adults; Cabeza 2002, Eyler & Kovacevic 2010). It is unclear whether some of the spreading of activation patterns in older people is caused by dedifferentiation of brain regions, which may reduce neuronal efficiency (Dixon et al. 2004). Nonetheless, cognitive neuroscience has begun to reveal that aging brains are more malleable than was previously thought, and that cognitive and lifestyle factors may positively alter the course of cognitive aging, perhaps through increasing cognitive reserve.

Emotional/Psychological Determinants

Defining emotional health in aging presents a different challenge than cognitive aging because many of the naturalistic age effects on emotional constructs are not associated with decline and may even be positive. Cross-sectional, longitudinal, and experience sampling investigations of age-related change in positive affect, negative affect, and life satisfaction generally indicate favorable changes with age (Mroczek 2001, Mroczek & Kolarz 1998). In addition to focusing on traditional indicators of well being, the CEHP initiative defined emotional health in later life more broadly, "as not just the absence of psychiatric illness or even the absence of negative affect" (Hendrie et al. 2006), including newer constructs such as emotional regulation that reflect the way in which older adults respond to and use emotions in daily life.

Few of the components of the quantitative studies reviewed above were psychological constructs; however, lay definitions of successful aging frequently included characteristics such as adaptability, positive attitudes, and optimism. These qualitative findings are consistent with lifespan-developmental depictions of healthy aging, such as proposed by Baltes & Schulz (Schulz & Heckhausen 1996) as well as by Vaillant & Mukamal (2001). Maintenance of well-being in the presence of adversity, via the adoption of new behavioral strategies, may account for older adults rating themselves as aging successfully when in fact few would meet objective criteria based on physical capacities. Operationalizing psychologically adaptive responses is difficult because resilience can be characterized as a pattern of responses to a single event (e.g., recovery from a loss) or as a general protective trait. Our research group assessed the psychometric properties of the Connor Davidson Resilience Scale (Lamond et al. 2008) in a sample of 1395 older women and found that higher self-reported resilience was associated with reduced depression, higher self-rated successful aging, and other markers of health. The factor structure of the scale was somewhat different from that found among younger adults: A factor representing tolerance of negative affect and adaptability to change accounted for greater variance in other positive outcomes than did another factor consisting of active, persistence-related approaches to stress management.

Other positive psychological constructs, such as optimism, positive attitudes toward aging, and purpose in life have been identified as independent predictors of mortality in longitudinal studies of older adults. In a Dutch study of older men followed for a period of nine years,

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greater dispositional optimism predicted lower all-cause mortality, particularly cardiovascular mortality (Giltay et al. 2004). Other constructs, such as greater sense of usefulness to others in life (Gruenewald et al. 2007) and sense of purpose (Boyle et al. 2009), predict reduced risk of mortality. In each of these studies, baseline variation in other health-related variables was controlled for, mitigating against the possibility that positive psychological constructs were a function of better overall health at baseline. Optimism (and to an extent a sense of usefulness to others or a purpose) is commonly viewed as a dispositional trait; thus, whether optimism can be modified is an area in need of future study.

In addition to research linking positive psychological constructs with mortality risk, attempts have been made to determine how positive constructs influence health. Levy (2003) has conducted a number of elegant studies in the area of attitudes toward aging, which indicate that (*a*) people with positive attitudes toward aging followed for more than 20 years had a survival advantage of 7.5 years as well as greater engagement in health behaviors than did people with negative attitudes toward aging, and (*b*) experimental manipulation of aging attitudes, such as through priming paradigms, can positively or negatively impact performance on functional tasks, including handwriting, responsivity to cardiovascular stress, and walking speed. In understanding the mechanisms of these effects, Levy's integration of epidemiological and experimental paradigms represents a model for uncovering the mechanisms of psychological variables on outcomes.

