

Successful ageing: from cell to self

S. J. Lupien* and N. Wan

Laboratory of Human Stress Research, Douglas Hospital Research Center, Department of Psychiatry, McGill University, 6875 Boulevard Lasalle, Montreal, Quebec H4H 1R3, Canada

Many people see ageing as a time of cognitive and physical decline. For the past three decades, most scientists and the general public have accepted this negative age-stereotype as the norm, but fortunately this view is now challenged. New findings show that well-being and a positive view of ageing are major protective factors against the effects of age on the organism. These results challenge the scientific studies that place emphasis on the negative side of ageing. This ageism view has been observed in each sphere of science, from genetics to social sciences. Perspectives from each domain are described, and new integrative views of successful ageing are summarized.

Keywords: successful ageing; biological models; cognitive models; psychosocial models

1. INTRODUCTION

When a group of young and old participants were asked to describe the first image of old age that came to mind, they both spontaneously mentioned the following words: *'wise, slow, senile, ill, infirm, forgetful, frail and decrepit'* (Levy 1996, p. 1104). For the past 30 years, negative age-stereotypes have been widely accepted as the norm by most scientists and general public alike. The elderly have been viewed and labelled as, 'ill and/or disabled', 'impotent', 'ugly', 'mentally declining', 'mentally ill', 'useless', 'isolated', 'poor' and 'depressed' (Palmore 1990). Even gerontology has been defined as the science of drawing downwardly sloping lines (Minkler 1990). Negative stereotypes of ageing tended to marginalize perceptions of elderly individuals within a predominantly young-adult society, by placing them on opposite sides along the lifespan spectrum. Such stereotyping and discrimination is known as ageism.

In 1968, Pulitzer Prize winning author Robert N. Butler coined the word 'ageism' using this definition: 'ageism can be seen as a process of systematic stereotyping of and discrimination against people because they are old. . . .' (Butler 1969, p. 243). A few years later at a symposium on geriatric medicine, he condemned health professionals and academics for bringing about these stereotypes: 'medicine and the behavioural sciences have mirrored social attitudes by presenting old age as a grim litany of physical and emotional ills' (Butler 1977, p. 14). Like all prejudices, ageism influences the self-view and behaviour of its victims. Elderly individuals have a tendency to take on negative definitions of themselves and to perpetuate the very stereotypes directed against them, hence reinforcing society's beliefs. Such emphasis on senescence without acknowledging the growth, recuperation and improvement that occurs in ageing is a form of ageism.

Fortunately, this negative view of the elderly is now challenged. As the number of elderly people in the developed world has grown, the public has become increasingly aware of the problems the elderly face. The increased salience of the ageing population may have changed people's beliefs and prejudices about elderly individuals, with older individuals being recently seen in a more positive light. The term 'successful ageing' has thus made its entry into the popular and scientific literature. Although the study of successful ageing has certainly shed a positive light on the ageing population, many theoretical and methodological problems remain, with regard to what we define as 'successful ageing'.

In the following section, we present a historical perspective of research on ageing, from the negative to the positive view of the ageing process. We then discuss the various definitions of successful ageing, from the biological, psychological and psychosocial perspective, and we conclude by presenting and commenting on the multicriterion models of successful ageing.

2. THE MISMEASURE OF AGEING

The foundation of gerontology can be traced back to the early decades of the twentieth century, when the concept of ageing as a personal as well as a social problem dominated the images of researchers studying this domain (Ferraro 1997; Hirshbein 2001). Along with being considered a 'problem', there was an early acknowledgement that the study of ageing occupied several disciplines, in particular, medicine, psychology and sociology. One of the professional groups that displayed increasing interest in the subject of ageing as a topic for professional intervention was psychology. As early as the 1920s, psychologists G. Stanley Hall and Lillian Martin advocated shifting the study of psychology from the early stages of life towards the later stages of life (Hall 1922; Martin & de Gruchy 1930). In the 1930s, several psychologists began to expand their work by incorporating old age into their work on developmental psychology. In their report on cross-sectional studies on

* Author for correspondence (sonia.lupien@mcgill.ca).

One contribution of 12 to a Discussion Meeting Issue 'The science of well-being: integrating neurobiology, psychology and social science'.

the life trajectory of measurable abilities, both Miles (1933) and Bird (1940) showed that individuals peaked in childhood and declined in old age. However, in defining 'normal ability of performance' in the elderly, they compared the ability of older people with the average performance of children and young adults, thus generating a biased definition. Thus, despite psychologists' genuine efforts to expand scientific knowledge on old age, their bias towards children may have added to the growing idea that old age meant degeneration and declining ability.

During the 1940s, theoretical models of the biology of ageing concerning homeostatic mechanisms were produced (Griffiths 1997). As with psychology, the expanding biomedical interest in old age unintentionally extended the idea that old age was accompanied by inevitable pathology. Despite being supportive of the elderly, the medical model emphasized disease and disability as inevitable products of old age. In the 1950s the study of ageing, once again, began to focus heavily on a psychological perspective. Post-World War II was the launching period of the psychology of ageing in which myriad studies focused on linkages between early and later stages of human development, with particular emphasis on cognitive ageing. At the same time, there existed an increasing awareness of issues facing the older population that led to the expansion of research in social gerontology.

Early sociological models of ageing emphasized the negativity of the ageing process. In the 1960s, the disengagement theory emerged and proposed that ageing entailed a gradual social withdrawal or disengagement from personal relationships or society in general (Lynott & Lynott 1996). However, because of the negative connotation and conclusions of this theory, many sociologists became outraged and, as a result, made countless efforts to debunk and refute the main principles of disengagement theory. It may be argued that the theory was ageist, and hence attacked by sociologists and social psychologists in an attempt to make gerontology the study of normal ageing.

The 1970s witnessed a tremendous increase in the number of articles dealing with the changes in cognitive and physical functions observed during ageing, particularly those affecting memory and linguistic functions (for a complete review see Birren & Schaie (1985)). As with the first developmental studies performed by psychologists in the 1930s, it is through cross-sectional studies comparing the performance of young individuals with that of older individuals, that scientists were able to detect these modifications. However, such comparisons between different age groups revealed another important difference between young and old individuals: old individuals present a greater heterogeneity in cognitive performance when compared with young individuals.

Interestingly, however, most researchers neglected the increased variability in the cognitive manifestations of ageing for almost two decades (see Lupien & Lecours 1993). It was concluded that a general decline in cognitive performance with age was 'normal' (Dannefer 1988), leading again to the negative view of ageing. However, as Rowe & Kahn (1987) pointed out in their seminal *Science* paper on usual and successful ageing, if the group variance of elderly subjects is so high, it is in part a result of the fact that some individuals show very poor performance on the measure

taken (pathological ageing), whereas others show very high levels of performance (successful ageing), thus making any concept of a 'norm' for ageing totally meaningless.

This view was confirmed in the 1980s and 1990s, when several major longitudinal studies of ageing were developed (reviewed in Birren & Schaie 1985; Baltes & Baltes 1990). These studies revealed that movement, speed, visual acuity and several types of memory steadily and inexorably decline, but that this decline starts as early as the age of 20 years. Furthermore, several of these longitudinal studies have shown that many cognitive skills actually *improve* with age (Baltes & Lindenberger 1988; Schaie & Willis 1998). More recent data also revealed that the adult brain does not lose as many neurons as was once thought, but rather, it continues to sprout new neurons (Shingo *et al.* 2003). Finally, psychosocial studies show that with age, individuals tend to become happier, they have better mental health, they are better at managing interpersonal relationships, and they present fewer negative emotions (Helmuth 2003). Given the plethora of studies showing that the young and teenagers present significant problems of well-being, often leading to depression and suicide, one could eventually conclude that 'we may do very well to study older people to see how to help younger people' (L. Carstensen; cited in Helmuth 2003, p. 1300). Statements such as this reveal the extremely important changes in our view of ageing that developed from the 1920s to the new century.

3. THE MEANING OF SUCCESSFUL AGEING

Despite the varying perspectives of the biology, psychology and sociology of ageing, it is evident that both public and professional attention to old age has increased dramatically over the latter half of the twentieth century. This growing interest may be explained by the increasing number of elderly people in the USA and other developed countries over the past century. The numbers of elderly people has been growing substantially: in 1900 the population aged 65 and older in the USA was 3.1 million (4.1% of the total population), in 1950, this number had increased to 12.2 million (8.1% of the total population) and in 2000 it grew to 35.0 million (12.4% of the population) (Department of Health and Human Services 2001). Undoubtedly, these numbers are staggering, but what is of considerable interest is the way in which the study of ageing has shifted, from portraying old age in terms of its losses to the notion of 'successful ageing'.

The concept of successful ageing has been a subject of escalating interest since its initiation as the main theme of the 1986 annual meeting of the Gerontological Society of America (Fisher 1995). The following year, Rowe & Kahn's (1987) seminal study, 'Human aging: usual and successful aging' in *Science*, ignited another wave of interest in successful ageing by recommending that research on successful ageing should concentrate on people with above average physiological and psychosocial characteristics in later life, or 'successful agers' as opposed to 'usual agers'.

This certainly had a beneficial effect on research on ageing as it drew the attention of scientists to the positive aspects of ageing. However, at this point, there is still a lack of consensus on what defines a 'successful ager'. In the

following sections, we give the various definitions of successful ageing from these different scientific domains.

