UNDERSTANDING THE CONCEPT OF SUCCESSFUL AGING

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USING DATA FROM THE CANADIAN STUDY OF HEALTH AND AGING

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ABSTRACT

Objectives: There is a lack of consensus on the definition and measurement of successful aging. The objectives of this thesis were: (1) to conduct a systematic scoping review of the literature to identify indicators of successful aging; (2) to understand the underlying latent constructs of indicators identified in objective 1 using data from the Canadian Study of Health and Aging (CSHA); and (3) to examine the split-half reliability and stability of the constructs identified in objective 2.

Methods: Six databases (MEDLINE, EMBASE, PsychINFO, CINAHL, Sociological Abstracts, AgeLine) were searched for English language primary studies that included an operational definition of successful aging and were published between January 2000 and September 2010. Indicators of successful aging were extracted from 63 studies and used to guide the selection of variables from the CSHA. Exploratory factor analysis and structural equation modelling were used to develop and evaluate a measurement model of successful aging in 1,347 community-dwelling adults aged 75 to 102 from the CSHA. The reliability and stability of the model was assessed in an independent sample of 1,337 CSHA participants.

Results: A four-factor solution of Perceived Well-being, Physical Ability, General Health Status and Social Functioning constructs explained approximately 47% of variation and fit the data adequately (CMIN=259, df=48, p <.0001; CFI=.957; TLI=.930; RMSEA=.055, 90% CI: .049 to .062). Evaluation of the model using an independent sample of 1,337 participants revealed comparable parameter estimates and fit statistics, therefore suggesting reliability and stability of the constructs.

Conclusions: This thesis presents a unique contribution by suggesting and testing a theoretically meaningful four-factor model of successful aging in a large population-based sample. The findings contribute to our understanding of how indicators operate together to define successful aging in a cohort of Canadian seniors.

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TABLE OF CONTENTS

ABSTRACT ii
ACKNOWLEDGEMENTS iv
LIST OF FIGURES viii
LIST OF TABLES ix
LIST OF ABBREVIATIONS USED x
CHAPTER 1: INTRODUCTION 1
1.1 Background and Rationale 1
1.2 Research Objectives 3
1.3 Thesis Overview 4
CHAPTER 2: CONCEPTUAL FRAMEWORKS OF SUCCESSFUL AGING 6
2.1 Models and Theories of Successful Aging 6
2.1.1 Rowe and Kahn's Model of Successful Aging 6
2.1.2 Selective Optimization with Compensation (SOC) 8
2.2 Critiques of the Frameworks of Successful Aging 9
2.3 Conclusions 11
CHAPTER 3: SYSTEMATIC SCOPING REVIEW OF EMPIRICAL STUDIES 13
3.1 Rationale 13
3.2 Methodology 15
3.3 Findings 16
3.3.1 Well-being and Life Satisfaction 18
3.3.2 Physical Functioning and Ability 19
3.3.3 General Health Status 19
3.3.4 Social Functioning 20
3.3.5 Mental Status and Cognitive Functioning 21
3.3.6 Psychological Functioning 21
3.3.7 Self-rated Successful Aging 22
3.3.8 Additional Indicators 23
3.4 Discussion 24
3.5 Summary 26

CHAPTER 4: ANALYTICAL METHODS 28
4.1 Canadian Study of Health and Aging (CSHA) 28
4.1.1 Study Sample 31
4.1.2 Ethical Considerations 32
4.1.3 Selection and Construction of Indicators 33
4.1.3.1 Short Happiness and Affect Research Protocol (SHARP) 34
4.1.3.2 Center for Epidemiologic Studies Depression Scale (CESD-10) 35
4.1.3.3 Health-related Quality of Life (HRQL) 36
4.1.3.4 Common Health Problems 37
4.1.3.5 Activities of Daily Living (ADL) 37
4.1.3.6 Modified Mini-Mental State Exam (3MS) 38
4.1.3.7 Social Network and Supportive Ties 39
4.1.3.8 Engagement with Life 40
4.1.4 Demographic Variables 40
4.2 Analytic Approach 41
4.2.1 Assumptions of Factor Analysis 41
4.2.2 Model Development 43
4.2.2.1 Common Factor Analysis 43
4.2.2.2 Structural Equation Modelling (SEM) 45
4.2.3 Model Validation 47
CHAPTER 5: DATA ANALYSIS AND RESULTS 49
5.1 Sample Characteristics 49
5.2 Model Development 51
5.2.1 Common Factor Analysis 51
5.2.2 Structural Equation Modelling: Measurement Model 53
5.3 Cross-Validation 55
5.4 Summary 56
CHAPTER 6: DISCUSSION AND CONCLUSION 57
6.1 Discussion 57
6.2 Contributions and Limitations of this Research 61
6.3 Conclusions 63

REFERENCES 64
APPENDIX A: Literature Search Strategy.....91
APPENDIX B: Features of Studies of Successful Aging Included in Review (n=63).....93
APPENDIX C: Measurement of Components of Definitions of Successful Aging Included in Review 100

LIST OF FIGURES

Figure 1: Rowe and Kahn's Model of Successful Aging.....77
Figure 2: Baltes and Baltes' Theory of Selective Optimization with Compensation.....78
Figure 3: Scoping Review Flow Diagram 79
Figure 4: Common Factor Analysis: Cattell Scree Test Plot.....80
Figure 5: Hypothesized Model of Successful Aging 81
Figure 6: Revised Measurement Model of Latent Constructs and Observed Variables....82

LIST OF TABLES

Table 1: Descriptive Statistics for the Entire Sample and Subsamples 83

Table 2: Correlations of Successful Aging Variables 84

Table 3: Common Factor Analysis: Eigenvalues and Percent of Variance Explained 85

Table 4: Common Factor Analysis: Rotated Factor Matrix 86

Table 5: Maximum Likelihood Parameter Estimates for Hypothesized Model using the Calibration Sample (n=1,347) 87

Table 6: Comparisons of Alternate Models: Goodness-of-Fit Indexes 88

Table 7: Maximum Likelihood Parameter Estimates for Revised Measurement Model using the Calibration Sample (n=1,347) 89

Table 8: Maximum Likelihood Parameter Estimates for Revised Measurement Model using the Validation Sample (n=1,337) 90

LIST OF ABBREVIATIONS USED

3MS	Modified Mini-Mental State Exam
ADL	Activities of Daily Living
aHRQL	Recent Activity Limitation
CESD-10	Center for Epidemiological Studies Depression Scale, Short Version
CFI	Comparative Fit Index
CMIN	Model Chi-square
CSHA-1	Canadian Study of Health and Aging Wave 1, 1991-1992
CSHA-2	Canadian Study of Health and Aging Wave 2, 1996-1997
CSHA-3	Canadian Study of Health and Aging Wave 3, 2001-2002
HRQL	Health Related Quality of Life
IADL	Instrumental Activities of Daily Living
mHRQL	Recent Mental Health
ML	Maximum Likelihood
PADL	Personal Activities of Daily Living
pHRQL	Recent Physical Health
RMSEA	Root Mean Squared Error of Approximation
SD	Standard Deviation
SEM	Structural Equation Modelling
SHARP	Short Happiness and Affect Research Protocol
SOC	Selective Optimization with Compensation
TLI	Tucker-Lewis Index

CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Globally the population of older adults[1] is growing more rapidly than any other age segment. Three decades from now, the number of seniors worldwide is projected to surpass the number of children under age 15 for the first time (UN, 2009). This shift is expected to take place much sooner, if not already, in regions where population aging is "far advanced" (UN, 2009; PHAC, 2006). Factors contributing to this demographic transition include declining fertility rates, increasing life expectancy, and the aging of the baby boomer cohort (born between 1946 and 1964) which began turning age 65 in 2011 (UN, 2009; Statistics Canada, 2007).

In Canada seniors are projected to represent 24.5% of the population (9.8 million) in 2036, compared to 13.2% (4.2 million) in 2005 (Statistics Canada, 2007). The proportion of seniors is projected to continue to increase through to 2056, albeit at a lower rate (27.2% of total, or 11.5 million) (Government of Canada, 2007). The fastest growing segment of the senior population are those aged 85 and over (the "oldest-old") which are projected to increase from 1.5% of the population (492,000) in 2005 to 5.8% (2.5 million) in 2056 (Statistics Canada, 2007; Government of Canada, 2007).

With respect to the development of morbidity in the aging population, there are two hypotheses: (i) the compression-of-morbidity hypothesis, and (ii) the expansion-of-

[1] This thesis uses the terms "older adult," "senior" and "older person" broadly to describe someone aged 65 or older, while acknowledging that this is not a homogeneous age group.

morbidity hypothesis. Thirty years ago, Fries' (1980) proposed that the factors that promote longevity such as better preventive practices and improvements in medical care, may delay the onset of disease (Haan et al., 1991), in effect "compressing" the period of morbidity. This hypothesis has recently been challenged. First, contrary to the compression-of-morbidity hypothesis which argues that there is a natural limit to the life span, life expectancy does not seem to be approaching a maximum average life span (Doblhammer & Kytir, 2001). Second, trends in morbidity and mortality suggest a higher prevalence of numerous individual diseases, as well as an increase in the number of comorbid diseases (Crimmins & Saito, 2000; Crimmins & Beltran-Sanchez, 2010). Crimmins and Beltran-Sanchez (2010) suggest that little has been done to eliminate or delay disease, adding that while "substantial strides have been made in dealing with the consequences of disease" evidence supports an "expansion in life with disability and mobility functioning loss" (p.83).

The rapid aging of the population and the compression-versus-expansion of morbidity debate make it ever more important to understand the positive aspects of the aging process. This includes our understanding of what it means to age in a healthy or "successful" manner. This focus on health promotion and disease prevention is needed not only to contain costs of healthcare and social resources, but is also necessary in order for society to garner the benefits of the many contributions of seniors, in all aspects of life, including their families and communities (PHAC, 2006).

The concept of "successful aging" was proposed and defined in the early 1960s as "adding life to years" (as opposed to "years to life") and "feeling satisfaction with past

and present life" (Havighurst, 1961). It was later popularized in the 1980s by Rowe and Kahn (1987) emphasizing that "growing older need not be synonymous with loss and decline" (Whitbourne, 2005). The concept has since been used interchangeably with terms such as healthy aging (Rogers, 1995; Darnton-Hill, 1995; Payne et al., 1997), productive aging (Butler, 2002; Kerschner & Pegues, 1998), active aging (WHO, 2002), and optimal aging (Brummel-Smith, 2007).

There is a lack of consensus in the research community on the definition and measurement of successful aging (Depp, Vahia & Jeste, 2010; Bowling, 2007; Depp & Jeste, 2006). This inconsistency is reflected in the wide range of models and indicators used in the literature covering different approaches to the study of aging. These include largely biomedical definitions that emphasize the maintenance of health and functioning (e.g., Rowe & Kahn, 1997); psychosocial theories that emphasize life satisfaction or psychological resources such as adaptation (e.g., Baltes & Baltes, 1990); and other theories that emphasize cultural or environmental factors (e.g., Riley, 1998). Although important elements of successful aging have emerged in the literature, each model alone has received criticism for not fully recognizing the inherent multidimensionality of the concept (Riley, 1998; Strawbridge & Wallhagen, 2003). The development of a comprehensive model is required in order to clarify understanding, direct future research, and illustrate a foundation for practical interventions (Kahn, 2002).

1.2 Research Objectives

Although the literature on successful aging is not specific about the number of constructs or factors that are important, relatively few studies have used factor analysis techniques to explore the factor structure underlying potential indicators from the literature. The specific research objectives of this thesis were as follows:

(1) To conduct a systematic scoping review of the literature to identify indicators of successful aging;

(2) To understand the underlying constructs of indicators identified in objective 1 using data from the Canadian Study of Health and Aging (CSHA). Specifically, common factor analysis and structural equation modelling (SEM) were used to develop and evaluate a measurement model of successful aging; and

(3) To examine the split-half reliability and stability of the constructs identified in objective 2.

1.3 Thesis Overview

This thesis is structured into six chapters. Following this introduction to the background, rationale and research objectives, Chapter Two, *Conceptual Frameworks of Successful Aging*, provides a review of the key theories and models of successful aging that are currently in use and have guided this research. An assessment of the relative

contributions and limitations of this theoretical literature leads to a discussion of the need for an integrative, comprehensive framework of successful aging.

Chapter Three, *Scoping Review of Empirical Studies*, presents the rationale, methodology and key findings of a scoping review of the published literature evaluating successful aging. Themes and indicators emerging from the literature are explored in the context of theory and the findings of previous reviews on the subject.

Chapter Four, *Analytical Approach*, details the methodology and analytical techniques adopted to investigate the latent structure of successful aging using data from the CSHA. Presented first are the secondary data source, study samples, ethical considerations and variables of interest in the dataset. The subsequent sections of Chapter Four detail the process of model development using factor analysis and SEM, and model validation using a procedure put forth by Cudeck and Browne (1983).

In Chapter Five, *Data Analysis and Results*, a summary of the descriptive statistics of the two independent samples precedes presentation of the latent constructs emerging from the data. All modifications to the hypothesized model and measurement model are detailed, and several indexes of model fit are presented.