Research on the neurobiological basis of positive psychological constructs relevant to aging is another fruitful avenue. For example, wisdom is an ancient human virtue that is often associated with healthy aging (Ardelt 2004, Baltes et al. 1991, Blazer 2006, Vaillant 2002). As with successful aging, there is no consensual construct (Ardelt 2003, Blazer 2006, Sternberg 1990, Takahashi 2000), although recent work by Jeste & Vahia (2008) identified striking similarities in modern interpretations of wisdom and those found in ancient texts, such as the *Bhagavad Gita* (Ardelt & Oh 2010). Meeks & Jeste (2009) examined the putative neurobiological basis for the components of wisdom identified in the literature, which were (*a*) management of uncertainty, (*b*) emotional homeostasis, (*c*) social decision making/pragmatic knowledge, (*d*) reflection/self-understanding, (*e*) prosocial attitudes/behaviors, and (*f*) value relativism/tolerance. On the basis of primarily functional neuroimaging studies with experimental paradigms, the authors proposed a model explaining how the identified components of wisdom mapped onto the brain. The prefrontal cortex is a prominent center for regulation of many of these wisdom-related traits (e.g., emotional regulation, decision making, value relativism), primarily via top-down regulation of limbic and striatal regions. The lateral prefrontal cortex is involved in facilitation of reason-based decision making, whereas the medial prefrontal cortex is implicated in maintaining emotional balance and enabling prosocial attitudes/behaviors. Reward neurocircuitry (ventral striatum, nucleus accumbens) may also be involved in promoting prosocial attitudes/behaviors. Monoaminergic activity (especially dopaminergic and serotonergic) prominently regulates subcomponents of wisdom such as emotional regulation (including impulse control), decision making, and prosocial behaviors. Thus, there may be common, partially overlapping neurobiological mechanisms underlying these various domains of wisdom; other psychological constructs are candidates for similar investigation.

Social/Environmental Determinants

Social factors may have direct and indirect influence on nearly all of the phenotypes and mechanisms described above. For instance, the extent to which cognitive stimulation is available, such as whether an individual has access to education, determines the amount of cognitive reserve attainable. The built environment influences the degree to which individuals have access to nutrition and physical activity, which is of great concern in the development of

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communities for older adults (Jackson 2003, Kerr et al. 2010, Oswald et al. 2007). More direct effects of socioeconomic status are evident on numerous health variables, including susceptibility to viruses (Cohen et al. 2008). In addition to psychological and emotional phenotypes, older adults cite friendships, marriage, and social resources as a central determinant of successful aging (Reichstadt et al. 2007, von Faber et al. 2001).

Social interaction and social support have long been viewed as stress buffering and protective against emotional distress. In the MacArthur studies of successful aging, an operationalized construct of "social integration" included having a spouse, close relatives and friends, participating in religious services or activities, and/or participating in clubs or other social organizations (Loucks et al. 2006). Higher scores on this index predicted lower C-reactive protein concentrations after controlling for a host of potential confounds (Loucks et al. 2006). Social networks may also provide a vector for positive or negative states of health, as identified in innovative social network analyses showing the dynamic spreading of obesity (Christakis & Fowler 2007), smoking behavior (Christakis & Fowler 2008), and even happiness (Fowler & Christakis 2008) in the Framingham Cohort. Thus, linking social relationships with physiological markers, as well as viewing health as a function of the social network and of the individual, helps to explain how social factors determine positive health states. Finally, social activity has also been linked to reduced risk of dementia (Buchman et al. 2009), which may be due to its cognitive demands and/or through its stress-buffering effects.

Summary of the Determinants of Successful Aging

We have reviewed, in cursory form, the growing body of literature on the biological, psychological, and environmental mechanisms that may positively influence cognitive and emotional outcomes in later life. The myriad influences on aging include genes, basic cellular processes, trajectories in neurobiological structures, functional abilities such as memory, and the social and built environment. Some exciting avenues of research such as stress and stress resistance have begun to integrate findings across these levels. In regard to the mechanisms of cognitive and emotional health, it is likely that (*a*) genes and other "hardware" provide parameters around individual age-related trajectories, (*b*) fundamental age-related process such as those involved with inflammation and stress resistance are linked to cognitive ability and with environmental stress, and (*c*) psychological factors and cognitive reserve contribute to the surprising plasticity apparent in aging and partially explain why so many older people believe they are aging well despite disabilities and losses. Largely omitted from the above mechanisms of successful aging are lifestyle factors, which include physical activity, nutrition, and social activity. We describe the evidence for these in the context of interventions to promote successful cognitive and emotional aging in the next section.