4. MODELS OF SUCCESSFUL BIOLOGICAL AGEING: BORN TO LIVE LONG

Most of the models of successful biological ageing consider that successful ageing is represented by two main factors: compression of morbidity and longevity. To understand the importance of these factors for the definition of biological successful ageing, it is important to distinguish between 'maximum lifespan' and 'average lifespan' or 'life expectancy'. The maximum lifespan represents the longest-lived member(s) of the population or species. In humans, the oldest individual ever recorded was Jeanne Calment, who died in 1997 in France at the age of 122 years. By contrast, the average lifespan is represented by the age at which 50% of a given population are still alive. Interestingly, the average lifespan of humans has increased over time, while the maximum lifespan has remained constant, around the age of 90 to 100 years (Cutler 1990).

The average lifespan has been shown to depend on various environmental factors such as socio-economic status and nutritional status (Cutler 1990). It is mainly a result of a significant improvement in sanitary conditions over the past century that the average life expectancy at birth is now *ca.* 74.6 years in males, and 79.8 years in females in the USA (World Health Organization 2003). In 2000, the World Health Organization recognized that quality of life in old age is as important as increased longevity, so it created an index of health expectancy at birth, which calculates the number of years an individual is expected to live without major diseases. Using this index, it has been calculated that the average healthy active life expectancy is *ca.* 67 years of age in males, and 71 years of age in females in the USA (World Health Organization 2000).

(a) *Compression of morbidity*

Although the average life expectancy at birth has increased in the past century, there are still many diseases that can decrease life expectancy. Sheldon (1948) identified diseases that were thought to be attributable to old age, which led to the theory that the development of these diseases was part of 'normal' ageing (age-associated diseases). The age-associated diseases that have been mostly studied in this context are cardiovascular disease, cancer, stroke, diabetes and dementia. Although most of these age-associated diseases do not occur exclusively in older people and/or in all older people, it is interesting to note that the high prevalence of these diseases in the elderly has created the impression that disease is a necessary part of ageing. Given this later definition of ageing as being a time of disease, it is not surprising to see that one part of the biological definition of 'successful ageing' is compression of morbidity (Fries 1980). Hence, to increase successful ageing in humans, one should increase the number of people living into old age, while at the same time limiting the age-associated diseases to a shorter period before death (Fries 1980). The idea behind the notion of compression of morbidity is that if the period from onset of chronic infirmity to death can be shortened, this would benefit both the individual and society (Fries 1993). Interventions based on primary preventions (smoking cessation, exercise, cholesterol reduction, etc.) have had significant effects on the number

of age-associated diseases, which reveals that the notion of compression of morbidity has a positive impact on successful living (reviewed in Fries 1993).

(b) *The role of genetic factors*

In contrast to average lifespan, which is sensitive to major diseases and environmental challenges, it has been shown that maximum lifespan, which represents the longest-lived member(s) of the population or species, is species specific and very stable. This stability suggests that genetic factors might make a major contribution to the maximum lifespan of an individual. In this context, the centenarian phenotype has been used as a model of biological and genetic successful ageing. Centenarians are a model of successful ageing because they have escaped or survived the common age-associated diseases (see Perls *et al.* 2002a), and they are living close to the maximum lifespan. Many studies have examined the centenarian phenotype to identify factors associated with maximum lifespan. These include body fat and metabolism (Paolisso *et al.* 1995), cardiovascular risk factors (Barbagallo *et al.* 1995; Baggio *et al.* 1998), immune function (Effros *et al.* 1994; Franceschi *et al.* 1995) and cognitive function (Silver *et al.* 1998, 2001; Andersen-Ranberg *et al.* 2001; Hagberg *et al.* 2001). Interestingly, none of these extrinsic and intrinsic factors has been shown to correlate with the ability to survive into extreme old age (Karasawa 1979; Beregi 1990; Beard 1991; Poon 1992; Perls *et al.* 1999).

The factors that predict maximum lifespan are believed to be mainly genetic factors. A familial study comparing siblings of centenarians to siblings of non-centenarians revealed that siblings of centenarians have four times the probability of surviving to the age of 91 years when compared with the other group of siblings (Perls *et al.* 1998). However, this result does not necessarily confirm the major contribution of genes in maximum longevity, because other factors such as environmental, attitudinal or lifestyle factors could explain these findings. Still, the results obtained from this and other familial studies (Perls & Fretts 1998; Rybicki & Elston 2000; Kerber *et al.* 2001; Perls *et al.* 2002b) led scientists to search for longevity-modifying genes. Here, the approach is to look for lifespan-altering genes in organisms in which lifespan is short enough that it allows multigenerational experiments within a reasonable time frame (Guarente & Kenyon 2000). The organisms that have been mostly studied in this context are yeast, the worm *Caenorhabditis elegans*, *Drosophila* and mice (Jazwinski 1999; Imai *et al.* 2000). Studies in these lower organisms, and particularly the yeast, revealed that lifespan is determined mainly by 19 genes, whose functions implicate four basic determinants of lifespan, namely metabolic control, resistance to stress, gene dysregulation and genetic stability (see Perls *et al.* (2002a) for a comprehensive review).

(c) *Selective pressure on genes*

If longevity is genetically determined, then it implies that selective pressure on specific genes has been applied throughout evolution. Here, it is interesting to note that species with a short lifespan have generally a higher fertility rate (Williams 1966). This trade-off between life expectancy and reproductive capacity has led to the disposable soma theory (Kirkwood 1977; Kirkwood & Holliday

1979), which comprises three major premises. The first is that in natural populations (with the exception of humans), most deaths generally occur accidentally. This means that the probability of reaching maximum life expectancy is low. The second premise is that the long-term survival of an individual depends on maintenance of the organism, a process that is energetically costly. The third premise is that it is not advantageous for an individual to invest a large fraction of metabolic resources in long-term survival if only a small fraction of these resources is necessary to survive in reasonably good condition. Basically, this theory recognizes the importance of the allocation of resources between growth, maintenance and reproduction. If one increases maintenance of the organism, this will promote survival. However, this will be done at the expense of resources that could be used for growth and reproduction. In summary, the price to pay for reproduction of a species is finite survival. In these conditions, getting old with the minimum load of age-associated diseases is the biological definition of successful ageing.

5. MODELS OF SUCCESSFUL COGNITIVE AGEING: THE POWER OF COMPARISONS

The measurement of individual differences is of central importance for the models of successful cognitive ageing. In this approach, the characteristics of individuals that are deviant from the age normals are contrasted with those of persons ageing more in accordance with the normative expectations. In this sense, the cognitive models split the ageing process into pathological, usual and successful. Here, usual ageing implies the normative pattern, and individuals ageing successfully and those with premature or excessive cognitive frailty are ageing atypically (reviewed in Stones *et al.* (1990)).

The entire approach of models of successful cognitive ageing stands on three types of comparison of an aged individual to other groups. In the first approach, the cognitive performance of an older person is compared with normative data obtained in individuals of the same chronological age (the normative approach). Here, a successful ager will be defined as someone being above normative values when controlling for age, education level and socio-economic status. In the second approach, the cognitive performance of the individual is compared with the mean performance of a group of individuals within the same chronological age range (the age-related approach). Here, a successful ager is defined as someone showing a higher performance (by two or three standard deviations) than the mean of the group. In the third approach, the cognitive performance of the individual is compared with that of a group of young individuals. In this case, a successful ager is defined as someone having a cognitive performance as good as that of young individuals (the age-difference approach).

These three approaches are similar in the use they make of the increased inter-individual variability with ageing. Indeed, all approaches index successful ageing by functions that are characterized by relative homogeneity in young adulthood but heterogeneity thereafter. Because it is known that aged individuals exhibit more heterogeneity in their cognitive performance, one can thus infer that inferior performance in an older individual represents an acquired decrement, whereas a performance similar to that of young

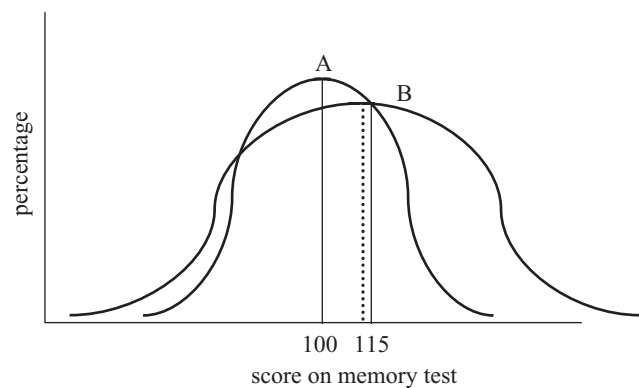


Figure 1. Inconsistencies in the categorization of successful ageing using age-related data. The data represent scores on a memory test obtained by men with a mean education level of 10 years, from medium socio-economic status. The distribution curve A represents the scores of a normative sample of men aged exactly 80 years. The solid line represents the mean score (100) of this group on the test. The distribution curve B represents the scores of a group of men aged between 75 and 85 years selected for a particular study. The solid line represents the mean score (115) of this group on the test. The dotted line represents the score (113) of one individual on the test. This individual would be categorized as a successful ager if compared with the distribution curve A, but would be categorized as a normal ager if compared with the distribution curve B.

individuals will mean successful ageing, because it implies that cognitive function was maintained throughout life. These three approaches carry with them very important differences for the ways that they will categorize someone as being a successful ager. Indeed, all three approaches are independent in that a given individual could easily be defined as a successful ager using one type of comparison, and as a normal or pathological ager using another type of comparison.