Chapter Six, *Discussion and Conclusion*, discusses the overall findings, contributions and limitations of this thesis, and presents concluding thoughts on future successful aging research.

CHAPTER 2: CONCEPTUAL FRAMEWORKS OF SUCCESSFUL AGING

This chapter reviews existing knowledge and current thinking on the concept of successful aging, with emphasis on two of the most influential frameworks put forth by Rowe and Kahn (1987; 1997) and Baltes and Baltes (1990). A selection of published critical commentaries on the limitations of these models and avenues for improvement are also considered, specifically the recommendations of Riley (1998*)* on the role of structural influences and Strawbridge and Wallhagen (2003) on the value of individual experiences. The proponents of the above mentioned models and theories were selected and included as they have produced some of the most frequently cited works in the discourse on successful aging. The chapter concludes with a discussion concerning the need for an integrated comprehensive framework of successful aging.

2.1 Models and Theories of Successful Aging

2.1.1 Rowe and Kahn's Model of Successful Aging

In a 1987 landmark paper, John Rowe and Robert Kahn argued for a conceptual distinction between "usual" and "successful" aging as two subclasses of normal aging. While acknowledging the importance of differentiating pathological changes from changes attributable to chronological aging, the authors argued that this dichotomization of people into diseased (pathologic) versus normal (non-pathologic) states has three limitations: (i) it implies that a non-diseased state is normal and therefore not in need of "modification"; (ii) it assumes the non-diseased group is without risk of disease and

disability; and (iii) most importantly, it neglects the substantial heterogeneity within age groups (Rowe & Kahn, 1987). As an alternative, Rowe and Kahn suggested that many age-associated declines are the consequence of an accumulation of modifiable environmental risk factors (e.g., diet, exercise, personal habits and psychosocial environment) that are extrinsic to the aging process. In distinguishing among persons in the non-diseased group, the authors proposed the term "usual aging" to describe older adults who are functioning well yet are at high risk of disease and disability, and "successful aging" to refer to those with high function and at low risk of disease and disability (Rowe & Kahn, 1997).

In a subsequent publication, Rowe and Kahn (1997) proposed a multidimensional model of successful aging, supported by their work with the MacArthur Foundation Research Network on Successful Aging[2]. Rowe and Kahn's Model of Successful Aging (Figure 1) consists of the following three components: (1) low probability of disease and disease-related disability, including the absence of risk factors; (2) high cognitive and physical functional capacity; and (3) active engagement in life, including maintenance of interpersonal relations and productive activities (Rowe & Kahn, 1997). Overall, this framework challenged the view that aging consists of inevitable decline, and instead proposed that age-associated losses in function may be the consequence of modifiable

[2] The Research Network on Successful Aging, commissioned by the MacArthur Foundation and lead by Dr. John Rowe, was largely responsible for bringing the concept of successful aging to the forefront of research on aging. Specifically, this network was responsible for the MacArthur studies of successful aging—a longitudinal study of community-dwelling Americans aged 70 to 79 years, followed from 1988 to 1996.

extrinsic factors. This model appears to be the most widely used approach in successful aging research (Bowling, 2007).

2.1.2 Selective Optimization with Compensation (SOC)

Paul Baltes and Margret Baltes' (1990) Selective Optimization with Compensation (SOC) is another influential model (summarized in Figure 2). According to this psychosocial life-span model, aging is conceptualized as a changing balance between gains and losses (Ouwehand, 2007) and successful aging as a process of adaptation by way of selection, optimization and compensation strategies. Baltes and Baltes (1990) claim that, while persons will likely engage these components throughout their lifetime in order to meet life goals, the dynamics of this process of adaptation are unique in older age due to declines in biological, mental and social reserves, and losses of function. As described by Baltes and Baltes (1990), the first component, *selection*, refers to reducing or transforming the number of life domains in order to concentrate on or sustain those life activities that are the most valued. The second component, *optimization*, refers to engaging in behaviours to optimize the resources that facilitate success in these selected life domains. Finally, the element of *compensation* refers to the use of alternative means such as mnemonics or technology to compensate for losses and reach one's goals.

By accommodating various individual trajectories (Rakowski et al., 2003), the model of SOC incorporates the important concept of interindividual variability or aged heterogeneity (Dannefer, 1988). For example, Baltes and Baltes (1990) explain that the

way these strategies "are realized depends on the specific personal and societal circumstances individuals face and produce as they age" (p.1). As a result, the use of SOC strategies may enable individuals to contribute to their own successful aging (Baltes & Baltes, 1990).

2.2 Critiques of the Frameworks of Successful Aging

Existing models of successful aging have each received criticism for not fully recognizing the multidimensionality of the concept. To broaden current conceptualizations, two key recommendations for the inclusion of additional components have been proposed in the literature.

First, current models have generated criticism for not considering the influence of broader social structures including the allocation of resources and opportunities, cultural contexts, and norms and behavioural expectations (Ryff & Singer, 2009). For example, in one of the initial constructive critiques of Rowe and Kahn's model, Matilda Riley (1998) argued that it focused primarily on individual factors and overlooked the influence of surrounding structural or contextual factors on the process of successful aging. Drawing on her Theory of Structural Lag (Riley & Riley, 1990), Riley asserted that "changes in lives and changes in social structures are fundamentally interdependent," and therefore success is contingent on the availability of structural opportunities or interventions in society (Riley, 1998). Riley further argued that the availability of such structural opportunities "lag behind" the added years of life experienced by many older adults (Riley, 1998). The structural lag hypothesis therefore emphasized what societies

can do to provide external resources through policies, services and programs to older adults in order to facilitate continued productivity and engagement (Kahn, 2002).

Second, Strawbridge and Wallhagen (2003) have criticized current conceptualizations for their failure to acknowledge and incorporate layperson perceptions and experiences of successful aging. For example, in a study by Strawbridge, Wallhagen and Cohen (2002) evaluating two definitions of successful aging, 50% of older adults rated themselves as aging successfully while only 19% met an operational definition of the criteria proposed by Rowe and Kahn (1997). In another study by von Faber and colleagues (2001), 81.5% of the subset of participants who took part in the qualitative interview felt they were aging successfully however, only 10% met the researcher's criteria of successful aging defined as a state of optimal overall functioning (physical, social, psycho-cognitive) and well-being. Participants generally viewed success as a process of adaptation, valuing well-being and social functioning more than physical and psycho-cognitive functioning (von Faber et al., 2001). Additional elements that have been identified by older adults themselves include: happiness; social relationships, support, activities and productivity; psychological resources, including personality, personal growth, accomplishments, sense of purpose, self-acceptance, coping, positive outlook, sense of humour; spirituality; lifestyles; and neighbourhood, financial circumstances and security (Bowling, 2007). Overall, studies comparing researcher and layperson definitions of successful aging have revealed that older individuals view the concept as multidimensional (Phelan et al., 2004; Bowling, 2007) and that while some overlap exists, certain elements of their definitions have been poorly captured by the

models of Rowe and Kahn and Baltes and Baltes (Depp, Vahia, & Jeste, 2010; Bowling, 2007; Bowling & Dieppe, 2005). Many argue that a greater incorporation of layperson perspectives into the framework of successful aging would allow for greater recognition of "the diversity of life trajectories and routes to aging successfully" (Bassett, 2007) and further help to alleviate concerns about the value and usefulness of the concept (Bowling, 2007; Phelan & Larson, 2002; Torres, 2003).

2.3 Conclusions

A theoretical framework is a conceptual model of a set of relationships among several factors or constructs that serves to facilitate understanding of a concept (Radhakrishna et al., 2007). This chapter introduced current theories of successful aging through a discussion of the perspectives of Rowe and Kahn (1987; 1997), Baltes and Baltes (1990), Riley (1998) and Strawbridge and Wallhagen (2003). Collectively, this theory emphasizes minimal risk of disease and disability and maintenance of physical, mental and social capacities; the process of adaptation to deterioration of these capacities; the influence of broader social structures; and the value of individual experiences of successful aging. These perspectives use a multicriterion approach to successful aging and also recognize the heterogeneity among older adults (Lupien & Wan, 2004). Given the interconnectedness among the various dimensions of aging, some experts agree that interdisciplinary perspectives are useful and should be viewed as complementary, rather than in competition with one another (Kahn, 2002; Glass, 2006; Bowling, 2007). A theoretical integration of these perspectives is therefore necessary to provide a more

comprehensive understanding of the key constructs and processes linked to successful aging (Bowling, 2007; Kahn, 2002; Phelan and Larson, 2002; Phelan et al., 2004; Inui, 2003).

CHAPTER 3: SYSTEMATIC SCOPING REVIEW OF EMPIRICAL STUDIES

This chapter presents the rationale, methodology and key findings of a scoping review of the published literature evaluating successful aging. The themes and indicators from the literature were analyzed in the context of theories of successful aging and, when possible, the findings of previously published reviews on the subject. The findings of this review were used to identify a list of potential indicators with which to explore the important elements of successful aging (objectives 2 and 3 of this thesis).

3.1 Rationale

Several published reviews have examined the diverse ways in which successful aging has been defined and operationalized in the research literature (e.g., Phelan & Larson, 2002; Peel, Bartlett & McClure, 2004; Bowling & Dieppe, 2005; Peel, McClure & Bartlett, 2005; Depp & Jeste, 2006; Bowling, 2007; Depp, Vahia & Jeste, 2010; Jeste, Depp & Vahia, 2010). These reviews evaluated studies that ranged from eight to 170 papers and varied in terms of the research question, review type, scope of inquiry and search strategy. The following components or domains of successful aging were identified: longevity, absence of disease, freedom from disability, independent functioning, good cognitive functioning, life satisfaction/well-being, mastery/growth, positive adaptation, personality traits, social/productive engagement, environmental factors, and layperson views of successful aging. The most common element defined in successful aging was independent functioning, defined more broadly as physical,

cognitive and social functioning (Phelan & Larson, 2002) or more specifically as a lack of dependency or need of assistance (Peel, McClure, & Bartlett, 2005). Similarly, physical functioning/disability was the only component to appear in more than half of the definitions examined by Depp and Jeste (2006). These previously published reviews were considered inadequate for use in the present research due to the limited number of terms used in the literature search; the limited number and type of databases searched; and insufficient methodological description of the search strategy.

In order to address the research question, *what are the indicators of successful aging in the published literature evaluating successful aging or a related concept in adults*, the decision was made to conduct a scoping review of the most recent literature. A scoping review may be undertaken "to clarify conceptual understanding of a topic where definitions are unclear or disputed" and/or "to map and make sense of the extent, range and nature of research undertaken in a particular area" (Anderson et al., 2008 supplementary file). As such, the focus tends to be on breadth of coverage whereas other traditional approaches to reviewing the literature tend to address both the depth and breadth of a research topic (Rumrill, Fitzgerald & Merchant, 2010). A scoping review may also be conducted systematically however unlike traditional systematic reviews they typically do not include an evaluation of the quality of the set of studies being considered (Rumrill, Fitzgerald & Merchant, 2010). Scoping reviews deviate from narrative reviews "in that the scoping process requires analytical reinterpretation of the literature" (Levac, Colquhoun & O'Brien, 2010). The present review followed the guidelines for conducting a scoping review outlined in the Arksey and O'Malley (2005) framework, as well as the

recommendations of Levac, Colquhoun and O'Brien (2010) which clarify and enhance this methodology. The five stages of this methodological framework include: identifying the research question; identifying relevant studies; study selection; charting the data; and collating, summarizing and reporting the results.

3.2 Methodology

A literature search strategy was developed after consultation with a professional research librarian, and applied to six electronic databases (MEDLINE, EMBASE, PsychINFO, CINAHL, Sociological Abstracts, AgeLine) on September 7th and 8th, 2010. These databases were selected to be comprehensive and covered a wide range of fields including medicine, nursing, psychology, sociology and gerontology. Six terms were entered as text words: "successful ag(e)ing", "healthy ag(e)ing", "optimal ag(e)ing", "active ag(e)ing", "productive ag(e)ing", and "ag(e)ing well". The complete search strategy is provided in Appendix A. Database searches covered the period from January 2000 to September 2010 and were restricted to English-language peer-reviewed citations. Books, book reviews, conference abstracts and proceedings, comments, letters, editorials, dissertations and case reports were excluded. The a priori inclusion criteria were: English language, peer-reviewed primary studies with an operational definition of successful aging in adults.

Web-based review software DistillerSR (Evidence Partners, Ottawa, Canada) was used to perform two levels of screening prior to data extraction. The first screening level consisted of a title and abstract scan. Full-text articles were then obtained for all relevant

papers for a more in-depth screen against the *a priori* inclusion criteria. As the goal of this review was to identify and summarize indicators of successful aging, only empirical studies providing an operational definition of successful aging were considered. Papers with a more specialized focus on the role of genetics[3], biology, physiology or immunology were excluded in an effort to keep the review focused on a manageable number of studies. Also beyond the scope of this review were qualitative studies on lay definitions of successful aging (n=117). Data extraction was performed on the final set of relevant studies.