INTERVENTIONS TO PROMOTE SUCCESSFUL COGNITIVE AND EMOTIONAL AGING

In light of the lack of agreement on the definition of successful aging, it is unclear what a comprehensive intervention to increase successful aging would include. Interestingly, a literature search for "successful aging intervention" revealed a group educational program used as an attention control condition in randomized controlled trials for exercise (Rejeski et al. 2009). Nonetheless, there is recent compelling evidence about the plasticity of neurobiology and modifiable factors with relevance to successful aging. In this section, we describe recent evidence from specific intervention modalities that were (*a*) designed to positively alter trajectories of normal aging (maintaining our focus on cognitive and emotional aging) and (*b*) influence multiple components of the definitions of successful aging reviewed above. We briefly summarize the available data on effectiveness, mechanisms, and future directions.

Physical Activity

The breadth of the benefits of physical activity is impressive, with longitudinal data indicating that greater exercise participation predicts lower risk for mortality, disability, cardiovascular disease, osteoporosis, and certain types of cancer. Nevertheless, the prevalence of physical activity in older adults in the United States is lower than that of younger adults, and women older than age 65 have the lowest rate of exercise participation of any age group (Macera et al. 2005).

In addition to benefits for physical health, growing evidence indicates that physical exercise may enhance cognitive and emotional functioning. Reduced risk for dementia related to increased physical activity has been seen in a longitudinal study (Larson et al. 2006). Animal studies have demonstrated reduced neurodegeneration with exercise (Cotman et al. 2007). In a meta-analysis of 18 clinical trials in older adults, Colcombe & Kramer (2003) found that both aerobic exercise and fitness training led to improvements in cognitive function in sedentary older adults. Although benefits were most pronounced in executive processes, controlled processes and visuospatial processes also showed benefits. Increases in brain volume in gray- and white-matter regions associated with aerobic exercise were found in a recent randomized controlled trial in sedentary older adults that compared six months of aerobic activity to a stretching control condition (Colcombe et al. 2006). The presumed mechanisms of exercise on improvements of brain function are in the promotion of neurotrophic factors and the reduction of inflammation and oxidative stress.

A complementary set of studies has indicated antidepressant effects of physical activity. In a seminal clinical trial conducted in 202 adults with major depressive disorder, Blumenthal and colleagues (1999) demonstrated that after four months, patients who were randomized to a supervised exercise intervention had remission rates comparable to patients on antidepressant medications and superior to placebo. A number of randomized controlled trials have evaluated the effect of exercise on depression in community-dwelling older adults (Belza et al. 2002, Castro et al. 2002, Chin A Paw et al. 2004, Damush & Damush 1999, Gary et al. 2004, Timonen et al. 2002, Williams & Lord 1997). These studies involved different types of exercise, including group exercise with a focus on aerobics, strength training, balance, and resistance exercise, or combinations thereof. Multiple hypothetical mechanisms have been proposed to explain the antidepressant effects of physical activity. These include a potential increase in brain serotonin levels (Gomez-Merino et al. 2001), norepinephrine secretion (Dishman 1997), dopaminergic activity (Bliss & Ailion 1971), elevated endogenous opioids (Boecker et al. 2008) and endocannabinoids (Dietrich & McDaniel 2004), and possibly reduction in neurodegeneration and inflammation (Maes et al. 2009), which are believed to underlie depression. Proposed psychological mechanisms for benefits of exercise include the experience of mastery, increased self-efficacy (Mendes de Leon et al. 1996, Stathopoulou et al. 2006), and behavioral activation (Hopko et al. 2003).