Figures 1 and 2 give a schematic representation of these differences. Figure 1 depicts age-related inconsistencies in the categorization of a successful ager, whereas figure 2 presents age-difference inconsistencies in the categorization of a successful ager.

(a) *Age-related inconsistencies in the categorization of a successful ager*

In figure 1 the distribution curve A represents memory data from a representative population sample in which the age is exactly 80 years (normative data). Here, let us assume that the normative mean for this group is 100. If an 80-year-old man scores 113 on the memory test, one could say that this individual is a 'successful ager' because his score is higher than the norm. The distribution curve B represents memory data from a non-representative aged sample (with a mean age of 80 years) recruited for a particular study with a 10 year age range. One might think that the score distribution of this population should be the same as the normative database. However, the mean of this population is higher than the mean of the representative sample (distribution curve A), and the distribution curve is flatter than the distribution curve A.

Many factors can explain these differences. First, in population B, the individuals below the age of 80 could contribute in increasing the mean, and the age range could

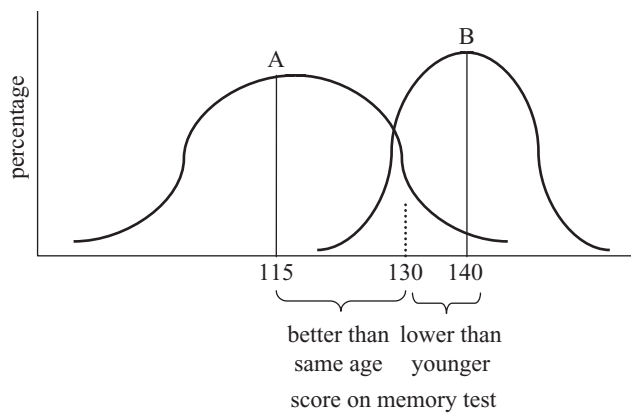


Figure 2. Inconsistencies in the categorization of successful ageing using data on age differences. The distribution curve A represents the scores on a memory test for a group of men and women aged between 75 and 85 years, with mean education levels of 10 years, from medium socio-economic status. The mean score of this group was 115 (solid line), with an s.d. of 5 (dotted line within the same distribution curve). The distribution curve B represents the scores on a memory test for a group of young men and women ranging from 25 to 35 years, with a mean education levels of 12 years, from medium socio-economic status. The mean score of this group was 140 (solid line), with an s.d. of 2 (dotted line within the same distribution curve). The dotted line represents the score (130) of one aged individual on the test. This individual would be categorized as a successful ager if compared with the distribution curve A, but would be categorized as a normal ager if compared with the distribution curve B.

contribute in increasing the standard deviation of the group. Second, it is well known that aged individuals who tend to volunteer for a particular study are generally more educated, have a higher income and are in better physical shape than those who do not readily volunteer (reviewed in Lupien & Lecours 1993). All of these factors have been shown to be related to better cognitive function in old age (Schaie 1993). This fact would thus tend to push the mean towards an upper limit (in this case, 115). The individual with a score of 113, who was previously categorized as a successful ager when compared with normative data, is now considered to be a usual ager, because his performance is not different than that of the mean of group B.

From this example, one could conclude that comparing the performance of an aged individual with normative data is the best way to categorize successful cognitive ageing. This might, unfortunately, not be the case because it has been shown that existing age-based norms for cognitive tests are almost certainly contaminated by cases of unsuspected incipient Alzheimer's disease and other age-related cognitive pathologies (Morris *et al.* 1991). The presence of unsuspected incipient cases of age-related cognitive impairments in normative databases will thus decrease the mean, allowing for a larger proportion of aged individuals to meet the criterion for successful cognitive ageing when one compares an individual with normative data.

(b) Age-difference inconsistencies in the categorization of a successful ager

In figure 2, age-difference inconsistencies in the categorization of a successful ager are depicted. In this figure, the distribution curve A represents memory data from a

non-representative aged sample (with a mean age of 80 years), recruited for a particular study with a 10 year age range. The distribution curve B represents memory data from a non-representative young sample (ranging from 25 to 35 years) recruited for the same study with a 10 year age range. The mean performance obtained in the aged population is 115 with a standard deviation of five, whereas the mean performance obtained in the young population is 140 with a standard deviation of two. If an 80-year-old man with a score of 130 on the test is compared with the aged population, he could be categorized as a successful ager, given that his score falls outside two standard deviations of the mean of the aged group ($115 + 5 + 5 = 125$; man's score is 130). However, if the score of the same man is compared with that of the young population, the man would not be categorized as a successful ager because his score falls more than two standard deviations below the mean of the young population ($140 - 2 - 2 = 136$; man's score is 130). Given that the young population shows less variability in performance (mean with 2 s.d.) when compared with the aged population (mean with 5 s.d.), this difference in categorization is an artefact that is induced by the large differences in variance in the two different populations.

This example illustrates the important difficulties that one faces when trying to define successful cognitive ageing. Because of the increased variability in cognitive performance known to exist in aged human populations, it is extremely hazardous to define a successful ager based on comparisons to either a norm, or a mean from aged or young populations. Moreover, each approach defined above has its inherent methodological and theoretical pitfalls. First, as we have previously discussed, comparison with a norm can be difficult given the fact that these norms can be pushed downwards by the presence of incipient cases of age-related cognitive pathologies in the normative group tested. Second, comparison with the mean of an aged population leads directly to an elitist definition of successful ageing (Masoro 2001; Minkler & Fadem 2002). Indeed, it is well known that education level is positively related to cognitive function. Therefore, by using this method, there is a high probability that those individuals who will be defined as successful agers will be those who were successful during their entire life (high education, high income, etc.). Comparison with the mean of a young population decreases the probability of categorizing someone as being a successful ager given the presence of large differences in variances between the young and aged populations (see Lupien & Lecours 1993), and more importantly, it increases the probability of having a cohort effect.

(c) Gender balance of samples

There are other problems that arise when comparing young and aged populations. These include the gender balance of samples, and the functional equivalence of the tests used in these populations. Many scientists are aware of the inherent difficulties in establishing an equal proportion of aged women and men when creating an experimental sample, because the former generally volunteer more often than the latter. This may be explained by intrinsic characteristics of women, and/or by the fact that there is a smaller proportion of men than women particularly at older ages (Cutler & Harootyan 1975; Hendricks & Hendricks

1977; Botwinick 1978). Consequently, an experimental protocol incorporating an equal number of men and women in both the young and aged samples is not representative of the population. The disproportion between the men and women is largely a result of the relatively poor health and premature death of elderly men (Cutler & Harootyan 1975). Studying the performance of an equal number of men and women within an aged population means that, on average, the men are likely to be in poorer physical health, which would hardly be the case in a young population.

(d) *Education balance of samples*

In addition to the problem of gender imbalance, the average level of education is less in older compared with younger populations. In fact, there is no existing criterion that allows the assignment of equivalent education levels to individuals having different educational histories (Krauss 1980). We also know that it is not prudent to rely on number of years of education because many trades practised by older adults that were acquired through experience are now taught in specialized schools. An even more complex problem is related to the fact that a smaller proportion of aged people are highly educated, which does not reflect a difference in aptitude but in availability and social norms (Cutler & Harootyan 1975). Hence, the idea of selecting subjects on the basis of an equal number of years of education would lead the researcher to study an extreme group of elderly people if the education criterion is high, or a limited group of young subjects if the education criterion is low. The use of an apparently objective criterion (number of years of education), in establishing a control for the education levels of groups being studied will thus produce misleading conclusions about age differences, because the selected group would not be representative of the general population.

(e) *Functional equivalence of cognitive tests*

The problem of the functional equivalence of cognitive tests arises mainly with experimental designs in which the emphasis is placed on obtaining an interaction between the 'age' variable and one or several tasks (Baltes & Goulet 1971; Labouvie 1980). The degree of validity that we can attribute to such designs depends on the assurance that the tasks evaluate the same processes in all age groups. It is possible that certain measures that are formally identical are linked to totally different types of information processing in two or more different age groups. For example, word meanings and word associations may be different for different generations, and the widespread use of rote learning as the predominant teaching method for the older generation contrasts with an emphasis on understanding meaning, rather than rote learning among more recent generations. Such generational differences in the meaning or salience of stimuli, or in styles of learning and remembering, can be misinterpreted as genuine age differences when they are in fact generational or cohort differences.

Recent functional brain imaging data have revealed important differences in the pattern of brain activation in young and aged subjects, despite no differences in test performance. Cabeza *et al.* (2004) scanned younger and older adults with functional magnetic resonance imaging while performing three different tasks tapping into different cog-

nitive processing: working memory, visual attention and episodic retrieval. The results showed that older adults performed as well as younger individuals, although they presented important differences in the pattern of brain activation induced by each task. In all three tasks, older adults showed weaker occipital and hippocampal activity and stronger prefrontal and parietal activity than younger adults. In the working memory and visual attention tasks, the older adults showed more bilateral patterns of prefrontal activity than younger adults. Finally, in the episodic memory task, the older adults showed stronger parahippocampal activity than the younger participants. These results have been taken to suggest that both common and specific factors play an important role in cognitive ageing.