3.3 Findings

The screening and selection process from start to finish is displayed in a flow diagram in Figure 3. A total of 5,435 papers were identified by the search strategy. After the removal of duplicated and excluded citations, 138 out of 2,450 papers satisfied the inclusion criteria. However, for feasibility reasons data extraction was performed only on the subset of papers published during the most recent five years (i.e., from January 2006 onward; n=63). Where possible, these findings were compared with those of previously published reviews on successful aging. Analysis of the included studies involved both a descriptive numerical summary and a thematic analysis of the data (Arksey & O'Malley, 2005).

[3]Although beyond the scope of this review, the contribution of genetic factors to successful aging is an emerging and important field of research. See Glatt et al. (2007) for a review of studies analyzing the influence of genes on multidimensional definitions of successful aging.

The characteristics of the 63 studies in this review are outlined in Appendix B, and include sample size, population characteristics, successful aging definitions and any associations with individual components of successful aging or composite definitions. Sample size ranged from 45 to 39,945 participants, however most included less than 1,000 adults. The majority of individuals were aged 60 and over, however some studies included adults in their fifties or younger while only one (Gondo et al, 2006) focused solely on centenarians. Most participants were females living in North America, Europe, or Asia. The majority of studies included community-dwelling adults, five included clinical populations (Cohen et al, 2009; Cooper et al., 2009; Knappe & Pinquart, 2009; Livingston et al., 2008; Warburton & Peel, 2008) and one was restricted to institutionalized persons (Ramage-Morin, 2006). Furthermore, most studies were cross-sectional and were derived from large population-based epidemiological investigations (e.g., Australian Longitudinal Study of Ageing, Cache County Memory Study, Canadian Community Health Survey, Canadian National Population Health Survey, English Longitudinal Study of Ageing, Health and Retirement Study, MacArthur Studies of Successful Aging, Singapore Longitudinal Aging Study, Whitehall II Study).

Three categories of operational definitions of successful aging were identified among the 63 studies. The most common type was a composite definition which met a set of criteria or indicators, while the second most common type consisted of the use of one or more individual indicators. A subjective rating of successful aging was the third and least frequently used type of definition. Appendix C lists the indicators that were extracted from operational definitions in this literature, grouped according to ten

dominant themes or categories: Well-being and Life Satisfaction; Physical Functioning and Ability; General Health Status; Social Functioning; Mental Status; Psychological Functioning; Self-rated Successful Aging; Risk Factors; Longevity; and Environment. The number of these themes or categories covered by any one operational definition ranged from one to six (mean 2.6 ± 1.7 SD) and the number of indicators from one to 27.

3.3.1 Well-being and Life Satisfaction

Thirty-five (55.6%) of the 63 studies included at least one indicator of well-being, life satisfaction or a related component in an operational definition of successful aging making it the only dimension to be included in over half of the studies reviewed. The proportion is greater than findings from previous reviews where between 17.3% (Bowling, 2007) and 31.0% (Depp & Jeste, 2006) of the literature included a well-being component. This theme was most commonly ascertained using life satisfaction, health-related quality of life, well-being, morale, affect or depression scales as indicators of successful aging. Some definitions included separate measures or subscales assessing both cognitive (e.g., life satisfaction, environmental mastery, autonomy) and emotional (e.g., positive/negative affect, depression) aspects of well-being. Further, an assessment of well-being was used as the only indicator of successful aging in ten studies (Cooper et al, 2009; Evans, 2009; Hsu, 2009; Jopp & Smith, 2006; Lawler-Row & Piferi, 2006; Lawler-Row, 2010; Litwin, 2006; Livingston et al., 2008; Wiesmann & Hannich, 2008; Woloski-Wruble et al., 2010). In general, well-being associated positively with social,

psychological and environmental factors as well as self-rated successful aging, and negatively with functional disability, affective symptoms and illness.

3.3.2 Physical Functioning and Ability

Twenty-nine studies (46.0%) included at least one indicator of physical functioning or ability in an operational definition of successful aging, compared to 89.7% of definitions in a previous review (Depp & Jeste, 2006). Physical functioning and ability was most commonly ascertained using activities of daily living (ADL) scales, including the Barthel Index and the Katz scale. Other measures included the Medical Outcomes Study (MOS) physical functioning instrument, the Short Form-36 survey physical functioning scale (ten items which are also contained in the MOS physical functioning measure), a subjective physical function rating in comparison to other individuals of the same age, and whether or not the individual was living independently. Overall, higher physical function associated positively with education, cognitive functioning, physical activity, environmental factors such as housing and income, self-reported health and self-rated successful aging, and negatively with physical and psychological resources and depression.

3.3.3 General Health Status

Twenty-six studies (41.3%) included one or more measures of general health status in an operational definition of successful aging. Specifically, 20 studies (31.7%)

assessed level of disease or impairment, while six (9.5%) assessed perceived health status (compared to 10.3% and 20.7%, respectively, in a 2006 review by Depp and Jeste). Level of disease or impairment was primarily assessed based on self-report of an absence of chronic conditions, and less often using a count of hospital admissions over a defined period of time (Engberg et al., 2009; Gilhooly et al., 2007). Cardiovascular disease, stroke, cancers, lung disease, Parkinson's disease, diabetes and vision and hearing were the most commonly considered conditions. Self-rated health was typically assessed using a single rating of subjective health. The majority of these studies categorized good/very good/excellent self-rated health as successful compared to fair/poor ratings. Overall, better general health status associated positively with positive reappraisal (i.e., finding positives under negative or challenging circumstances), parental lifespan, physical activity, engagement in productive activities and satisfaction with family relations, and negatively with neuroticism in midlife.

3.3.4 Social Functioning

Twenty-four studies (38.1%) included at least one indicator of social functioning in an operational definition of successful aging, compared to between 17.3% (Bowling, 2007) and 27.6% (Depp & Jeste, 2006) of the literature in two previous reviews. Analogous to Bowling's (2007) observations, these indicators varied greatly in their measurement (more so than the indicators of other domains) revealing a lack of standardization when it comes to deciding on definitions of the various social elements involved in successful aging. Measures of the social health of individuals were broad and

included frequency of social contact; social network size; quality of interpersonal relationships such as interpersonal trust; self-rated satisfaction with social support; engagement in productive activities such as hours of paid employment, caregiving or volunteering; leisure activities such as hours spent reading; and a sense of belonging to the community. In general, social functioning associated positively with personal income, self-reported health, resilience, cognitive functioning, physical functioning and affective resources, and negatively with functional limitations and depression.

3.3.5 Mental Status and Cognitive Functioning

Mental status or cognitive functioning was included in the definition of successful aging in 23 studies (36.5%) compared to 44.8% of the literature reviewed by Depp and Jeste (2006). These indicators were most often measured using global or domain specific neuropsychological tests, mainly the Mini-Mental State Exam (MMSE). Some definitions included measures of both test-based performance and subjective concerns about one's cognition (Cohen et al, 2009; Vahia et al., 2010). Factors shown to be associated with mental status and cognitive functioning included age, education, parental lifespan, social network/support factors, resilience and lifestyle behaviours such as physical activity and hobbies.

3.3.6 Psychological Functioning

Eleven studies (17.5%) included at least one indicator of psychological functioning or resources in an operational definition, compared to 10.7% of the literature reviewed by Bowling (2007). Indicators included measures of resilience, personality traits and resources, optimism, self-efficacy, personal mastery, purpose in life, health locus of control, perceived stress, coping strategies and psychosocial adjustment. In general, better psychological function was positively associated with self-reported successful aging and negatively associated with depression. However, numerous other studies included in this review treated such elements of psychological functioning (personality traits in particular) as predictors of successful aging rather than key components of the definition of successful aging.

3.3.7 Self-rated Successful Aging

Seven studies (11.1%) included self-rated successful aging as either a sole measure of successful aging (Ferri, James & Pruchno, 2009; Lee, 2009; Moore et al., 2007; Robson & Hansson, 2007) or in addition to other indicators (Lamond et al., 2009; Montross et al., 2006; Vahia et al., 2010), compared to 6.9% of the operational definitions reviewed by Depp and Jeste (2006). A subjective rating was most commonly obtained using a ten-point Likert scale ranging from least successful to most successful (Lamond et al., 2009, Montross et al., 2006; Moore et al., 2007; Vahia et al., 2010). Other methods include a sum score across eight items (Robson & Hansson, 2007), or categorization according to agreement with statements such as “Do you think your aging has been successful?” or “I am aging well” (Lee, 2009; Montross et al., 2006). Self-rated

successful aging was significantly associated with health-related quality of life, resilience, activity participation, number of close friends, cognitive functioning, social support, life satisfaction and subjective health.

3.3.8 Additional Indicators

Four studies (6.3%) included measures of risk factors in the definition of successful aging. These factors included smoking, body mass index, blood pressure, exercise, dental status, years of education and chronological age. However, a far greater number of studies identified in this review and others (see Peel, McClure & Bartlett, 2005) treated such measures as covariates or determinants of successful aging rather than key constituents.

Three studies (4.8%) included longevity in the definition of successful aging, compared to 13.8% of the literature reviewed by Depp and Jeste (2006). Indicators included: being alive at follow-up (Britton et al., 2008); reaching a certain age with good mental health status (Almeida et al., 2006); and high functioning after a period of five years (Habib, Nyberg & Nilsson, 2007). Conversely, two studies included parental longevity as a predictor of successful aging (Gjonca & Zaninotto, 2008; Tyas et al., 2007) while another study included longevity as an outcome (Gruenewald et al., 2007).

Financial or environmental indicators were included in the definition of successful aging in one study, similar to the 2006 findings of Jeste and Depp (n=2). These factors included gross annual income as well as perceived social capital items such as subjective ratings of area facilities and neighbourhood safety (Bowling & Iliffe, 2006). In this study

a multidimensional model consisting of biomedical, social, psychological and environmental indicators was used. Seniors who were classified as aging successfully, compared to those who were not, had over five times the odds of 'good' rather than 'not good' self-reported quality of life (odds ratio =5.5, 95% confidence interval: 2.7 to 11.4). The odds of 'good' versus 'not good' quality of life were lower for seniors who were classified as aging successfully using only a broad biomedical model, psychological model or social plus biomedical model (Bowling & Iliffe, 2006).

3.4 Discussion

The majority of operational definitions identified in this purposeful sample of the current empirical research (63/138) focused on aspects of well-being and life satisfaction (n=35/63 or 55.6%). Fewer definitions included indicators of physical functioning and ability (46.0%); general health status (41.3%); social functioning (38.1%); mental status and cognitive functioning (36.5%); psychological functioning (17.5%); self-rated successful aging (11.1%); risk factors (6.3%); longevity (4.8%); or the environment (1.6%). The multitude and variety of measures identified in this review highlight the need for a consensus on the definition and measurement of successful aging.

One important observation is that all studies were focused on individual indicators of successful aging. Other models such as Riley's Theory of Structural Lag (1998) emphasize the importance of society-level indicators of successful aging, in addition to individual-level indicators, for an adequate definition. For example, a recent study by Hsu and colleagues (2010) explored indicators of six dimensions of area-level successful

aging in Taiwan. In addition to health status, health lifestyle, health-care resources and utilization, and natural environment, other important dimensions included social participation (i.e., employment and productive activities, economic security, education, community development, volunteer) and social environment (i.e., safety, infrastructure) (Hsu et al., 2010). The neglect of society-level and environmental factors in operational definitions of successful aging is an important finding and significant gap in the current literature.

Several previously noted methodological issues (Depp & Jeste, 2006; Bowling, 2007) also remain, making it increasingly difficult to compare across studies and draw conclusions about the importance of these factors. For example, the determinants or outcomes investigated in many of the studies coincided with fundamental aspects of aging in others (e.g., absence of disability, self-rated health, psychological resources, physical resources). An important overall finding of this review is that researchers have treated measures of different indicators of successful aging as interchangeable and in doing so have neglected, or made assumptions about, the underlying latent structure of successful aging (Pruchno et al., 2010). Moreover, relatively few studies have used factor analysis techniques to explore the factor structure underlying potential indicators from the literature (Abbott et al., 2006; Kahng, 2008; Doyle et al., 2010; Pruchno et al., 2010).

Two-factor (Doyle et al., 2010; Pruchno et al., 2010), three-factor (Kahng, 2010) or four-factor (Abbott et al., 2006) models of successful aging were developed in four different studies using factor analysis techniques. Although each of the factor models included varying sets of indicators, all four included measures of physical functioning

(e.g., ability to walk a quarter mile, long-term disability, functional independence) while three models included measures of social functioning or engagement with life (e.g., participation in hobbies/social activities, social support, formal/informal social integration, paid/unpaid work). Two of the four models included measures of mental functioning, well-being or adaptability (Kahng, 2010; Abbott et al., 2006) while just one study included a subjective rating of successful aging (Pruchno et al., 2010).

Across models, indicators of physical functioning and social functioning consistently loaded onto separate factors, whereas indicators of physical functioning and disease or risk factors loaded on the same factor. Furthermore, measures of depression, self-efficacy and cognitive impairment in one study (Kahng, 2010) and measures of depression, pleasing appearance and tendency to worry in another (Abbott, 2006), all loaded on a separate factor from the indicators of physical or social functioning. Pruchno and colleagues (2010), on the other hand, suggested a two-factor model of "objective success" (e.g., measures of functional ability, pain, disease) and "subjective success" (e.g., aging well, successful aging, life ratings). Despite their differences, these models collectively suggest the possibility of at least two or three underlying factors of successful aging.