Public health interventions to sustainably increase physical activity among older adults have proven challenging. Older adults have a unique set of barriers that lowers their adherence to physical activity (e.g., pain, fear of injury/falls, absence of company to exercise with, lower self-efficacy) (Brawley et al. 2003). They may also have lower motivation, especially those older adults with mild depressive symptoms (Schutzer & Graves 2004). Important questions for future research agendas are: Which kind, which format, and what dose of exercise produces the greatest cognitive effects, and how can adherence to physical activity be sustained?

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Caloric Restriction/Dietary Influences

ACTIVE: Advanced Cognitive Training for Independent and Vital Elderly

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Laboratory experiments in multiple organisms, including rodents and primates, have indicated that caloric restriction can increase both median and maximum longevity (Rock 2010). The magnitude of these changes is quite remarkable in rodents, with increases in lifespan estimated at 30% to 40% (Bordone & Guarente 2005, Masoro 2005). Several small trials among humans, involving reduction of caloric intake from baseline, have identified improvements in blood pressure, cholesterol profiles, body mass index, and triglycerides (Bordone & Guarente 2005, Heilbronn et al. 2006). Caloric restriction may also be neuroprotective. A recent randomized control trial with 50 normal and overweight older adults indicated that a three-month trial caloric restriction of 30% had beneficial effects on memory relative to a group receiving an increase in unsaturated fatty acids and a no-treatment control group (Witte et al. 2009).

Although the mechanisms of caloric restriction remain a subject of debate, there are many plausible theories as to how caloric restriction may increase overall health and brain function, and this area of research is rapidly developing in light of the magnitude of positive effects (Masoro 2005). Caloric restriction alters metabolism, appearing to increase efficiency and subsequently to reduce the oxidative stress produced by energy metabolism. Insulin sensitivity is also altered by caloric restriction, and effects are also seen in cell signaling and activation of the sirtuins that are involved in DNA repair. Hormesis, described above in relation to stress, may be the mechanism by which caloric restriction triggers defensive responses that are beneficial to longevity, including neurotrophic factors such as brain-derived neurotrophic factor (BDNF). In the Witte et al. (2009) recent human clinical trial described above, memory improvements were correlated with improvements in insulin sensitivity and in inflammatory markers, but not with BDNF.

A key question in the application of caloric restriction to enhancing human aging is its palatability. It needs to be understood whether compliance with the calorie-restricted diet over the long term can be maintained and whether the diet can be safely used in subsets of older adults with medical illnesses. Nevertheless, caloric restriction and other dietary influences on brain health are an active area of study because the brain, like all organs, requires a sufficient intake of glucose and nutrients (Gomez-Pinilla 2008). Diets supplemented with folic acid, omega 3 fatty acids, and antioxidants have been associated with positive cognitive effects (Gomez-Pinilla 2008). Importantly, a number of studies suggest that high-calorie diets and obesity may increase the risk of dementia (Whitmer et al. 2008); because the prevalence of obesity is rising, the importance of dietary factors in brain health may become increasingly important.

Cognitive Stimulation and Training

The number of commercial "brain-training" games has increased dramatically over the past decade. These products have coincided with the accumulation of longitudinal data on the relationship between cognitively stimulating activities and reduction of risk for later dementia (Verghese et al. 2003, Wilson et al. 2002).

Recent trials of cognitive interventions also have indicated positive effects on cognitive ability among older adults without cognitive impairments (Vahia et al. 2010). The largest such trial to date is the Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial, funded by the National Institute of Aging (Jobe et al. 2001). The aims of this multisite trial, with 2832 participants, were to determine whether three cognitive training interventions, shown to improve performance on basic measures of cognition in laboratory and small field conditions, translated to improvement on measures of cognitively demanding daily activities in a large sample of nondemented older adults. Participants were randomized into one of four groups: memory training, reasoning, speed of processing, or control. The initial training phase consisted of ten 60–75 minute sessions over six weeks in small group settings, with a subset receiving booster training

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11 months after completing the initial training phase (Jobe et al. 2001). At two-year follow-up, cognitive interventions improved participants' performance on measures specific to the cognitive ability for which they were trained (e.g., memory training on memory measures); however, these results did not generalize to performance on everyday activities at two years. However, five-year follow-up results found that compared to the control group, groups that received cognitive training reported less difficulty in performing instrumental activities of daily living (Willis et al. 2006).