(f) *The importance of cognitive reserves*

Finally, it is important to note that comparing an elderly individual to other people, to define successful ageing, does not take into account the fact that most aged individuals still show the capacity to learn new information, which suggests that one could *become* a successful ager later in life. Indeed, substantial reserve capacity exists in the domain of cognitive functioning. Studies have shown that healthy elderly people between the ages of 60 and 80 benefit from practice and demonstrate an increase in performance in the specific abilities that are trained. Further, this augmented performance is similar in its magnitude to the ageing decline found in untrained individuals in longitudinal studies (Baltes & Lindenberger 1988; Schaie & Willis 1998). In addition, it has been shown that healthy elderly are able to learn and acquire new cognitive skills, for instance, by becoming memory experts (Kliegl *et al.* 1989). These findings suggest that for many older individuals, cognitive functioning during old age continues to operate in generally the same way as it did in the earlier stages of life. Therefore, older adults are able to use their cognitive mechanisms to acquire new information.

As older adults have the cognitive reserves to acquire new forms of knowledge, cognitive ageing is not only made up of the preservation of past functioning. Rather, the data suggest that, contrary to negative ageing stereotypes, 'new learning' is possible and that older adults continue to produce new forms of adaptive capacity (Baltes & Baltes 1990).

6. MODELS OF SUCCESSFUL PSYCHOSOCIAL AGEING: THE POWER OF WELL-BEING

The models of successful psychosocial ageing emphasize social interaction, life satisfaction and well-being as major determinants of successful ageing. One of the first views to emerge in the psychosocial models was the activity theory, which stated that because growing older involves the loss of roles such as retirement and widowhood, older adults who wish to retain a positive sense of self need to find satisfaction in other, often newly substituted roles (Ferraro 1997). In the 1960s, the disengagement theory posited that ageing involves a gradual withdrawal or disengagement from interpersonal relationships or society in general, thus resulting in the marginalization of other people in society. Given this theoretical perspective, social withdrawal or decreased interaction is a usual response to the expectation of death, perception of a decreasing lifespan and decreasing energy experienced by ageing individuals (Ferraro 1997). How-

ever, this theory has been strongly criticized by researchers who found a lack of evidence that older people disengage from their surroundings. Whereas older people's social relationships change and possibly have fewer social ties, it was found that these relationships are often deeper and more meaningful (Helmuth 2003).

(a) *The importance of social support*

More recently, psychosocial research and approaches to defining successful ageing focus on topics including subjective well-being (George 1979, 1981), social support and interactions, as well as life satisfaction (Herzog & Rodgers, 1981). A substantial body of research shows that social support is a key determinant of successful ageing (Rowe & Kahn 1998; Leviatan 1999; Unger *et al.* 1999; Seeman *et al.* 2001*b*). Research has indicated the health benefits of social integration and social support. Older adults reporting a greater number of social ties have been shown to have lower mortality risks, and both social integration and social support have been associated with better mental and physical health outcomes (reviewed in Berkman 1995; Cohen & Herbert 1996; Seeman 1996). Studies have also suggested that social environment may have an impact on patterns of cognitive functioning. In a study examining the relationship of social ties and support to patterns of cognitive ageing in the MacArthur studies of successful ageing, Seeman *et al.* (2001*b*) showed that participants receiving more emotional support had higher baseline cognitive performance.

Furthermore, growing bodies of research have shown that social integration and support are linked to protection against physical and mental health conditions such as cardiovascular diseases, hypertension and depression, which are each related to cognitive decline. It has been postulated that because social interactions have essential intrinsic cognitive components and hence sustain ongoing cognitive engagement, they may also contribute to enhanced cognitive function: the 'use it or lose it' paradigm (Baltes & Baltes 1990; Rowe & Kahn 1998). Bassuk *et al.* (1999) conducted a longitudinal, population-based cohort study of older adults and over a 12 year follow-up, a greater baseline of social engagement (indexed by more reported contact with friends and family and more engagement in group activities) was shown to be protective against cognitive impairment. Fratiglioni *et al.* (2000) found similar findings in that greater reported social networking was protective against onset of dementia.

(b) *Subjective well-being*

Studies examining the notion of successful ageing and life satisfaction have shown that although the two concepts are different, they both contributed to subjective well-being in the aged population. Fisher (1995) explored the meanings older people attached to successful ageing and life satisfaction among 40 individuals between the ages of 61 and 92 years. It was shown that the term successful ageing reflected an attitudinal or coping orientation nearly twice as often as those for life satisfaction. Life satisfaction seemed to represent basic needs, whereas successful ageing was linked more closely to higher-order needs, such as self-understanding, helping others and feeling like one has made a difference. Another key difference that emerged from the study was that life satisfaction was described in

terms of past expectations and present circumstances, whereas successful ageing was more oriented to strategies for coping in later life and maintaining a positive outlook (Fisher 1992).

(c) *The importance of personality traits*

It is important to note that most of the psychosocial models of successful ageing do not take into account the potential impact of personality traits on life satisfaction and well-being in old age. Scholars have long debated the malleability of human personality. Self-concept and attitudes, in addition to other factors, contribute to stability and change in personality, which in turn influence the prospect of successful ageing. Personality traits have been assessed in many studies to examine whether personality is stable or not during late adulthood. Indeed, it appears that as much of an argument can be made for stability as for change, depending on one's interpretation, and depending on the level at which personality is examined (McAdams 1994). Some longitudinal studies have shown that personality is very stable over time (Costa & McCrae 1988), whereas others have found changes in personality in the later years of life (Shanan 1991).

Recent research has shown that five relatively stable independent factors or dimensions may encapsulate the domain of personality (McCrae & Costa 1984; Costa & McCrae 1986; McCrae & John 1992; Goldberg 1993). These factors are referred to, by both clinicians and researchers, as the 'big five' model. The five dimensions include neuroticism, extraversion, openness to experience, agreeableness and conscientiousness (McCrae & Costa 1984; Costa & McCrae 1986; McCrae & John 1992; Goldberg 1993). A substantial amount of research related to the big five model indicates the consistency and stability of personality across lifespan (Costa & McCrae 1986).

Many studies have shown that personality traits are among the most potent predictors of psychological well-being (reviewed in McCrae 2002). A study by Costa & McCrae (1980) revealed that personality traits early in life predicted well-being years in advance. For example, negative affect was associated with neuroticism and low levels of well-being, whereas positive affect was associated with extraversion and high well-being. These results suggest that well-being, as a marker of successful ageing, might be highly dependent on certain personality traits, which develop very early in life. This would support the idea that the pathways to successful ageing are determined very early in life.

7. MULTICRITERIA MODELS OF SUCCESSFUL AGEING

The analysis of the biological, cognitive and psychosocial models of successful ageing reveals that unique markers of successful ageing often present weaknesses because they cannot predict or explain other aspects of the ageing process. For this reason, some scientists have used multicriteria models of successful ageing; that is, models that take into account the biological, cognitive and psychosocial aspects of ageing.

Two main perspectives of successful ageing exist that use a multicriterion approach to successful ageing. The first looks at successful ageing as a state of being, a condition that can be objectively measured at a certain moment. The

second views successful ageing as a process of continuous adaptation. Both perspectives are based on the recognition of heterogeneity among older adults. Rowe & Kahn (1987) hold the first view and have defined successful ageing in terms of multiple physiological and psychosocial variables, whereby successful ageing is the positive extreme of what is considered normal ageing.

8. MULTICRITERION MODEL OF ROWE & KAHN (1987)

In 1987, Rowe and Kahn published a seminal paper in *Science* in which they described successful ageing as having three main components: avoidance of disease and disability, maintenance of cognitive capacity, and active engagement in life. To examine the validity of this concept, various scientists collaborated on a study of successful ageing funded by the MacArthur Foundation in the USA. They tested 4030 participants as part of a larger study, and 1931 met the multicriterion of successful ageing, which included the three main components of Rowe & Kahn's definition, i.e. avoidance of disease and disability, maintenance of cognitive capacity, and active engagement in life (Berkman *et al.* 1993). After defining these individuals as successful agers based on cross-sectional data, scientists then followed this particular group of aged individuals over time.

(a) *Main findings of the MacArthur studies on successful ageing*

Studies performed on this group first revealed that at the cross-sectional level, low levels of education were associated with poorer psychological function, poorer health behaviours and biological conditions, and larger social networks (Kubzansky *et al.* 1998). At the longitudinal level, it was found that some psychological, psychosocial and physiological variables predicted cognitive decline later in life. At the psychological level, it was found that certain measures of learning and memory (Li *et al.* 2001; Chodosh *et al.* 2002; Tabbarah *et al.* 2002), as well as low emotional support at baseline (Seeman *et al.* 2001*b*) were strong predictors of cognitive decline measured 7 years later. At the psychosocial level, results showed that a low number of social ties at the time of entry into the study predicted cognitive decline 7 years later (Unger *et al.* 1999; Kubzansky *et al.* 2000). Finally, at the physiological level, it was reported that elevated baseline plasma levels of interleukin-6 are a significant predictor of cognitive decline 2.5 years later (Weaver *et al.* 2002).

(b) *Stress and ageing*

The study also revealed the impact of stress on cognitive function in this population. First, it was found that older women are more reactive to stress, in terms of secretion of cortisol (a stress hormone), than men (Seeman *et al.* 1995*a*), and that level of self-esteem is a potent predictor of cortisol reactivity to stress (Seeman *et al.* 1995*b*). Second, the study showed that aged women who presented a significant increase in cortisol levels (a stress hormone) over a period of 2.5 years were more likely to show declines in memory performance over the same period of time (Seeman *et al.* 1997*a*). This result extended a previous study performed by our group showing that in a population of aged men and women, a significant increase of stress hormone levels over a period of 4 years is significantly related to both memory impairments (Lupien *et al.* 1994)

and atrophy of the hippocampus, a brain structure that is involved in learning and memory (Lupien *et al.* 1998).