3.5 Summary

A review of existing literature aimed to combine a broad research question with a clearly articulated scope of inquiry. The challenge, as with many scoping reviews, was to balance the breadth and comprehensiveness of the review with feasibility of resources

(Levac, Colquhoun & O'Brien, 2010). The list of indicators extracted from the most recent set of studies covered a broad range of important elements of function and well-being. Overall, the results of this review corroborate several key findings of previous reviews, principally that there is a lack of consensus on the definition of successful aging and its measurement (Phelan & Larson, 2002; Peel, Bartlett & McClure, 2004; Bowling & Dieppe, 2005; Peel, McClure & Bartlett, 2005; Depp & Jeste, 2006; Bowling, 2007; Depp, Vahia & Jeste, 2010; Jeste, Depp & Vahia, 2010). Furthermore, researchers have treated indicators of successful aging as interchangeable and, in doing so, neglected or made assumptions about the underlying latent structure of successful aging.

CHAPTER 4: ANALYTICAL METHODS

This chapter presents the methodology and analytical techniques adopted to investigate the latent structure of successful aging using data from the Canadian Study of Health and Aging (CSHA). The chapter first examines details of the secondary data source, study samples, ethical considerations and variables of interest from the dataset. Analytical methods of model development and model validation are subsequently discussed.

4.1 Canadian Study of Health and Aging (CSHA)

The CSHA is a ten-year population-based cohort study which initially evaluated the prevalence and impact of cognitive impairment and dementia, and was later expanded to address a wide variety of other health questions (---, 1996). In 1991-1992, a representative sample of 10,263 Canadians (9,008 from the community and 1,255 from institutions) aged 65 and older were contacted (CSHA-1). Surviving respondents were re-contacted in 1996-1997 (CSHA-2) and again in 2001-2002 (CSHA-3) (CSHA Working Group, 2000). At each wave of data collection, progression through the components of the study (Screening Interview, Clinical Examination, Neuropsychological Assessment, Blood Collection, Caregiver/informant Interview) was determined by the results of certain previous assessments (e.g., the Clinical Examination was selectively undergone according to the results of a cognitive screening exam that was administered during the Screening Interview). The Screening Interview questionnaire was the starting

assessment for every participant at both CSHA-1 and CSHA-3, regardless of residence status. At CSHA-2, the Screening Interview was conducted with community dwelling respondents only, who had not been diagnosed with dementia at CSHA-1.

In CSHA-1, 36 urban and surrounding rural areas were sampled in ten Canadian provinces with equal representation from the Atlantic, Quebec, Ontario, Prairies and British Columbia regions (McDowell et al., 2001). An estimated 66% of Canadians aged 65 and older lived in the areas that were sampled (McDowell et al., 2001). The community sample frame was obtained via random selection from computerized records of provincial health insurance plans or, in Ontario, electoral and municipal records. The institutional sampling frame was developed from a comprehensive list of institutional dwellings, grouped by size (---, 1996). Specifically, a stratified random sample of institutions was drawn and residents were then sampled randomly from these institutions (see McDowell et al., 2001; ---, 1996). Older age groups were intentionally over-sampled using an optimal allocation technique[4]. The study exclusion criteria included: persons residing in the Yukon and Northwest Territories (as the numbers of elderly people living in those areas are very small and widely distributed), on Indian reserves or in military units; those with a life-threatening illness (e.g., a condition necessitating life support or terminal cancer); and persons non-fluent in either English or French (CSHA Working Group, 1994; ---, 1996).

[4] The sampling fraction in the 75 to 84 year age group was twice that in the 65 to 74 year age group; the fraction in the 85 year and older group was 2.5 times that in the 65 to 74 year age group (CSHA Working Group, 1994).

Of the 15,677 individuals who were eligible for the study, 10.5% (n=1651) could not be contacted at CSHA-1 (CSHA Working Group, 1994). Further, 26.8% (n=3763) of 14,026 contacted individuals refused to participate. The total representative sample of 10,263 Canadians aged 65 and over at CSHA-1 therefore reflected a 73.2% participation rate of all those who were eligible and could be contacted (CSHA Working Group, 1994). This rate was 72.1% for the 9,008 individuals in the community and 81.7% for the 1,255 individuals in institutions.

Of the 9,008 community-dwelling participants, 402 (4.5%) were diagnosed with dementia at CSHA-1, and 1,867 (20.7%) died between the first and second waves of the study. A further 128 (1.4%) could not be reached at CSHA-2 and 123 (1.4%) were inaccessible due to hospitalization or not being in the study area at the time of follow-up. Of the remaining 6,488 community-dwelling individuals who were eligible for the CSHA-2 Community Screening Interview, 587 (9.0%) refused to participate and 198 (3.1 %) were unable to participate due to illness or cognitive impairment. As such, 5,703 seniors participated in the CSHA-2 Community Screening Interview.

A total of 5,490 individuals (53.5% of the original CSHA-1 sample of 10,263) were included in the third and final wave of the study. Of these, 1,600 (29.1%) were deceased (specifically, 1,598 had died prior to the first CSHA-3 contact, and two were known dead at CSHA-2 but contact had not been made with a relative at the time); 78 (1.4%) could not be contacted; 56 (1.0%) were inaccessible; 13 (0.2%) had undergone a previous CSHA Clinical Exam but were not screened at CSHA-3; 77 (1.4%) were unable to be screened; and 332 (6.0%) refused to participate. The remaining 3,334 participants

took part in the CSHA-3 Screening Interview; a subset (n=2,884) of these individuals were used in this thesis, as described below.

4.1.1 Study Sample

Although some indicators of successful aging were available in the early waves of the study, the CSHA-3 Screening Interview was found to be most suitable for selecting measures of successful aging according to the wide range of indicators identified in a systematic scoping review (see Chapter Three). However, it should be emphasized that because CSHA-3 was a ten year follow-up of the original study sample, it was no longer a representative sample of the population but rather a sample of survivors (Kristjansson, Karam, & McDowell, 2003). Further, all seniors involved in CSHA-3 were a minimum of 75 years of age. A discussion of the implications of this on the generalizability of the findings is presented in Chapter Six (section 6.2).

All participants who were not diagnosed with dementia at CSHA-2, and were awake, alert and able to hear, were first assessed at CSHA-3 with the introductory Screening Interview (n=3,334). This face-to-face interview was conducted by a trained examiner and included questions about demographic information, social network and social support, functional ability and general health status, as well as the Modified Mini-Mental State Exam or 3MS (a screening test for cognitive impairment). Additional questions covering various aspects of successful aging, including absence of diseases, engagement with life and subjective well-being, were included to form the Successful Aging Substudy. Following Rowe and Kahn's (1998) Model of Successful Aging,

successful aging was conceptualized by CSHA investigators as being physically and mentally healthy and engaged with life, which "implies good relationships with other people and behaviour that is productive" (Kristjansson, Karam, & McDowell, 2003). The investigators broadened the Rowe-Kahn approach by adding subjective well-being, rationalizing that "it is difficult to envision successful aging without a high level of happiness or life satisfaction" (Kristjansson, Karam, & McDowell, 2003).

Some of the questions from the Successful Aging Substudy, in particular those measuring psychological aspects of aging, were not suitable for "severely cognitively impaired" participants (---, 1996). Given the questionable validity of responses from such cases, the scales and items of the Successful Aging Substudy (comprising the latter portion of the CSHA-3 Screening Interview) were not administered to 448 individuals in the community sample who performed poorly on two questions from the Modified Mini-Mental State Exam or 3MS exam, i.e. a score of <12 on Question 5 (temporal orientation) or a score of <2 on Question 15 (second recall) (---, 1996). Two additional respondents did not complete the Substudy due to severe physical impairment or reluctance to spend time on the interview. This thesis used data on the remaining 2,884 community-dwelling respondents who completed the Screening Interview and Successful Aging Substudy at CSHA-3.

4.1.2 Ethical Considerations

All CSHA participants provided written consent at the beginning of each interview and component at each wave of the study. Prior to the Screening Interview, all

participants were informed of the content and purpose of the Interview and a signed consent was obtained of which the participant received a personal copy (---, 1996). If during this Interview the respondent received a score of <65 on the 3MS exam, supporting consent was sought from a relative (e.g., spouse, son or daughter) or occasionally a non-relative (e.g., caregiver) (---, 1996). Because the present research used only secondary data analysis and posed no risk to the participants, further consent from individual participants was not required. All data accessed for this thesis were in de-identifiable format and handled in strict accordance with the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans (---, 2010).

4.1.3 Selection and Construction of Indicators

A number of measures from CSHA-3 were selected to explore the underlying factor structure of successful aging. As with any secondary data analysis, these items were chosen from among an existing set of variables and therefore were constrained by the information that was previously collected. The selection of variables from the dataset was guided by the findings of the systematic scoping review of the literature evaluating successful aging. This was done in order to help minimize bias from the omission of important indicators. The majority of measures in the CSHA-3 also had well-established psychometric properties which helped to minimize bias from measurement error (Kline, 2005). One of the assumptions of factor analysis is that variable scores fall on an interval scale. However, ordinal data from a Likert scale is commonly considered quasi-interval and can be used under the following three conditions: the sample size is reasonably large

(>1000 in this case); the number of Likert categories is four or higher; and skew and kurtosis are within normal limits (Garson, 2011). The inclusion of dichotomous variables in factor analysis tends to introduce "difficulty factors" that are "due only to variation in endorsement rates across items and not to the underlying construct" (Floyd & Widaman, 1995). Therefore only variables with scores that fell on interval or quasi-interval (e.g., Likert-type) scales were considered in the analysis.

The measurement characteristics and properties of 16 variables as possible indicators of successful aging are described below under the following headings: Short Happiness and Affect Research Protocol (SHARP); Clinical Epidemiologic Studies of Depression (CESD-10); Health-related Quality of Life (HRQL); Common Health Problems; Activities of Daily Living (ADL); Modified-Mini Mental State Exam (3MS); Social Network and Supportive Ties; and Engagement With Life. Each section includes empirical justification for inclusion, i.e. how these variables map onto the elements identified in the scoping review; known aspects of the validity and reliability of the measurements; and clarification of whether the indicators were singe items, total scores or another scale measure (Boomsma, 2000).

4.1.3.1 Short Happiness and Affect Research Protocol (SHARP)

In line with the viewpoint of Strawbridge and Wallhagen (2003), several indicators of well-being were identified in the published literature evaluating successful aging (see Appendix C). Subjective well-being was measured in the CSHA-3 using the Short Happiness and Affect Research Protocol or SHARP (Stones et al., 1996), a short

version of the Memorial University of Newfoundland Scale of Happiness or MUNSH (Kozma & Stones, 1980). To maintain content validity, the SHARP includes the twelve MUNSH items with the highest correlations with self-rated happiness, while remaining balanced with respect to the four areas of content: positive affect, negative affect, long-term happiness, and long-term unhappiness (Stones et al., 1996). The SHARP has been shown to correlate repeatedly with the MUNSH at $r > 0.9$ (Stones et al., 1996). CSHA-3 respondents answered "yes" or "no" to twelve questions, which were then scored according to the method outlined by Stones and colleagues (1996) whereby affirmative responses are given a score of 1 for items 1, 2, 6, 7, 8 and 12, and -1 for the remaining items (negative responses or items left blank are scored 0). The summary score reflects a total of the positive and negative items and ranges from a maximum of +6 to a minimum of –6.

4.1.3.2 Center for Epidemiologic Studies Depression Scale (CESD-10)

Indicators of emotional well-being were also identified in the published literature evaluating successful aging (see Appendix C). The CSHA measured depressive symptoms using a short form of the Center for Epidemiological Studies Depression Scale (CES-D) for older persons, referred to as the CESD-10 (Radloff, 1977). This short form has close agreement with the full-length version ($\kappa = 0.97$) and a test-retest reliability of 0.71 (see Andresen et al., 1994). The CESD-10 measures short-term depression and includes ten items covering the frequency of several symptoms of depression in the

preceding week, each rated on a four-point scale. The maximum total score is 30, with higher scores indicating greater depressive symptoms.

4.1.3.3 Health-related Quality of Life (HRQL)

Measures of subjective health and physical and mental health-related quality of life (HRQL) and were identified as possible indicators of successful aging in the empirical literature (see Appendix C). The CSHA-3 Screening Interview included four general health questions as a short measure of HRQL. These questions are from the U.S. Behavior Risk Factor Surveillance System's HRQL Survey Tool (Hennessy, 1994) and have been previously validated in a sample of older Canadian adults (see Ounpuu, 2000). Perceived Health Status was assessed using a single rating on a five-point scale ranging from 1-'very good' to 5-'very poor'. Recent Physical Health (pHRQL) was measured by self-report of the number of days in the past 30 days when physical health (including physical illness, injury) was not good. Recent Mental Health (mHRQL) was measured by self-report of the number of days in past 30 days when mental health (including stress, depression, and problems with emotions) was not good. Separate items assessing recent physical and mental health were included in order to "distinguish periods when a person may be experiencing excellent physical health but poor mental health" and vice versa (Hennessy, 1994). Finally, Recent Activity Limitation (aHRQL) was measured by self-report of the number of days in past 30 days when poor physical or mental health kept them the respondent from doing their usual activities such as self-care, work or recreation.