Other cognitive training programs include computerized approaches and nontraditional cognitive remediation. Mahncke et al. (2006) evaluated computerized brain plasticity training in healthy older adults over the age of 60 (n = 182) randomized into one of three groups: (*a*) the computerized brain plasticity training program (n = 62), (*b*) an active control group (n = 61) that used a computer-based educational program, and (*c*) a no-contact control group (n = 59). The training consisted of 60-minute sessions five times per week for 8–10 weeks. The experimental training program consisted of six exercises that progressively increased in difficulty as the user's ability improved. Participants in the experimental training group displayed significant improvement in task-specific performance in speed of processing, spatial syllable match memory, forward word-recognition span, and working and narrative memory tasks (Mahncke et al. 2006).

Alternative interventions have studied the effects of systematic engagement in cognitively demanding activities on cognitive performance (Park et al. 2007). Noice and colleagues (2004) evaluated theater training in a sample of 124 community-dwelling older adults. The authors chose acting because it requires engagement of cognitive, emotional, and physiological faculties. At the conclusion of the study, the theater group demonstrated significant improvement over a no-treatment group in the cognitive domains of recall and problem solving and in quality of well-being; at a four-month follow-up, the problem-solving and memory effects were maintained, and the recall scores improved over time. A later study with a different sample that was older, less well educated, and lived in subsidized, primarily low-income, retirement homes also identified positive effects of the acting intervention on cognition (Noice & Noice 2008). Other interventions utilizing everyday activities include learning to quilt or to take digital photos (Park et al. 2007) and participation in a structured autobiographic writing workshop (de Medeiros et al. 2007).

Despite these promising findings, the magnitude and generalization of benefit for cognitive training and cognitive stimulation have been questioned. Salthouse (2006) challenged the validity of the use-it-or-lose-it hypothesis, in particular because there remains a lack of convincing evidence that the rate of cognitive aging (versus between-person effects) was altered by participating in cognitively stimulating activity. Another concern is that even if improvements are seen in cognitive tests, the meaningfulness of these improvements depends upon the extent to which they transfer to everyday functioning. In the ACTIVE study, the effects on everyday functioning measures were less strong than were cognitive test performance improvements. Additionally, there has been a rapid increase in the number of commercial products purported to enhance cognitive ability that are marketed to middle-aged and older adults, yet these products are rarely associated with empirical studies (Vahia et al. 2010).

Social Interventions

Several studies have investigated the cognitive and emotional effects of social activity and socially mediated activity. Senior Odyssey, an adaptation of a program that was initially developed for grade-school children, focuses on presenting novel problems and encouraging group collaboration in forming creative solutions. Examples might be working as a team to create a play to describe a historical event. Engaging in these novel activities demands planning, working memory, and prospective memory

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MM: mindfulness meditation

TM: transcendental meditation

(Stine-Morrow et al. 2007). Initial findings from a sample of 95 older adults suggest positive effects on processing speed for Senior Odyssey participants in comparison to a control group. Another innovative program is the Experience Corps, an intergenerational program in Baltimore, Maryland, that trains older adults to help at-risk students in math and reading skills in collaboration with public schools. In addition to providing a meaningful contribution to the community, participants showed improvements in executive functioning and memory. Additionally, participants spent less time watching television and more time engaged in cognitively demanding activities as a result of the program (Studenski et al. 2006). Although both the Experience Corps and Senior Odyssey are less well researched than traditional cognitive training, they have the advantage of directly reducing cognitive inactivity as well as providing meaningful social interaction to older adults.