The bulk of data obtained for the effects of stress hormones and other biological measures led to the evaluation of the model of allostatic load, proposed by McEwen & Stellar (1993). The term 'allostatic load' refers to a cumulative, multisystemic view of the physiological toll that may be exacted on the body through attempts at adaptation. In this sense, allostatic load is the price that the body may ultimately pay for its adaptational efforts (see Seeman *et al.* 1997*b*). Recent studies performed by Seeman and collaborators (Seeman *et al.* 1997*a,b*, 2001*a*; Karlamangla *et al.* 2002) examined the hypothesis that risks for declining cognitive and physical functioning in elderly individuals are related to differences in allostatic load. In their study, they measured allostatic load by 10 parameters reflecting levels of physiological activity across a range of important regulatory systems (e.g. blood pressure, cholesterol, cortisol levels, etc.). They reported that higher allostatic load scores were associated with poorer cognitive and physical functioning. More importantly, they also showed that allostatic load scores predicted larger decrements in cognitive and physical factors later on. These results showed that allostatic load measures could provide a basis for the description of major risk factors in the development of the pathological ageing processes.

(c) *Successful ageing: an elitist definition?*

Clearly, the multiple studies that were performed within the MacArthur study of successful ageing led to very important findings that related to all aspects (biological, cognitive and psychosocial) of ageing. However, although this study yielded significant results on the factors that can contribute to successful ageing, there is an important problem about how the researchers defined and studied successful ageing in the first cross-sectional study, and in subsequent studies (Berkman *et al.* 1993). The study performed by the MacArthur Foundation was a cross-sectional study in which the authors chose, as successful agers, the top 30% of the population in terms of cognitive factors. However, and as we have shown in our discussion of the models of successful cognitive ageing, it is well known that education level and socio-economic income are both positively related to cognitive function. As we have discussed, splitting a cross-sectional population at the top 30% means that those individuals who will be defined as successful agers will be those individuals who were successful during their entire life (high education, high income, etc.), thus leading to an elitist definition of successful ageing. In fact, in the first published report from the MacArthur group, it was shown that within the largest population from which the successful agers were selected, the participants who were included in the low-functioning group using the lowest tertile were almost three times as likely to have a low income compared with the high-functioning group (Berkman *et al.* 1993). This result confirms that those individuals who were categorized as successful agers in the MacArthur study were the same individuals who had been successful during their entire life.

Consequently, the results obtained by the MacArthur group are not necessarily generalized over the entire population. Moreover, this approach does not take into account the factors that prevent an individual from show-

ing age-related decline in biological, cognitive or psychosocial factors, when this individual is not part of the upper tertile of the population in the first place; that is, when this individual is part of the norms early and/or late in life. Also, this approach prevents anyone with functional disabilities, such as the physicist Stephen Hawking, to be defined as a successful ager later in life (Minkler 1990; Minkler & Fadem 2002). Clearly, many individuals who are not part of the upper tertile of a given population have the capacity to become a successful ager, but unfortunately, the working definition of successful ageing used by the MacArthur study prevents the assessment of these important factors. In summary, although the MacArthur study of successful ageing has generated a wealth of very important data, the method that was used to define successful ageing may have created the impression that success in old age is limited to only a small percentage of the population.

9. MULTICRITERION MODEL OF BALTES & BALTES (1990)

Baltes and colleagues have developed a meta-model of selective 'optimization with compensation' for the assessment of successful ageing (Baltes & Baltes 1990). Their goal is to explain what people in fact do when they age successfully. Recognizing that the meaning of success is highly individualized in nature, their aim has been to widen the focus beyond the 'theoretically normative psychological outcome that has seriously limited our understanding of successful aging' (Baltes & Carstensen 1996, p. 398).

(a) *The model of selective optimization with compensation*

The model of selective optimization with compensation describes a general process of adaptation and it attempts to explain the dynamic interchange of gains and losses throughout life, and how age-related and self-produced changes in oneself can be seen as an example of the plasticity of the ageing mind. Selective optimization with compensation is a meta-model of successful development that explains how individuals make adaptations when faced with changes brought about by the ageing process. The model conceptualizes three main processes that demonstrate people's ability to be resilient in their thinking, feelings, behaviours or environments to attain desired goals throughout development and ageing.

First, there is the element of *selection* that refers to the restricted options of available functional domains because of an ageing loss in the range of adaptive potential. Selection implies that individuals adjust their expectations to allow the subjective experience of satisfaction and personal control (Baltes & Baltes 1990). The second element, *optimization*, reflects a view that people engage in behaviours that assist them in reaching higher and more desirable levels of functioning. Examples of optimization include training, practice or education. Studies on plasticity have shown that older people continue to be able to perform this optimizing process (Baltes & Baltes 1990). Optimization holds the potential for growth that comes about when we master the uncertainties and changes of old age. In this way, Baltes and Baltes view successful ageing as the process by which the elderly achieve their individual goals in the face of simultaneous losses. The third element,

compensation, results from restrictions in the range of plasticity or adaptive potential, similar to selection. The process of compensation occurs when an individual's behavioural capacities are lost or reduced below a level necessary for adequate functioning. This limited capacity is experienced particularly in situations that require a wide range of activity and a high level of performance, such as competitive sports or situations that require quick thinking and memorization. Compensatory efforts include, for instance, use of mnemonic strategies when internal memory strategies are inadequate (Baltes & Baltes 1990). This meta-model of ageing provides strategies that individuals can follow to contribute to their own successful ageing.

Clearly, the multicriterion model of selective optimization with compensation proposed by Baltes & Baltes (1990) holds its premises in the psychosocial models of successful ageing, which view successful ageing as the successful adaptation of an individual to the changes inherent to the ageing process. It is thus a model of resilience and coping, and it has the advantage of not using an elitist definition of successful ageing. However, there are two potential weaknesses of the model of selective optimization with compensation. First, although the model uses a multicriterion approach to define successful ageing, these criteria are psychosocial in nature and do not include any biological or cognitive criteria. However, individuals who are in excellent health up into their old age might never be confronted with the need to select, optimize and compensate to deal with the changes that occur with ageing. The model would suggest, however, that even in the case of these individuals, they would have to compensate for other age-related losses such as retirement, loss of income, loss of spouse, etc. Still, the capacity for resilience and coping might significantly differ as a function of various factors such as health and cognitive capacity. Therefore, it is unclear at this point how the model can include these variables. The second problematic aspect of the model is its reliance on the individual as the sole instigator of successful ageing. In this respect, the studies of the Kibbutz communities teach us something interesting.

(b) *Studies on the Israeli Kibbutz and the importance of social arrangements*

Although several studies on successful ageing have shown that social interactions and support impact cognitive functioning, research on the ageing members of the Israeli Kibbutz communities has shown that the impact of social arrangements and social support are strong predictors of successful ageing, expressed in high life expectancy and positive well-being. Twenty years of research on the elderly population of Kibbutzim show that their demonstration of successful ageing is mostly a result of the social arrangements and policies assumed by their communities in the areas of work, social relationships, stability in social roles and surroundings (Leviatan 1999). The Kibbutz uniqueness in their way of life allows its aged members to demonstrate successful ageing. The continuation of the worker role after retirement, shared responsibility by both individual and community in health preservation, formal community institutions as a means of social support to replace non-existent close family members, and constant adjustment of jobs to changing abilities, are a few of the social arrangements that allow for lower mortality rates and

potential longevity among the Kibbutz communities (Leviatan 1989, 1999).

Support for the importance of social arrangements is also shown by the negative effects of well-being that result from structural changes, experienced by some Kibbutzim, in the course of becoming more similar to industrialized societies. As their population is very homogeneous compared with other societies, a study has shown that when comparing the occurrence of structural changes, those elderly members from Kibbutzim that underwent the structural changes, as compared with members from Kibbutzim without them, experienced more alienation and 'feeling of powerlessness', less satisfaction with life, and less satisfaction with Kibbutz life (Leviatan 1999). Therefore, in the case of the experience of the Israeli Kibbutz, any structural or social change in the life domains of its elderly members would seem to result in a disruption of the stability in social roles, environmental conditions, social arrangements and life experiences that has been shown to lead to successful ageing.

The study of the Kibbutz shows that social stability is a key determinant of successful ageing among members of their society. However, when faced with structural changes, the question of adaptation arises. The uniqueness of the Kibbutz is that its *society adapts to the needs of its members*, which, in turn, leads them to age successfully. By contrast, the model proposed by Baltes & Baltes (1990) suggests that successful ageing is the successful adaptation of the individual to changes during the course of ageing. Hence, the attainment of successful ageing can arguably be recognized as taking two approaches: the societal approach, in which the concern is with what society should or should not do to raise elderly individuals to the functioning level of successful ageing; and the individual approach, in which the concern is with what individuals should or should not do to experience successful ageing. Such divergence in the approaches to attaining successful ageing exemplifies how the notion of successful ageing continues to lend itself to more than one interpretation or perspective.