4.1.3.4 Common Health Problems

To determine comorbid health condition status, CSHA-3 respondents were asked if they had any of 16 common health problems during the previous year, most of which were drawn from the Manitoba Study entitled "Living Arrangements and Primary Care - Their Relevance for Health Care" (Kristjansson, Karam & McDowell, 2003). The health conditions identified in the scoping review of the empirical literature were used to guide the selection of relevant health problems from the conditions inquired about in the Screening Interview. Affirmative responses to the nine most commonly observed indicators in the literature were used to derive a new count variable that reflected: high blood pressure (whether controlled by medication or not); heart or circulation problems (hardening of the arteries, heart troubles, or other blood diseases); stroke or effects of stroke; Parkinson's disease or other neurological problems; eye trouble not relieved by glasses (cataracts, glaucoma); ear trouble (hearing loss); chest problems (asthma, pneumonia, TB, emphysema, bronchitis, breathing problems); cancers; and/or diabetes.

4.1.3.5 Activities of Daily Living (ADL)

Indicators of functional ability were frequently included in definitions of successful aging in the empirical literature. Fourteen questions on self-reported ADL, taken from the Older Americans Resources and Services (OARS) multidimensional functional assessment questionnaire (Fillenbaum & Smyer, 1981), were included in the

CHSA-3 Screening Interview. These questions served as a subjective measure of disability at the time of evaluation, and tested the capability of doing the activity and not whether or not the activity was ever performed. Seven of the 14 questions probed basic or personal ADL (PADL) and included: eating, dressing, taking care of appearance, walking, getting in and out of bed, taking a bath or shower and toileting. The remaining seven questions probed higher level or instrumental ADL (IADL) and included: telephoning, getting to places out of walking distance, shopping, preparing meals, housework, taking medicine and handling money. For each question, respondents were asked whether they could do the activity without any help (score = 2), with some help (including the use of assistive devices; score = 1), or not at all (score = 0). In a factor analysis performed by Fillenbaum (1988), the PADL and IADL items were found to load onto two separate factors, suggesting that IADL items reflect higher levels of function than PADL items. Accordingly, two separate scores were created by summing the scores on the seven PADL items and seven IADL items, respectively. These summary scores range from 0 to14 for both measures, with high scores reflecting greater independence. However, it should be noted that subsequent transformation of the PADL score and IADL score variables resulted in reverse scoring of the original variables so that higher scores reflected worse independence (see Chapter Five, section 5.1).

4.1.3.6 Modified Mini-Mental State Exam (3MS)

The Modified Mini-Mental State Exam or 3MS (Teng & Chui, 1987) was used in the CSHA-3 as a screening tool for cognitive impairment and dementia. The 3MS is an

extended version of the Mini-Mental State Exam or MMSE (Folstein, Folstein & McHugh, 1975) which was frequently used as an indicator of mental status in the empirical literature evaluating successful aging (see Appendix C). Compared to the MMSE, the 3MS consists of an additional four items (date and place of birth, word fluency, similarities and delayed recall of words) and a modified scoring procedure. As a result, the 3MS exam appears to be more sensitive than the MMSE; in a direct comparison of the two measures, by McDowell and colleagues (1997), the 3MS was found to perform better as a community screening tool for dementia. Total test scores range from 0 to 100, with high scores indicating higher cognitive function.

4.1.3.7 Social Network and Supportive Ties

Both successful aging theory (e.g., Rowe & Kahn, 1997) and the empirical literature reviewed in the scoping review suggest the importance of a supportive social network for successful aging. Social circumstances were assessed in the CSHA-3 by asking respondents to indicate the number of individuals they can count on for help in time of need, and also the number of people they spend time with on a regular basis (i.e., at least once a month). These variables are referred to as "Supportive Ties" and "Social Network", respectively. The maximum response coded for both was capped at ten by study investigators, meaning that respondents who reported exactly ten individuals were not differentiated from those who reported more than ten. Both measures cover the quantity of social and supportive ties, but not necessarily the quality of these ties.

4.1.3.8 Engagement with Life

Both successful aging theory (e.g., Rowe & Kahn, 1997) and the empirical literature suggest that engagement with life is important to the definition of successful aging. Respondents' level of engagement with life was assessed with four open-ended items (so as to not miss any activities that were important to the respondent) inquiring about activities and interests during the past year (Kristjansson, Karam, & McDowell, 2003). The questions covered all four seasons for all respondents (Kristjansson, Karam, & McDowell, 2003). The following four activity domains were covered: "Personal Hobbies" or crafts, such as woodworking, knitting or sewing; "Physical Activities/ Exercise", such as walking, swimming, sport or working in the yard; "Group Activities", such as going to clubs, church or community centers, playing cards; and "Helping Others", such as family and friends or volunteering. Four separate variables were created to represent a count of all appropriate activities recorded by study personnel under each domain. The maximum number of activities mentioned by any one respondent was capped by study investigators at five for the Personal Hobbies and Helping Others variables, and at six for the Physical Activities/Exercise and Group Activities variables.

4.1.4 Demographic Variables

Four demographic variables were considered in order to provide a description of the characteristics of the samples: age, sex, years of education, and the language (English or French) used to complete the CSHA-3 Screening Interview.

4.2 Analytic Approach

The underlying constructs of 16 indicators of successful aging from the CSHA-3 dataset were explored using common factor analysis and SEM. The goal of this analysis was to understand patterns of correlations among the set of variables and to explain as much of their variance as possible with a model that: (i) shows face validity with theoretical frameworks for successful aging; and (ii) has reasonable statistical correspondence to the data (Kline, 2005). All statistical analyses were performed using SPSS version 18 for Windows (Rel. 18.0.0. 2009, Chicago: SPSS Inc) and the AMOS version 19 modelling tool.

4.2.1 Assumptions of Factor Analysis

The factor analysis literature identifies a variety of different rules of thumb for determining an adequate sample size (Guadagnoli & Velicer, 1988). One such rule is having ten to 20 times as many subjects as indicators (Garson, 2011a); with 16 variables in the present analysis, this gives 20*16 or 320 subjects. Another recommendation, as described in the CSHA-3 Protocol, is to use a minimum sample size for reliable estimates of three to five times the formula: k (k + 1)/2, where k is the number of variables in the covariance matrix. In the present analysis, the covariance matrix is calculated from, at most, 16 variables giving a suggested sample size of 5*[(16*17)/2] or 680 subjects. Many of these rules of thumb however, lack both theoretical rationale and empirical

support (Guadagnoli & Velicer, 1988; Streiner & Norman, 2008). For example, Guadagnoli and Velicer (1988) conducted a Monte Carlo procedure to examine the relationship between sample sizes of 50 up to 1,000 cases and the stability of the sample solution. Surprisingly, their findings suggested that absolute sample size and component saturation (i.e., the magnitude of component loadings) were the most important factors, and not sample size as a function of the number of variables. Also important, albeit to a lesser degree, was the number of variables per component; the more variables defining a component, the more stable the results (Guadagnoli & Velicer, 1988). Experts in the field also recommend using a larger sample size when other assumptions of factor analysis are not met, for example the data are skewed, kurtotic or incomplete (Garson, 2011a).

Based on the findings and recommendations above, the sample size of 2,884 CSHA-3 respondents was considered sufficient to address the objectives of this thesis. Specifically, this sample was large enough to be split in half so that part of the data could to be used for model development and the remaining part of the data for model validation. An approximate 50% random sample of cases was generated from the entire sample using the Select Cases option offered in SPSS. Each independent subsample was likely large enough to also allow for the deletion of subjects with missing variables.

Descriptive statistics for the variables were calculated for the entire sample as well as the two independent samples being compared. Independent t-tests were conducted to determine whether there were statistically significant mean differences on any of the demographic or model variables among the two subsamples. A Bonferroni-adjusted alpha level of .05/16 coefficients or .001 was specified in order to minimize the

likelihood of a Type I error as a result of multiple comparisons. Descriptive statistics were also used to investigate the assumption of normality; boxplots and measures of skewness and kurtosis were calculated to examine the distribution of each model variable in the analysis. While common factor analysis has no distributional assumptions, significance testing using SEM maximum likelihood (ML) estimation assumes multivariate normal distribution of the indicators. Variables with severe non-normal distributions were log-transformed using the formula: *Log10(x)* for positively skewed variables; and the formula: *Log10(y - x)* for negatively skewed variables, where *y* is one plus the maximum score for that variable. A constant of one was added to *x* when the variable contained zero (Streiner & Norman, 2008).

Finally, the frequency of missing values for all variables was generated to investigate potential for bias in the dataset due to large numbers of missing values. Listwise deletion, or complete case analysis, was selected to avoid having different sample sizes for different calculations, such as correlation coefficients (Garson, 2010).

4.2.2 Model Development

4.2.2.1 Common Factor Analysis

One of the exploratory uses of factor analysis is to understand the relations among a set of measured variables in terms of underlying constructs, using the common or principal factor analysis approach (Floyd & Widaman, 1995). This approach uses the principal axes method of estimating factors from the correlation matrix of measured

variables, to extract factors that account for maximum variance in the set of observed variables (Floyd & Widaman, 1995). The *a priori* assumption of this exploratory factor analysis was that any indicator may be associated with any factor. This was because the factor loadings were needed to intuit the factor structure of the data. Therefore, at the same time, this approach tested whether or not a single-factor model should be rejected in favour of a multi-factor model (Kline, 2005).

The suitability of performing a factor analysis was examined using Bartlett's test of sphericity, to test whether the correlations in the correlation matrix were greater than zero, and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. KMO values that exceed .6 are considered necessary for good factor analysis (Garson, 2010b). The factor solution that generated the most comprehensible factor structure (i.e., had face validity with current theoretical frameworks of successful aging) was selected from those suggested by both the Kaiser-Guttman criterion and the Cattell Scree Test plot. The Kaiser-Guttman criterion is to ignore all factors with eigenvalues <1.00. The Cattell Scree Test plots the eigenvalues (y-axis) against the factors (x-axis) and suggests retaining all factors up to and including the one starting the "elbow" in the curve toward less steep decline. The factors beyond these are ignored as they account for small amounts of the total variance (Garson, 2010b). Orthogonal varimax rotation was applied to the retained factors. This rotation keeps factors uncorrelated, and was used to minimize the number of variables that loaded highly on a factor and thus enhance factor interpretability (Floyd & Widaman, 1995). Minimum cut-off scores for considering a

variable as a defining part of a factor are somewhat arbitrary but, in line with common practice, this thesis used a minimum loading of.30 (Garson, 2010b).

4.2.2.2 Structural Equation Modelling (SEM)

The variables hypothesized to measure the underlying constructs of successful aging were expressed in terms of a measurement model. SEM with maximum likelihood (ML) estimation was used to test the fit of the specified model with the observed covariance structure of the measured variables (Floyd & Widaman, 1995). SEM was selected over other methods of analysis concerned with inter-correlations among observed variables, such as multiple regression techniques, because it differentiates between observed variables and latent variables, accommodates multiple-indicator measurement and takes into account measurement error in the observed variables (Kline, 2005). Moreover, SEM allows the evaluation of an entire model which "brings a higher-level perspective to the analysis" (Kline, 2005).

The following specifications were added to the conceptual model prior to ML estimation. First, each latent construct was considered an exogenous variable and allowed to covary with every other latent construct (i.e., connected by a curved, two-headed arrow) (Kline, 2005). Second, arrows pointing from measurement error terms to the indicators were added to represent the direct effects of all unmeasured sources of unique variance on the indicators (Kline, 2005). Third, the latent variables were scaled indirectly by fixing the unstandardized loadings of one variable per factor at 1.00 (Kline, 2005). To simplify the analysis, each indicator was assumed to measure only one

construct and the evaluation of such a model provided a specific test of convergent and discriminant validity. For example, high standardized factor loadings for each set of indicators would suggest that the model has convergent validity, and moderate to low factor correlations would suggest that the model has discriminant validity (Kline, 2005).