Meditation

Meditation represents a broad group of training regimens targeting emotional regulation through attentional tasks (Lutz et al. 2008). In addition to subjective improvements in stress, neuroimaging studies have demonstrated neurocircuitry and neurochemical changes in response to meditation, suggesting that pathways and chemicals that affect the brain's aging process may be modified using meditation, including increases in BDNF (Doraiswamy & Xiong 2007). Mindfulness meditation (MM) appears to improve control of stress (Jain et al. 2007), regulation of emotion (Miller et al. 1995), and relief from psychosomatic symptoms (Gardner-Nix et al. 2008). In a study comparing transcendental meditation (TM), MM, relaxation training, and a no-treatment control group in a sample of older adults (Alexander et al. 1989), the TM group improved most on measures of cognitive flexibility, learning tasks, behavioral flexibility, and systolic blood pressure. The MM group improved most on perceived control and word fluency. Both meditation groups improved to a greater extent than did the relaxation and no-treatment groups. Although the literature on meditation effects on aging is limited, available evidence suggests potential usefulness in improving both cognitive and emotional functioning of older persons.

Anti-Aging Interventions

Finally, it should be noted that in recent years the antiaging industry has seen an enormous growth, with many manufacturers making extreme claims for various dietary supplements and growth hormones. These products are often marketed as "cures" for aging and disability, and sales of these products gross billions of dollars each year, even though in many cases there is a general lack of evidence and some potential health risks (Perls et al. 2005). Currently, the U.S. Food and Drug Administration does not regulate these supplements as drugs, which contributes to the extreme variability of the actual contents of the products. In addition, even if these products are benign, they may divert older adults' attention away from lifestyle and other activities, which do have an evidence base supporting their use (Perls 2004).

Summary of Interventions

There appears to be cause for optimism regarding interventions to improve cognitive and emotional health in later life, with positive effects seen in community-dwelling adults of a variety of interventions such as physical exercise, dietary restriction, cognitive stimulation, social interventions, and stress reduction. It is remarkable that these disparate intervention modalities share biological mechanisms, particularly in the promotion of neurotrophic factors and reduction of inflammation and oxidative stress. It is also remarkable that general population trends, particularly in regard to rising obesity rates, are diametrically opposed to the targets of intervention in many cases. There are reasons to be cautious about these interventions, as the mechanisms are not fully understood, and the magnitude of effects is inconsistent across studies. In addition, there is debate as to whether interventions truly alter the rate of aging, and sustainability and palatability of some interventions may be a concern. Companies that commercially adapt these interventions (e.g., marketers of brain-training games) and the antiaging industry have generally avoided such caution. Nevertheless, there are rapid and exciting developments in the realm of interventions to promote positive cognitive and emotional aging.

CONCLUSION

We have endeavored to broadly describe the literature on successful aging, its determinants, and interventions that may increase its likelihood. Despite the inconsistencies in the definitions of the term, there is agreement that successful aging is a multidimensional concept in which cognitive and emotional constructs have received comparatively less study than physical health. There is a substantial amount of overlap in the mechanisms underlying successful cognitive and emotional aging, as well as a growing evidence base supporting the effectiveness of interventions to enhance cognitive and emotional health. Future work in this arena will benefit from increasing the consistency of measurement approaches and linking phenotypes with known mechanisms of biological aging, as well as discovering how the benefits of lifestyle and other interventions can broadly reach older adults in the community.

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SUMMARY POINTS

1. The definition of successful aging and its operationalization vary considerably across studies.
2. Qualitative depictions of successful aging more often emphasize adaptation and well-being, whereas quantitative studies center definitions on physical functioning/freedom from disability. Cognitive and emotional phenotypes of successful aging have been less well studied than physical health.
3. The genetic contribution to successful aging has been the subject of several family, linkage, and association studies, and there are plausible relationships between genes and multidimensional indices of successful aging. Environmental and behavioral influences on aging likely are greater than genetic influences, but may become more equal at extreme ages.
4. Stress and stress resistance display a complex relationship with aging. Severe stress engenders multiple negative physiological effects, whereas mild stress associated with caloric restriction, physical activity, and cognitive stimulation may increase cognitive and emotional health through hormesis.
5. Cognitive reserve may partially explain why some older adults are able to maintain cognitive function in the presence of neurodegeneration.
6. Interventions to increase cognitive and emotional health include physical activity, caloric restriction, cognitive stimulation, meditation, and social interventions.
7. Increasing the reach and acceptability of these interventions is a needed area of future research.

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