10. SUCCESSFUL AGEING AND THE POWER OF POSITIVE ATTITUDES TOWARDS AGEING

Research on the perception of age and ageing stereotypes has shown that well-being and a positive view of ageing are major protective factors against the effects of age on the organism (Linn & Hunter 1979; Levy 1996; Levy 2001; Levy *et al.* 2000a, 2002). The effects of attitudes and beliefs about ageing have been observed in various areas of science, from biological to sociological. In the biological domain of ageing research, studies have shown that older individuals' beliefs about ageing can have a direct impact on their health and longevity (Levy *et al.* 2000b, 2002). In the first study of its kind, Levy *et al.* (2000b) showed that negative attitudes towards ageing heightened cardiovascular response to stress whereas positive attitudes towards ageing exerted a protective effect, bringing their physiological changes back to baseline levels. The study suggests that negative attitudes towards ageing may contribute to health problems in the elderly without their awareness. This could lead to elderly individuals mistakenly attributing their deteriorating health to the inevitability of ageing, which may then reinforce the negative age stereotypes and prevent successful ageing (Levy *et al.* 2000a). Introducing

positive views of ageing reduced cardiovascular stress in the sample being studied, and therefore suggests that interventions designed to improve cardiovascular health in the elderly should emphasize the importance of including the promotion of positive ageing attitudes.

A further indication that positive attitudes play an important role in an elderly individual's physiological state is that positive self-perceptions of older individuals can influence longevity (Levy *et al.* 2002). Findings in this observational study showed a 7.5 year mean survival advantage for those who expressed a more positive self-perception of ageing compared with those holding more negative perceptions. This finding provides further support for the idea that the internalization of negative stereotypes can be seen as a significant health hazard, although it has to be noted here that these observational data may have numerous other interpretations related to the characteristics of the participants.

Research on the psychology of ageing has similarly contributed to studies on the impact of stereotypes on ageing (Linn & Hunter 1979; Levy 1996). In a recent study examining the impact of negative and positive attitudes towards ageing and their influence on memory performance, it was found that older participants exposed to negative age stereotypes tend to worsen their memory performance, self-efficacy and judgements of other elderly people (Levy 1996). In this study, general memory performance was compared before and after subliminal exposure to positive or negative words related to ageing (e.g. wise versus senile). Results showed that memory performance was significantly lower after exposure to negative words related to ageing, whereas it was higher when participants had been exposed to positive words related to ageing. Although these results raise the possibility that age stereotypes may have an important effect on memory performance in the aged human population, it has to be noted that the emotional valence of the words (positive versus negative) may be a more important factor in determining memory performance (see Fredrickson & Levenson 1998; Fredrickson 2001), than the fact that the words are related to ageing. However, in the study of Levy (1996), young participants exposed to the same positive and negative words related to ageing did not exhibit any of the significant interactions observed in the old participants. These results suggest that the ageing component of the words may indeed be an important modulatory factor of memory performance in the aged population.

Other psychology-based studies have found that perception of age in the elderly has an impact on psychological functioning (Linn & Hunter 1979). Specifically, it was found that older individuals who perceived their age as younger than others of the same age had more internal control, which has been related to more positive functioning. Internal control refers to the extent to which an individual sees their outcomes as being dependent on their own efforts and abilities as opposed to external circumstances or chance or fate (external control). In a similar vein, Palmore & Luikart (1972) reported that beliefs in personal control were related to enhanced life satisfaction. Also, Wolk & Kurtz (1975) and Wolk (1976) showed the relation between internality and life satisfaction among non-institutionalized elderly.

Across various spheres of science, positive attitudes towards ageing have been shown to positively influence memory performance, longevity, health, well-being, life satisfaction, will-to-live and other physiological and psychological functioning (Linn & Hunter 1979; Levy 1996, 2000a; Levy *et al.* 2002). However, debates concerning the determinants of successful ageing persist. Societal stereotypes as well as elderly individuals' self-perception play a key role in determining and affecting how an individual ages. From heightened cardiovascular responses to stress, longevity, will-to-live and memory performance, these particular variables have been shown to affect older individuals' ageing. Although these studies explored only one dependent variable at a time, in the real world, it is likely that self-perception and self-stereotyping occur in various spheres at once, whereby the effects are mutually reinforcing. For instance, an elderly person exposed to negative age stereotypes may show impaired memory and heightened stress levels. The impaired recall may worsen stress, and the elevated stress could impede memory performance even further (Levy 2001). Given that the effects of age stereotypes are mutually reinforcing and infiltrate into our everyday thinking and behaviour, the consequences of negative age stereotypes can have detrimental effects on older individuals' self-image, abilities and health, thereby preventing successful ageing.

11. CONCLUSION

In this paper, we have provided a historical and methodological analysis of the concept of successful ageing. Although the ageing process was originally viewed as a time of decline of physical and cognitive functions, the concept of successful ageing, put forward by Rowe & Kahn in 1987 triggered a large interest in the study of the biological, psychological and psychosocial determinants of successful ageing. We have exposed each perspective independently and described the factors that are thought to determine and/or define successful ageing within the biological, psychological and psychosocial perspectives.

This analysis revealed the presence of weaknesses intrinsic to each unique approach because the notion of successful ageing implies more than success at the biological, psychological or psychosocial level. Consequently, we have reviewed the multicriteria models of successful ageing as proposed by Rowe & Kahn (1987), and Baltes & Baltes (1990). Although these new multicriteria approaches have certainly contributed to the development of a multidisciplinary study of successful ageing, each of them also presents some problems in the definition of what constitutes a 'successful ager' and/or what one can do to become a 'successful ager'.

This analysis led us to review the impact of age stereotypes on the biological and cognitive determinants of ageing. Here, we see that the views that one holds about the process of ageing can have an important impact on physical health and cognitive performance in old age. It is, therefore, possible to propose that the determinants of successful ageing stem in part from the societal influences of age stereotypes and older individual's self-perception of ageing. To strive towards a more optimal view of the ageing process, research on successful ageing needs to focus not only on the models of biological and cellular ageing that

consider mainly the gradual deterioration of the organism, but also on psychological and sociologically related factors that are related to improvements or maintenance of function. With increasing research, there is strong evidence that positive self-concepts can have a reversing effect on what was once believed to be an inevitable declining process of ageing. With the knowledge that positive attitudes function as protective factors against the effects of age on the organism, viewing successful ageing from these perspectives provides us with an integrative view that blends the various realms of ageing, and goes beyond the cell to reach the self.

S.J.L. is funded by an Institute of Aging Investigator Award from the Canadian Institutes of Health Research.

REFERENCES

- Andersen-Ranberg, K., Vasegaard, L. & Jeune, B. 2001 Dementia is not inevitable: a population-based study of Danish centenarians. *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **56**, 152–159.
- Baggio, G. (and 12 others) 1998 Lipoprotein(a) and lipoprotein profile in healthy centenarians: a reappraisal of vascular risk factors. *FASEB J.* **12**, 433–437.
- Baltes, P. B. & Baltes, M. 1990 Psychological perspectives on successful aging: the model of selective optimisation with compensation. In *Successful aging: perspectives from the behavioural sciences* (ed. P. B. Baltes & M. M. Baltes), pp. 1–36. Cambridge University Press.
- Baltes, M. M. & Carstensen, L. L. 1996 The process of successful aging. *Aging Soc.* **16**, 397–422.
- Baltes, P. B. & Goulet, L. R. 1971 Explorations of developmental variables by simulation and manipulation of age differences in behavior. *Hum. Dev.* **14**, 149–170.
- Baltes, P. B. & Lindenberger, U. 1988 On the range of cognitive plasticity in old age as a function of experience: 15 years of intervention research. *Behav. Therapy* **19**, 283–300.
- Barbagallo, C. M., Averna, M. R., Frada, G., Barbagallo, C. M. & Averna, M. R. 1995 Plasma lipid apolipoprotein and Lp(a) levels in elderly normolipidemic women: relationships with coronary heart disease and longevity. *Gerontology* **41**, 260–266.
- Bassuk, S. S., Glass, T. A. & Berkman, L. F. 1999 Social disengagement and incident cognitive decline in community-dwelling elderly persons. *Ann. Internal Med.* **131**, 165–173.
- Beard, B. B. 1991 *Centenarians, the new generation*. New York: Greenwood Press.
- Beregi, E. 1990 Centenarians in Hungary. A social and demographic study. *Interdiscipl. Top. Gerontol.* **27**, 31–39.
- Berkman, L. F. 1995 The role of social relations in health promotion. *Psychosomatic Med.* **57**, 245–254.
- Berkman, L. F. (and 16 others) 1993 High, usual and impaired functioning in community-dwelling older men and women: finding from the MacArthur Foundation Research Network on Successful Aging. *J. Clin. Epidemiol.* **46**, 1129–1140.
- Bird, C. 1940 As we grow old. *Science Digest* **8**, 23–27.
- Birren, J. E. & Schaie, K. W. 1985 *Handbook of the psychology of aging: principles and experimentation*. New York: Van Nostrand Reinhold.
- Botwinich, J. 1978 *Ageing and behavior*, 2nd edn. New York: Springer.
- Butler, R. A. 1969 Ageism: another form of bigotry. *Gerontologist* **9**, 212–252.
- Butler, R. A. 1977 Successful aging and the role of the life review. In *Readings in aging and death: contemporary perspectives*, 2nd edn (ed. S. N. Zarit), pp. 13–19. New York: Harper & Row.