Following the recommendations of others (e.g., Kline, 2005; Schumacker & Lomax, 2004; McDonald & Ho, 2002; Boomsma, 2000; Garson, 2011a), four different goodness-of-fit indexes were considered: model chi-square (CMIN); Bentler's Comparative Fit Index (CFI; Bentler, 1990); Tucker-Lewis Index (TLI; Tucker & Lewis, 1973) also known as Non-Normed Fit Index (NNFI); and Root Mean Squared Error of Approximation (RMSEA; Steiger, 1990). Good fit is indicated by a chi-square p-value of >.05, signifying that the given model's covariance structure is not significantly different from the observed covariance matrix (Garson, 2011a). However, because this measure is sensitive to large sample sizes and prone to Type II error or rejecting a model that is true, a significant p-value was expected. One option is to use the normed chi-square which is calculated by dividing the CMIN value by the degrees of freedom (Kline, 2005). Normed chi-square values of 2.0 up to 5.0 have been recommended as indicating reasonable fit (Bollen, 1989). Others argue that the significance of the model chi-square test may be "discounted" if good approximate fit is indicated by other fit tests such as CFI, TLI and RMSEA, which are among the measures least affected by sample size (Garson, 2011a). Both the CFI and TLI indexes compare the given model with a null or baseline independence model where the correlations among the observed variables are constrained

to be zero (Kline, 2005)[5]. By convention CFI should be >.90 to suggest reasonably good fit (Hu & Bentler, 1999), indicating that greater than "90% of the covariation in the data can be reproduced by the given model" (Garson, 2011a). TLI values ≥.95 indicate good fit, whereas values <.90 indicate a need to respecify the model (Hu & Bentler, 1999). The RMSEA goodness-of-fit test, on the other hand, is a parsimony-adjusted index that corrects for model complexity or penalizes for lack of parsimony (Kline, 2005; Garson, 2011a). A rule of thumb is that RMSEA ≤.05 indicates close fit of the model in relation to the degrees of freedom, while values >.05 to <.08 suggest moderate fit. Further, a lower 90% confidence limit of, or very close to, zero and an upper limit of >.08, indicates a close fit of the model (Browne & Cudeck, 1993). There is widespread agreement that RMSEA values ≥.10 indicate poor fit (Browne & Cudeck, 1993; Garson, 2011a).

Modifications to the measurement model were exploratory and made one at a time in the form of removal of poor-performing indicators (e.g., low factor loading) until a theoretically meaningful and statistically acceptable model was found. The modelling of error in SEM requires that there be more than one measure of each factor. As such, factors with only a single significant loading were dropped from the analysis (Floyd & Widaman, 1995).

4.2.3 Model Validation

[5] However, such comparative fit indexes have been "criticized when the baseline model is the independence model... because the assumption of zero covariances is scientifically implausible in many (probably most) applications of SEM" (Kline, 2005).

The third and final objective of this thesis was to examine the split-half reliability and stability of the constructs in the final model. Because modifications to the measurement model were done in an exploratory manner, it was important to further consider whether the subsequent fit results were likely due to chance rather than to true improvements to the model (Boomsma, 2000). Cudeck and Browne (1983) developed a cross-validation procedure for use in SEM with latent variables when a new data sample is not available. Under this strategy, the original sample of 2,884 CSHA-3 participants was randomly split into two independent subsamples of approximately equal size to form a *calibration* sample (n=1,446) and a *validation* sample (n=1,438). Model development, using common factor analysis and SEM as previously described, was done using the calibration subsample only. This allowed the reliability and stability of the final constructs to be explored with SEM, using data other than those on which the model was developed. The reliability of the final model was determined by comparing the magnitude of the model fit statistics and measurement parameters of the validation sample with those of the calibration sample.

CHAPTER 5: DATA ANALYSIS AND RESULTS

This chapter begins by presenting a summary of the descriptive statistics of the entire sample and subsamples. This is followed by details of the five latent constructs emerging from the data; modifications made to the hypothesized model to form a four-factor measurement model; and indices of model fit for each of the independent samples.

5.1 Sample Characteristics

Summary descriptive statistics of the demographic and model variables for the entire sample and calibration and validation subsamples are displayed in Table 1. Independent t-tests revealed no statistically significant mean differences on any of the variables among the two independent subsamples. Examination of skewness and kurtosis indicated that the values of four model variables were not normally distributed and were subsequently log-transformed. Specifically, in both subsamples the PADL score and IADL score variables were highly negatively skewed while the Recent Mental Health (mHRQL) and Recent Activity Limitation (aHRQL) variables were highly positively skewed. Log transformations improved the distributions of these variables so that they were within, or at least much closer to, the range of normal distribution which is typically the range of +/-1.0 up to +/-3.0 (Garson, 2011a). As previously described in section 4.2.1, the formula [*Log10(y - x)*] used to transform the PADL score and IADL score variables resulted in reverse scoring of the original variables in that higher scores indicated worse independence.

Age ranged from 75 to 102 years with a mean of 82.0 (5.1 SD) years for the calibration subsample and 82.2 (5.1 SD) years for the validation subsample. Approximately 64.1% of the calibration subsample compared to 60.6% of the validation subsample was female. The number of years of education ranged from 0 to 33 with a mean of 10.9 (3.8 SD) years for both subsamples, and 80.6% (calibration subsample) compared to 82.1% (validation subsample) of respondents chose to complete the Screening Interview in English. The scores on the 3MS ranged from 57 to100 with a mean score of 88.8 (7.9 SD) for the calibration subsample compared to 88.9 (7.7 SD) for the validation subsample. In terms of physical functioning, PADL scores ranged from 1 to 14 with a mean of 13.6 (1.1 SD) for the calibration subsample compared to 13.6 (3.4 SD) for the validation subsample. IADL scores ranged from 0 to 14 with a mean of 12.8 for both the calibration (2.1 SD) and validation (1.1 SD) subsamples. The number of reported comorbid health conditions ranged from 0 to 7 with a mean of 1.9 (1.3 SD) for both subsamples. Further, the majority of seniors (84.9% for the calibration subsample and 83.9% for the validation subsample) rated their health as *very good* or *pretty good* on a five-point scale. On other HRQL questions, respondents in the calibration subsample compared to the validation subsample reported a mean of 4.9 (9.2 SD) compared to 4.7 (9.2 SD) days of poor physical health symptoms; 2.3 (6.5 SD) compared to 2.5 (6.8 SD) days of poor mental health symptoms; and 2.6 (6.8 SD) compared to 2.5 (6.8 SD) days when poor physical and mental health kept them from doing their usual activities. SHARP scores ranged from -6 to +6 with a mean score of 3.9 (2.2 SD) and 4.0 (2.3 SD) for the calibration and validation subsamples, respectively. CESD-10 scores ranged from

0 to 30 with a mean score of 4.5 for both the calibration (4.7 SD) and validation (4.8 SD) subsamples. In terms of social functioning, respondents in the calibration subsample compared to the validation subsample reported spending time with a mean of 6.3 (3.4 SD) compared to 6.0 (3.4 SD) individuals on a regular basis; and being able to count on a mean of 4.0 (2.6 SD) compared to 3.8 (2.5 SD) individuals for help in time of need. Finally, the mean number of activities and interests performed in the past year for the calibration subsample compared to the validation subsample were 1.3 (1.1 SD) compared to 1.2 (1.1 SD) for personal hobbies; 0.6 (0.8 SD) compared to 0.7 (0.8 SD) for helping others; 1.3 (1.1 SD) compared to 1.2 (1.1 SD) for group activities; and 1.5 (1.1 SD) compared to 1.4 (1.1 SD) for physical activities.

5.2 Model Development

Due to missing data in 99 cases (6.8%), model development was conducted using data from 1,347 out of 1,446 respondents from the calibration subsample.

5.2.1 Common Factor Analysis

The suitability of performing a factor analysis was supported both by Bartlett's test of sphericity, χ^2=5139.95 (df=120, p <.001), and by a KMO value of .82. The bivariate correlations among the 16 observed variables are shown in the lower left diagonal of Table 2. For the most part variables were not highly correlated, although moderate correlations existed between the following: PADL score and IADL score

(r=.62); pHRQL and aHRQL (r=.63); and CESD-10 score and SHAPR score (r=-.68). As would be expected, both variables in each of the pairs loaded on the same factor (discussed later).

The Kaiser-Guttman criterion suggested a four-factor solution (see the first four factors in Table 3) whereas examination of the Cattell Scree Test plot suggested a five-factor solution (see Figure 4). The difference between the two solutions was that the 3MS score and Personal Hobbies variables had factor loadings of less than .30 in the four-factors solution, but had acceptable loadings on a fifth factor in the five-factor solution. After examination of the theoretical meaningfulness of both solutions, the five-factor solution was maintained. The five factors explained just over 58% of variance in the data (Table 3).

The factor loadings with varimax rotation are displayed in Table 4. The first three items, namely CESD-10 score (.79), SHARP score (-.71) and Recent Mental Health (.58), loaded strongest on the first factor and were conceptually related to perceived well-being. The next three items, IADL score (.84), PADL score (.66) and Physical Activities/Exercise (-.41), loaded on the second factor and were related to physical ability. Three items related to general health, namely Recent Physical Health (.80), Recent Activity Limitation (.66) and Perceived Health Status (.36), loaded strongest on factor three. The fourth factor contained four items related to social functioning: Social Network (.62), Group Activities (.43), Supportive Ties (.42) and Helping Others (.36). Finally, the fifth factor contained two items possibly related to cognitive functioning: 3MS score (.61) and Personal Hobbies (.42). The Comorbid Health Conditions variable

failed to meet the minimum cut-off score of .30 for considering a variable as a defining part of a factor. Examination of the variable's factor loadings suggested that it belonged with either factor two (Physical Ability) with a loading of .27, or factor three (General Health Status) with a loading of .20. Further examination of the correlation matrix indicated that it was most correlated with the Perceived Health Status variable (r=.34) which loaded on factor three, followed by IADL score (r=.26) which loaded on factor two. The addition of the Comorbid Health Conditions variable to the General Health Status factor as a measure of comorbidity made sense theoretically and so the decision was made to retain the indicator as such. The conceptual model is presented in Figure 5 and includes the 16 observed variables (rectangles) and five latent constructs (ellipses).

5.2.2 Structural Equation Modelling: Measurement Model

The parameter estimates for the hypothesized five-factor model are reported in Table 5, including factor loadings, squared multiple correlations and factor covariances. All unstandardized estimates were significantly different from zero ($p < .001$). Reasonable divergent validity was indicated by moderate to low correlations (from -.32 to .64) between factors. However, nine out of 16 indicators had standardized correlations of less than .50, indicating poor convergent validity (Kline, 2005). Overall, the model explained approximately 42% of variance and indicated an acceptable fit: the CMIN value was 481 (degrees of freedom=94, $p < .0001$), the CFI value was .932, the TLI value was .901, and the RMSEA value was .053 (90% confidence interval .049 to .058).

The following modifications were made to improve the performance of the model. Three indicators (Comorbid Health Status, Supportive Ties, Personal Hobbies) were removed from the model one at a time because of both convergence problems (squared correlation=.12 to .17) and low factor loadings (β=.35 to .42). The removal of the Personal Hobbies variable resulted in removal of the entire fifth factor, including the 3MS score, in order to avoid including a factor with only one variable (Bollen, 1989). Fit statistics of the conceptual model and all subsequent models are presented in Table 6 for comparison.

The final measurement model, consisting of four latent constructs (rather than the hypothesized five) and 12 indicators from 16, explained approximately 47% of variation and had an acceptable fit to the data. The CMIN value was 259 (degrees of freedom=48, $p < .0001$), the CFI value was .957, the TLI value was .930, and the RMSEA value was .055 (90% confidence interval .049 to .062) for the final fitted model. The revised parameter estimates are reported in Table 7 and include factor loadings, squared multiple correlations and factor covariances. All factor loadings were substantial (i.e., >.400) and significantly different from zero ($p < .001$).

As shown in Figure 6, the final model explained approximately 78% of variance in CESD-10 score, 63% of variance in SHARP score and 35% of variance in Recent Mental Health. CESD-10 score (β=.88, $p < .001$) was most strongly associated with the Perceived Well-being construct, followed by SHARP score (β=-.79, $p<.001$) and mHRQL (β=.59, $p<.001$). Next, approximately 76% of variance in IADL score, 52% of variance in PADL score and 23% of variance in Physical Activities/Exercise were explained by the

model. IADL score (β=.87, p<.001) was most strongly associated with the Physical Ability construct, followed by PADL score (β=.72, p<.001) and Physical Activities (β=-.48, p<.001). Further, the model explained approximately 66% of variance in Recent Physical Health, 58% of variance in Recent Activity Limitation and 34% of variance in Perceived Health Status for the General Health Status construct. pHRQL (β=.81, p<.001) was most strongly associated with this construct, followed by aHRQL (β=.76, p<.001) and Perceived Health Status (β=.58, p<.001). Finally, approximately 31% of variance in Social Network and 23% of variance in both of Group Activities and Helping Others were explained by the four-factor model. The Social Network variable (β=.56, p<.001) was most strongly associated with the Social Functioning construct, followed by Group Activities and Helping Others (β=.48, p<.001 for both).

5.3 Cross-Validation

Due to missing data in 101 cases (7.0%), model validation was conducted using data from 1,337 out of 1,438 CSHA-3 respondents from the validation subsample. The bivariate correlations among the original 16 observed variables are shown in the upper right diagonal of Table 2. Results of ML estimation (using the final four-factor model with 12 variables) indicated that the magnitude of the standardized coefficients, factor loadings and factors correlations were comparable to those of the calibration sample (Table 8). The four-factor model explained approximately 47% of variation in this independent sample and values of the selected fit indices suggested acceptable overall fit of the data to the model, as shown in Table 6. In this sample, the CMIN value was 275

(degrees of freedom=48, p <.001), the CFI value was .954, the TLI value was .925, and the RMSEA value was .057 (90% confidence interval .051 to .064).

5.4 Summary

This thesis applied common factor analysis to a sample of 1,347 adults aged 75 to 102 from the CSHA-3 dataset to explore the underlying factor structure of 16 indicators of successful from the quantitative literature. SEM with ML estimation was used to test and revise the conceptual model until a theoretically meaningful and statistically acceptable four-factor measurement model was found. Evaluation of the final model using an independent sample of 1,337 participants revealed comparable parameter estimates and fit statistics, therefore suggesting reliability and stability of the constructs.

CHAPTER 6: DISCUSSION AND CONCLUSION

This chapter discusses the overall findings of this thesis, including its contributions and limitations, and presents some suggestions for future research.

6.1 Discussion

This thesis provides preliminary evidence for the existence of four higher-level constructs that may play an important role in defining successful aging. The first factor, labelled *Perceived Well-being*, suggests that fewer depressive symptoms, higher subjective well-being and fewer days of poor mental health are important for successful aging in older adults. CESD-10 score had the highest factor loading on this construct (β=.88) followed by SHARP score (β=-.79), therefore suggesting the importance of both emotional aspects such as managing depression, and cognitive aspects of well-being. Aspects of well-being and life satisfaction were also the focus of the majority of operational definitions identified in the systematic scoping review, and the findings of their importance are consistent with a substantial body of literature (Kahng, 2008; Strawbridge et al., 2002; Evans, 2009; Hsu, 2009; Mjelde-Mossey et al., 2009; Vahia et al., 2010; Gow et al., 2007; Litwin, 2006; Bowling, 2007).

The second construct, labelled *Physical Ability*, suggests that functional independence and physical activity are also important aspects of successful aging. IADL score (β=.87) and PADL score (β=.72) loaded most strongly on this construct, therefore suggesting that the ability to perform activities of daily living, in particular those

activities that require a higher more complex level of functional ability, is important (Rowe & Kahn, 1997; Depp & Jeste, 2006; Kaplan et al., 2008). Given that the CSHA-3 participants were those that survived the ten-year span of the study, it is not surprising that IADL score, which assesses higher levels of function, emerged as an important indicator in this sample. Further, McDowell and Newell (1996) explain that "most PADL questions reflect relatively severe levels of disability and so are insensitive to variations at the upper levels". It is therefore also not surprising that approximately 76% of variance in the IADL indicator, compared to 52% of variance in the PADL indicator, was explained by the model.

The third factor, labelled *General Health Status*, suggests that fewer days of poor physical health (β=.81), fewer days of activity limitation due to health (β=.76) and greater perceived health status (β =.58) are important elements of successful aging. On the other hand, the original model explained only 13% of variance in Comorbid Health Status (β=.36) and had a poorer fit to the data when this indicator was included compared to when it was removed (see Table 6). The influence of comorbidity is perhaps worth further investigation in samples of less healthy adults.

The fourth factor, labelled *Social Functioning*, suggests that a larger social network (β=.56), greater number of group activities (β=.48) and greater number of activities focused on helping others such as volunteering (β=.48) are important for successful aging. This factor supports the third component of Rowe and Kahn's Model of Successful Aging which emphasizes active engagement in life, including maintenance of interpersonal relations and productive activities (Rowe & Kahn, 1997). However, all

three factor loadings were among the lowest in the model. Furthermore, the model explained only 23% to 31% of variance in these three indicators, contributing to the model's poor convergent validity. One possible measurement limitation is that these variables were focused on the quantity and not necessarily the quality of social networks and activity engagement among CSHA-3 participants (Rohr & Lang, 2009). Similarly, only 17% of variance in the Supportive Ties indicator was explained by the model; it is hypothesized that a measure of the quality of one's supportive relationships would have been retained for contributing more to the model, if such a measure had been available in the dataset.

Moderate to low correlations among the four latent constructs indicated good discriminant validity, suggesting that the model did not have too many factors (Kline, 2005). On the other hand, the number of low multiple squared correlations indicated that the model did a poor job of explaining certain variables. For instance it explained only about 23% to 35% of variation in six of 12 indicators (Recent Mental Health, Physical Activities/Exercise, Self-perceived Health, Social Network, Group Activities, and Helping Others). Although each construct had at least three indicators, poor convergent validity suggests that the model may have too few indicators (Kline, 2005).

With regard to too few indicators, the only measure of mental status or cognitive function available in the CSHA-3 Screening Interview was 3MS score. As previously discussed, this variable loaded strongly on a fifth factor (β=.78) in the original hypothesized model along with the Personal Hobbies variable, suggesting the presence of an additional mental status or cognitive functioning factor. Current frameworks of

successful aging (i.e., Rowe & Kahn, 1997) and the findings of the scoping review also suggest the inclusion of a cognitive functioning construct. Interestingly, removal of the Personal Hobbies variable from the common factor analysis resulted in the loss of this separate fifth factor. Although the types of hobbies that were mentioned in response to this question were not available in the database, the Personal Hobbies indicator was initially included in this analysis because it appeared to have been designed to assess those activities and interests that are done independently, and not with others in a social context. For example, if "bowling" was mentioned as a personal hobby, study personnel recorded it under Physical Activities. Personal hobbies may include activities that are mentally stimulating, such as reading (Dodge et al., 2008). In this case, performing a higher number of such activities would be expected to be related to higher cognitive functioning. Future research on the effects of including valid measures of domain-specific cognitive functioning (e.g., memory), on the factor structure suggested in this thesis is needed to strengthen understanding of the role of cognition in successful aging.

The four-factor model also does not include the influence of individual and contextual level *adaptation* on the process of successful aging as such measures were not available in the CSHA-3 dataset. For example, frameworks such as Riley's Theory of Structural Lag (1998) support the concept of society-level indicators as major contributors to successful aging, in addition to indicators at the level of the individual. As such, indicators of area-level social participation (i.e., economic security, community development) and the social environment (i.e., safety, infrastructure) may also be of

importance to the Social Functioning construct and are worth future investigation (Hsu et al., 2010).

6.2 Contributions and Limitations of this Research

The advantages and disadvantages of using secondary data to assess the measurement structure of indicators of successful aging include speed and economy, with a lack of control over aspects of the study population and measurement (Grady & Hearst, 2007). Such limitations, principally of missing subjects and missing variables, pose constraints on the generalizability of the findings of this thesis and are worth discussing.

First, certain subgroups of seniors were either excluded (i.e., those residing in the Canadian Territories; those who do not speak English or French) or under-represented (i.e., those living in rural areas) in the CSHA. However these groups are likely to be small, with little effect on the findings. Second, although the amount of missing data was relatively small (<7%), the use of complete case analysis may have introduced additional bias if the missing cases differed in some way from the complete cases, other than at random (Kline, 2005). Selection bias may also be problematic as the sample that was used consisted of relatively healthy participants residing in the community, who were aged 65 or older at CSHA-1 and had survived to participate in the CSHA-3 ten years later. Further, only participants with good cognitive functioning were chosen to participate in the Successful Aging Substudy. Therefore, the present analysis did not take into account the effect of mortality and the findings should be interpreted as such. While this limits generalizability of the final model, this is still arguably an important segment

of the population to address. Another limitation of this research includes the use of cross-sectional (follow-up) data which did not allow the observation of successful aging over time. Although the suggested functioning and well-being factors are important in this cohort, the dynamic of the construct may be different in a sample of less healthy seniors or future baby boomer cohorts.

A potential pitfall of using SEM on a secondary dataset is to "place the data cart before the theory" and specify a model after the data have been collected rather than before (Kline, 2005). In fact, much of the research on the latent structure of successful aging has also been done using secondary datasets, many of which were designed to focus on research questions that did not explicitly include successful aging. The present research attempted to overcome this pitfall in two ways. First, potential indicators from the literature were used to guide the selection of variables from the dataset. While only a subset of indicators was available from the dataset, the literature showed that the ones selected had face validity. Second, the decision was made to use a dataset that was designed with a focus on successful aging. As previously mentioned, CSHA-3 data collection relied heavily on the perspectives of Rowe and Kahn (1997) and Strawbridge and Wallhagen (2003). However, because of this, it is possible that the factors that did emerge from the dataset were partly predetermined by the questions included in the Screening Interview (Abbott et al., 2006). For example, general health, physical function and engagement including interpersonal relations and productive activities, are key elements of Rowe and Kahn's Model of Successful Aging (1997), while Strawbridge and Wallhagen (2003) are proponents of the value of perceived well-being. Nonetheless,

additional constructs may be incorporated into the model with further research and as new evidence emerges.

Finally, while a cross-validation procedure did allow for the assessment of the reliability and stability of the constructs, it was not feasible to ascertain whether validity generalizes from this population to another. Construct validation is an ongoing process (Streiner & Norman, 2008); in order to investigate the extent to which this research can be generalized, further investigation is needed to examine whether these factors can be replicated in other cohorts and cultures.

6.3 Conclusions

Seniors are projected to represent a quarter (9.8 million) of Canada's population by the year 2036, compared to 13.2% (4.2 million) in 2005 (Statistics Canada, 2007). Contributing largely to this demographic transition are increasing life expectancy and the aging of the baby boomer cohort which began turning age 65 in 2011 (UN, 2009; Statistics Canada, 2007). A key challenge for researchers and policy makers is to elucidate ways to minimize the effects of disability and ill health, and extend the years of well-being and higher quality of life. Enhanced conceptualization and measurement of successful aging is one such avenue. Despite the limitations previously noted, this analysis presents a unique contribution by suggesting and testing a theoretically meaningful four-factor model of successful aging in a large population-based sample. The findings of this analysis contribute to our understanding of how indicators operate together to define successful aging in a cohort of Canadian seniors.

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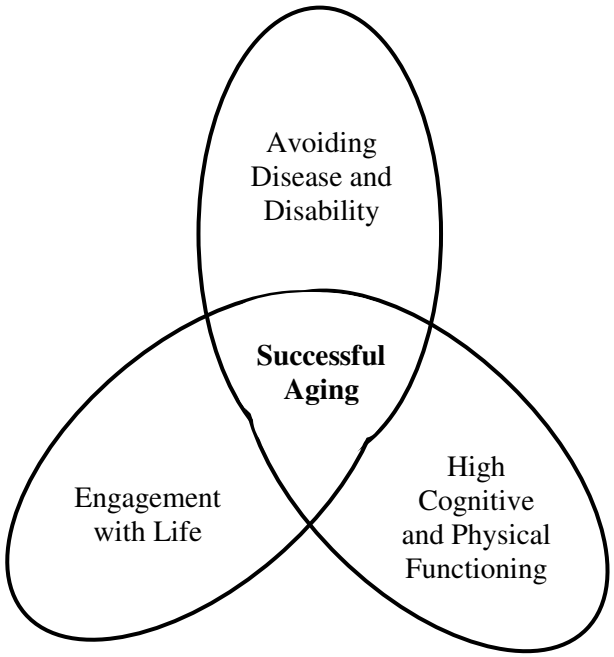
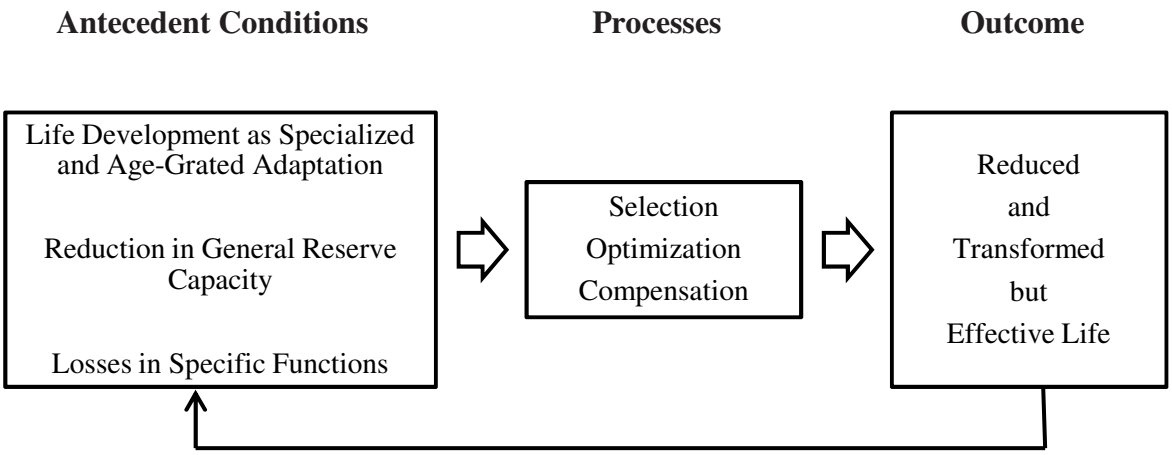
Figure 1: Rowe and Kahn's Model of Successful Aging[6]