- Cabeza, R., Daselaar, S. M., Dolcos, F., Prince, S. E., Budde, M. & Nyberg, L. 2004 Task-independent and task-specific age effects on brain activity during working memory, visual attention and episodic retrieval. *Cereb. Cortex* **14**, 364–375.
- Chodosh, J., Reuben, D. B., Albert, M. S. & Seeman, T. E. 2002 Predicting cognitive impairment in high-functioning community-dwelling older persons: MacArthur studies of successful aging. *J. Am. Geriatr. Soc.* **50**, 1051–1060.
- Cohen, S. & Herbert, T. B. 1996 Health psychology: psychological factors and physical disease from the perspective of human psychoneuroimmunology. *A. Rev. Psychol.* **47**, 113–142.
- Costa Jr, P. T. & McCrae, R. R. 1980 Influence of extraversion and neuroticism on subjective well-being: happy and unhappy people. *J. Personality Social Psychol.* **38**, 668–678.
- Costa Jr, P. T. & McCrae, R. R. 1986 Personality stability and its implications for clinical psychology. *Clin. Psychol. Rev.* **6**, 407–423.
- Costa Jr, P. T. & McCrae, R. R. 1988 Personality in adulthood. *J. Personality Social Psychol.* **54**, 853–863.
- Cutler, N. E. & Harootyan, R. A. 1975 Demography of the aged. In *Aging: scientific perspectives and social issues* (ed. D. S. Woodruff & J. E. Birren), pp. 45–55. New York: Van Nostrand.
- Cutler, R. G. 1990 Evolutionary perspective of human longevity. In *Principles of geriatric medicine and gerontology* (ed. W. R. Hazzard, R. Andres, E. L. Bierman & J. P. Blass), pp. 15–21. New York: McGraw-Hill.
- Dannefer, D. 1988 What's in a name? An account of the neglect of variability in the study of aging. In *Emergent theories of aging* (ed. J. E. Birren & V. L. Bengtson), pp. 432–456. New York: Springer.
- Department of Health and Human Services 2000 Older Americans 2000: key indicators of well-being. In *Federal interagency forum on aging related statistics*, p. 1–123. [See <http://www.agingstats.gov/chartbook2000/default.htm>.]
- Effros, R. B., Boucher, N., Porter, V., Zhu, X., Spaulding, C., Walford, R. L., Kronenberg, M., Cohen, D. & Schachter, F. 1994 Decline in CD28 T cells in centenarians and in long-term T cell cultures: a possible cause for both *in vivo* and *in vitro* immunosenescence. *Exp. Gerontol.* **29**, 601–609.
- Ferraro, K. F. 1997 The gerontological imagination. In *Gerontology: perspectives and issues*, 2nd edn (ed. K. F. Ferraro), pp. 3–18. New York: Springer.
- Fisher, B. J. 1992 Successful aging and life satisfaction: a pilot study for conceptual clarification. *J. Aging Stud.* **6**, 191–202.
- Fisher, B. J. 1995 Successful aging, life satisfaction and generativity in later life. *Int. J. Aging Hum. Dev.* **41**, 239–250.
- Franceschi, C., Monti, D., Sansoni, P. & Cossarizza, A. 1995 The immunology of exceptional individuals: the lesson of centenarians. *Immunol. Today* **16**, 12–16.
- Fratiglioni, L., Wang, H. X., Ericsson, K., Maytan, M. & Winblad, B. 2000 Influence of social network on occurrence of dementia: a community-based longitudinal study. *Lancet* **355**, 1315–1319.
- Fredrickson, B. L. 2001 The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions. *Am. Psychol.* **56**, 218–226.
- Fredrickson, B. L. & Levenson, R. W. 1998 Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. *Cogn Emotion* **12**, 191–220.
- Fries, J. F. 1980 Aging, natural death, and the compression of morbidity. *New Engl. J. Med.* **303**, 130–135.
- Fries, J. F. 1993 Medical perspectives upon successful aging. In *Successful aging: perspective from the behavioural sciences* (ed. P. B. Baltes & M. M. Baltes), pp. 35–49. Cambridge University Press.
- George, L. 1979 The happiness syndrome: methodological and substantive issues in the study of social-psychological well-being in adulthood. *The Gerontol.* **19**, 210–216.
- George, L. K. 1981 Subjective well-being: conceptual and methodological issues. In *Annual review of gerontology and geriatrics*. vol. 2 (ed. C. Eisdorfer), pp. 33–45. New York: Springer.
- George, L. K. 1986 Life satisfaction in later life. *Generations* **10** (Spring), 5–8.
- Goldberg, L. R. 1993 The structure of phenotypic personality traits. *Am. Psychol.* **48**, 26–34.
- Griffiths, T. D. 1997 Biology of aging. In *Gerontology: perspectives and issues*, 2nd edn (ed. K. F. Ferraro), pp. 53–67. New York: Springer.
- Guarente, L. & Kenyon, C. 2000 Genetic pathways that regulate ageing in model organisms. *Nature* **408**, 255–262.
- Hagberg, B., Bauer, A., Alfredson, B., Poon, L. W. & Homma, A. 2001 Cognitive functioning in centenarians: a coordinated analysis of results from three countries. *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **56**, 141–151.
- Hall, G. S. 1922 *Senescence: the last half of life*. New York: Appleton and Company.
- Helmuth, L. 2003 The wisdom of the wizened. *Science* **299**, 1300–1302.
- Hendricks, J. & Hendricks, C. D. 1977 *Aging in mass society: myths and realities*. Cambridge, MA: Winthrop.
- Herzog, A. R. & Rodgers, W. L. 1981 Age and satisfaction: data from several large surveys. *Res. Aging* **7**, 209–233.
- Hirshbein, L. D. 2001 Popular view of old age in America, 1900–1950. *Am. Geriatrics Soc.* **49**, 1555–1560.
- Imai, S. I., Armstrong, C. M., Kaerberlein, M. & Guarente, L. 2000 Transcriptional silencing and longevity protein Sir2 is an NAD-dependent histone deacetylase. *Nature* **403**, 795–800.
- Jazwinski, S. M. 1999 Molecular mechanisms of yeast longevity. *Trends Microbiol.* **7**, 247–252.
- Karasawa, A. 1979 Mental aging and its medico-social background in the very old Japanese. *J. Gerontol.* **34**, 680–686.
- Karlamañga, A. S., Singer, B. H., McEwen, B. S., Rowe, J. W. & Seeman, T. E. 2002 Allostatic load as a predictor of functional decline: MacArthur studies of successful aging. *J. Clin. Epidemiol.* **55**, 696–710.
- Kerber, R. A., O'Brien, E., Smith, K. R. & Cawthon, R. M. 2001 Familial excess longevity in Utah genealogies. *J. Gerontol. A. Biol. Sci. Med. Sci.* **56**, B130–B139.
- Kirkwood, T. B. L. 1977 Evolution of ageing. *Nature* **270**, 301–304.
- Kirkwood, T. B. L. & Holliday, R. 1979 The evolution of aging and longevity. *Proc. R. Soc. Lond. B* **205**, 531–546.
- 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. *Devl Psychol.* **25**, 247–256.
- Krauss, I. K. 1980 Between- and within-group comparisons in aging research. In *Aging in the 1980s* (ed. L. W. Poon), pp. 132–145. Washington, DC: American Psychological Association.
- Kubzansky, L. D., Berkman, L. F., Glass, T. A. & Seeman, T. E. 1998 Is educational attainment associated with shared determinants of health in the elderly? Findings from the MacArthur studies of successful aging. *Psychosom. Med.* **60**, 578–585.
- Kubzansky, L. D., Berkman, L. F. & Seeman, T. E. 2000 Social conditions and distress in elderly persons: findings from the MacArthur studies of successful aging. *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **55**, 238–246.
- Labouvie, E. W. 1980 Identity versus equivalence of psychological measures and constructs. In *Aging in the 1980s* (ed. L. W. Poon), pp. 31–47. Washington, DC: American Psychological Association.

- Leviatan, U. 1989 Successful aging: the Kibbutz experience. *J. Aging Judaism* 4, 71–90.
- Leviatan, U. 1999 Contributions of social arrangements to the attainment of successful aging: the experience of the Israeli Kibbutz. *J. Gerontol.* 54, 205–213.
- Levy, B. 1996 Improving memory in old age through implicit self-stereotyping. *J. Personality Social Psychol.* 71, 1092–1107.
- Levy, B. 2001 Eradication of ageism requires addressing the enemy within. *Gerontologist* 41, 578–579.
- Levy, B., Ashman, O. & Dror, I. 2000a To be or not to be: the effects of aging stereotypes on the will to live. *Omega* 40, 409–420.
- Levy, B., Hausdorff, J., Hencke, R. & Wie, J. 2000b Reducing cardiovascular stress with positive self-stereotypes of aging. *J. Gerontol. Psychol. Sci.* 55B, 205–213.
- Levy, B., Slade, M., Kundel, S. & Kasl, S. 2002 Longevity increased by positive self-perceptions of aging. *J. Personality Social Psychol.* 83, 261–270.
- Li, S. C., Aggen, S. H., Nesselroade, J. R. & Baltes, P. B. 2001 Short-term fluctuations in elderly people's sensorimotor functioning predict text and spatial memory performance: the MacArthur successful aging studies. *Gerontology* 47, 100–116.
- Linn, M. W. & Hunter, K. 1979 Perceptions of age in the elderly. *J. Gerontol.* 34, 46–52.
- Lupien, S. & Lecours, A. R. 1993 All things being otherwise unequal: reflection upon increased inter-individual differences with aging. *Revue de Neuropsychologie* 3, 3–35.
- Lupien, S., Lecours, A. R., Lussier, I., Schwartz, G., Nair, N. P. V. & Meaney, M. J. 1994 Basal cortisol levels and cognitive deficits in human aging. *J. Neurosci.* 14, 2893–2903.
- Lupien, S., DeLeon, M., DeSanti, S., Convit, A., Tarshish, C., Nair, N. P. V., Thakur, M., McEwen, B. S., Hauger, R. L. & Meaney, M. J. 1998 Longitudinal increase in cortisol during human aging predicts hippocampal atrophy and memory deficits. *Nature Neurosci.* 1, 69–73.
- Lynott, R. J. & Lynott, P. P. 1996 Tracing the course of theoretical development in the sociology of aging. *Gerontologist* 36, 749–760.
- McAdams, D. P. 1994 Can personality change? Levels of stability and growth in personality across the lifespan. In *Can personality change?* (ed. T. F. Heatherton & J. L. Weingerger), pp. 299–313. Washington, DC: American Psychological Association.
- McCrae, R. R. 2002 The maturation of personality psychology: adult personality development and psychological well-being. *J. Res. Personality* 36, 307–317.
- McCrae, R. R. & Costa, P. T. 1984 *Emerging lives, enduring dispositions: personality in adulthood*. Boston, MA: Little Brown.
- McCrae, R. R. & John, O. P. 1992 An introduction to the five-factor model and its applications. *J. Personality* 60, 175–215.
- McEwen, B. S. & Stellar, E. 1993 Stress and the individual: mechanisms leading to disease. *Arch. Int. Med.* 153, 2093–2101.
- Martin, L. J. & de Gruchy, C. 1930 *Salvaging old age*. New York: Macmillan.
- Masoro, E. J. 2001 Longevity: to the limits and beyond. *Gerontologist* 41, 414–418.
- Miles, W. R. 1933 Age and human ability. *Psychol. Rev.* 40, 114–115.
- Minkler, M. 1990 Aging and disability: behind and beyond the stereotypes. *J. Aging Stud.* 4, 245–260.
- Minkler, M. & Fadem, P. 2002 Successful aging: a disability perspective. *J. Dis. Policy Stud.* 12, 229–236.
- Morris, J. C., McKeel Jr, D. W., Storandt, M., Rubin, E. H., Price, J. L., Grant, E. A., Ball, M. J. & Berg, L. 1991 Very mild Alzheimer's disease: informant-based clinical psychometric and pathologic distinction from normal aging. *Neurology* 41, 469–478.
- Palmore, E. 1990 *Ageism: negative and positive*. New York: Springer.
- Palmore, E. & Luikart, C. 1972 Health and social factors related to life satisfaction. *J. Hlth Social Behav.* 13, 68–80.
- Paolisso, G., Gambardella, A., Balbi, V., Ammendola, S., D'Amore, A. & Varricchio, M. 1995 Body composition, body fat distribution and resting metabolic rate in healthy centenarians. *Am. J. Clin. Nutr.* 62, 746–750.
- Perls, T. & Fretts, R. 1998 Why women live longer than men. *Sci. Am. Presents* 9, 100–103.
- Perls, T. T., Bubrick, E., Wager, C. G., Vijg, J. & Kruglyak, L. 1998 Siblings of centenarians live longer. *Lancet* 351, 1560.
- Perls, T. T., Bochen, K., Freeman, M., Alpert, L. & Silver, M. H. 1999 Validity of reported age and centenarian prevalence in New England. *Age Ageing* 28, 193–197.
- Perls, T., Kunkel, L. M. & Puca, A. A. 2002a The genetics of exceptional human longevity. *J. Am. Genet. Soc.* 50, 359–369.
- Perls, T., Levenson, R., Regan, M. & Puca, A. 2002b What does it take to live to 100? *Mech. Aging Dev.* 123, 231–242.
- Poon, L. W. 1992 *The Georgian centenarian study*. Amityville, NY: Baywood.
- Rowe, J. W. & Kahn, R. L. 1987 Human aging: usual and successful aging. *Science* 237, 143–149.
- Rowe, J. W. & Kahn, R. L. 1998 *Successful aging*. New York: Pantheon Books.
- Rybicki, B. A. & Elston, R. C. 2000 The relationship between the sibling recurrence–risk ratio and genotype relative risk. *Am. J. Hum. Genet.* 66, 593–604.
- Schaie, K. W. 1993 The optimization of cognitive functioning in old age: predictions based on cohort-sequential and longitudinal data. In *Successful aging: perspectives from the behavioural sciences* (ed. P. B. Baltes & M. M. Baltes), pp. 94–117. Cambridge University Press.
- Schaie, K. W. & Willis, S. L. 1998 Can adult intellectual decline be reserved? *Devl Psychol.* 22, 223–232.
- Seeman, T. E. 1996 Social ties and health. *Ann. Epidemiol.* 6, 442–451.
- Seeman, T. E., Singer, B. & Charpentier, P. 1995a Gender differences in patterns of HPA axis response to challenge: MacArthur studies of successful aging. *Psychoneuroendocrinology* 20, 711–725.
- Seeman, T. E., Berkman, L. F., Gulanski, B. I., Robbins, R. J., Greenspan, S. L., Charpentier, P. A. & Rowe, J. W. 1995b Self-esteem and neuroendocrine response to challenge: MacArthur studies of successful aging. *J. Psychosom. Res.* 39, 69–84.
- Seeman, T. E., McEwen, B. S., Singer, B. H., Albert, M. S. & Rowe, J. W. 1997a Increase in urinary cortisol excretion and memory declines: MacArthur studies of successful aging. *J. Clin. Endocrinol. Metabol.* 82, 2458–2465.
- Seeman, T. E., Singer, B. H., Rowe, J. W., Horwitz, R. I. & McEwen, B. S. 1997b Price of adaptation: allostatic load and its health consequence. *Arch. Int. Med.* 157, 2259–2268.
- Seeman, T. E., McEwen, B. S., Rowe, J. W. & Singer, B. H. 2001a Allostatic load as a marker of cumulative biological risk: MacArthur studies of successful aging. *Proc. Natl Acad. Sci. USA* 98, 4770–4775.
- Seeman, T. E., Lusignolo, T. M., Albert, M. & Berkman, L. 2001b Social relationships, social support, and patterns of cognitive aging in healthy, high-functioning older adults: MacArthur studies of successful aging. *Hlth Psychol.* 20, 1–13.

- Shanan, J. 1991 Who and how: some unanswered questions in adult development. *J. Gerontol. Psychol. Sci.* **46**, 309–316.
- Sheldon, J. H. 1948 *The social medicine of old age*. London: Oxford University Press.
- Shingo, T., Gregg, C., Enwere, E., Fujikawa, H., Hassam, R., Geary, C., Cross, J. C. & Weiss, S. 2003 Pregnancy-stimulated neurogenesis in the adult female forebrain mediated by prolactin. *Science* **299**, 117–120.
- Silver, M., Newell, K., Hyman, B., Growdon, J., Hedley-Whyte, E. T. & Perls, T. 1998 Unravelling the mystery of cognitive changes in old age: correlation of neuropsychological evaluation with neuropathological findings in the extreme old. *Int. Psychogeriatr.* **10**, 25–41.
- Silver, M. H., Jilinskaia, E. & Perls, T. T. 2001 Cognitive functional status of age-confirmed centenarians in a population-based study. *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **56**, 134–140.
- Stones, M. J., Kozma, A. & Hannah, T. E. 1990 The measurement of individual differences in aging: the distinction between usual and successful aging. In *Cognitive and behavioural performance factors in atypical aging* (ed. M. L. Have, M. J. Stones & C. J. Brainerd), pp. 181–218. New York: Springer.
- Tabbarah, M., Crimmins, E. M. & Seeman, T. E. 2002 The relationship between cognitive and physical performance: MacArthur studies of successful aging. *J. Gerontol. A. Biol. Sci. Med. Sci.* **57**, 228–235.
- Unger, J. B., McAvay, G., Bruce, L. M., Berkman, L. & Seeman, T. 1999 Variation in the impact of social network characteristics on physical functioning in elderly persons: MacArthur studies of successful aging. *J. Gerontol. B. Psychol. Sci. Soc. Sci.* **54**, 245–251.
- Weaver, J. D., Huang, M. H., Albert, M., Harris, T., Rowe, J. W. & Seeman, T. E. 2002 Interleukin-6 and risk of cognitive decline: MacArthur studies of successful aging. *Neurology* **59**, 371–378.
- Williams, G. C. 1966 *Adaptation and natural selection*. Princeton University Press.
- Wolk, S. 1976 Situational constraints as a moderator of locus of control–adjustment relationship. *J. Consulting Clin. Psychol.* **44**, 420–427.
- Wolk, S. & Kurtz, J. 1975 Positive adjustment and involvement during aging and expectancy for internal control. *J. Consulting Clin. Psychol.* **43**, 173–178.
- World Health Organization 2003a. *The World Health Report 2003: Shaping the Future*, pp. 1–131. Geneva: World Health Organization. [See <http://www.who.int/whr/2003/en/>]
- World Health Organization 2003b. *The World Health Report 2003: Annex 4. Healthy life expectancy (HALE) in all member states; Estimates for 2002*; p. 166. Geneva: World Health Organization. [See <http://www.who.int/whr/2003/en/Annex4-en.pdf>]