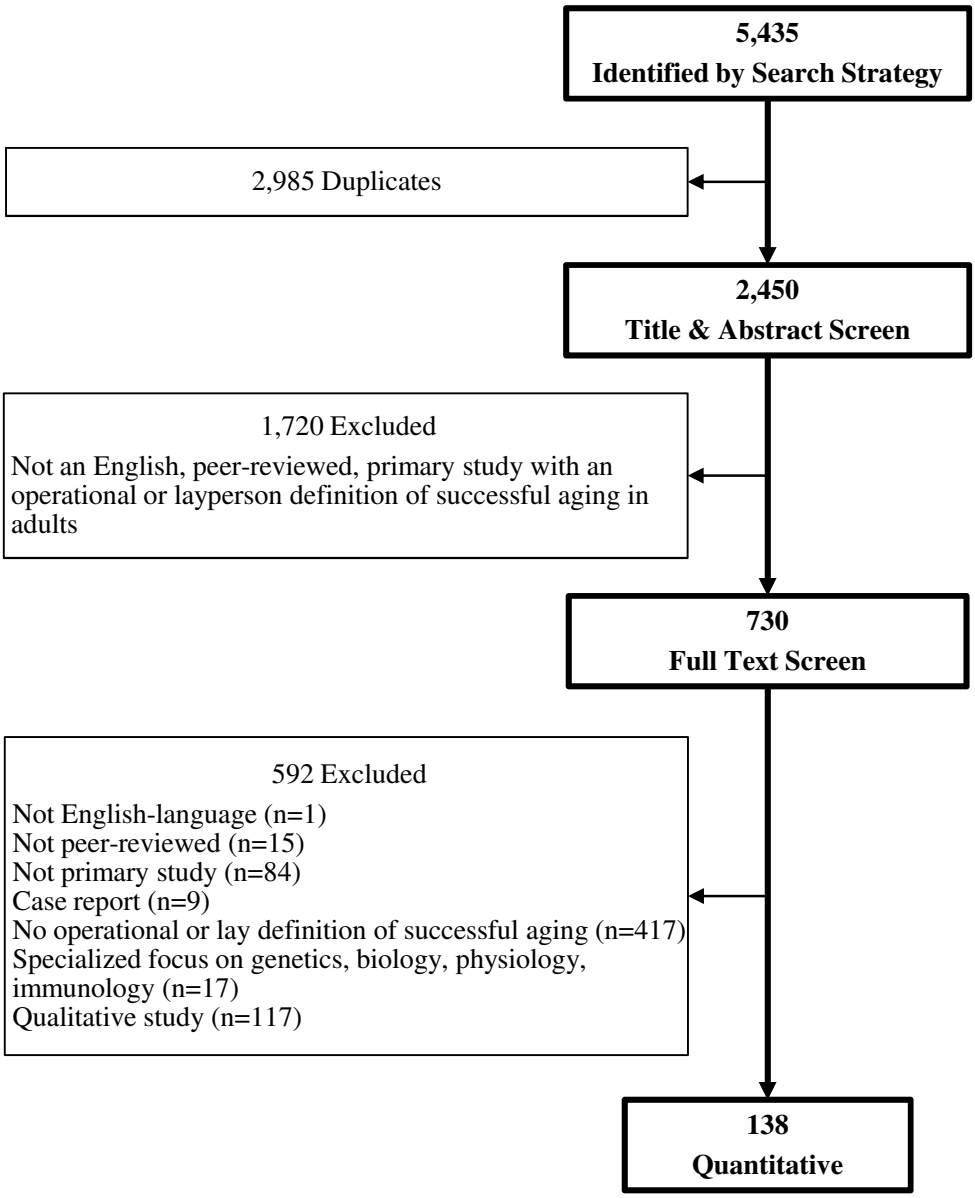
[6] Figure is reproduced from Rowe and Kahn (1997), p.434.

Figure 2: Baltes and Baltes' Theory of Selective Optimization with Compensation[7]



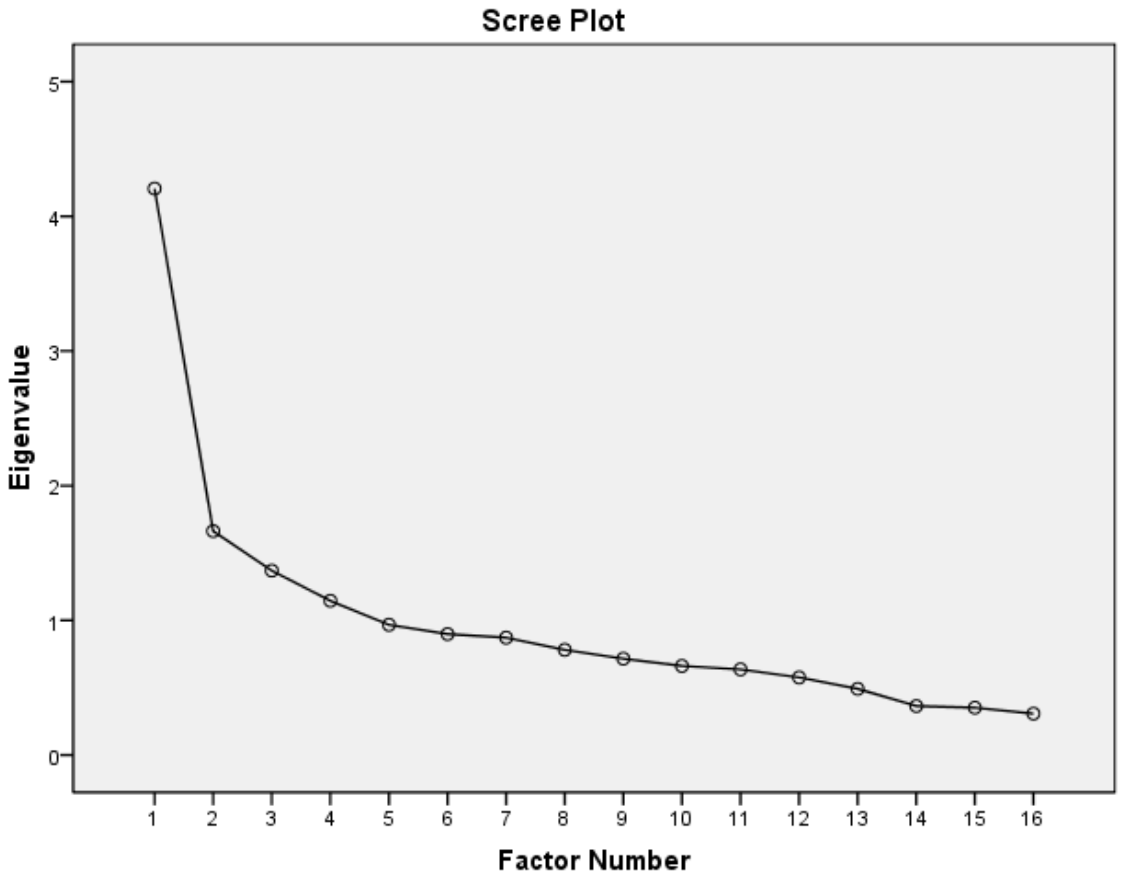
[7] Figure is reproduced from Baltes and Baltes (1990), p.22.

Figure 3: Scoping Review Flow Diagram



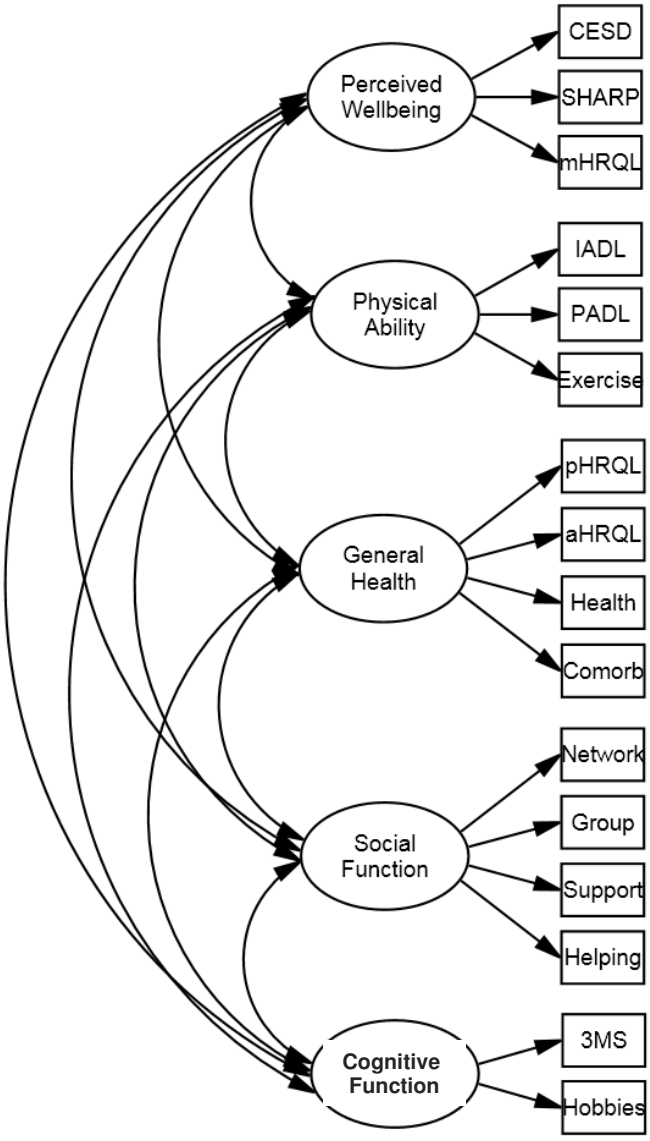
This flow diagram depicts the hierarchical screening process beginning with 2,450 individual studies that met the search criteria and ending with 138 quantitative studies that met the selection criteria.

Figure 4: Common Factor Analysis: Cattell Scree Test Plot



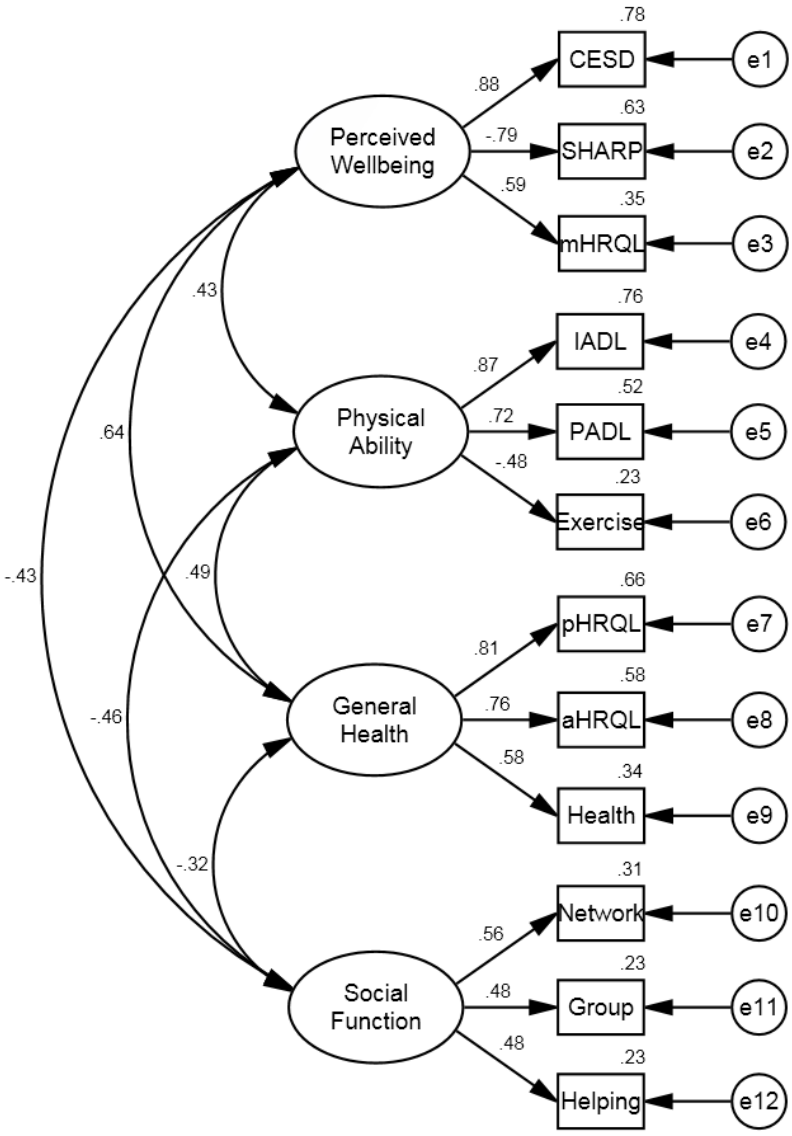
Note: The Cattell Scree Test plots the factors on the X axis and eigenvalues on the Y axis. The Scree Test says to retain all factors up to an including the factor starting the "elbow" toward less steep decline (Garson, 2010b). This plot suggested a five-factor solution.

Figure 5: Hypothesized Model of Successful Aging



Comorb = number of comorbid health conditions; *Exercise* = number of physical activities; *Health* = perceived health status; *Group* = number of group activities; *Helping* = number of activities helping others; *Hobbies* = number of personal hobbies; *Network* = number of social ties; *Support* = number of supportive ties.

Figure 6: Revised Measurement Model of Latent Constructs and Observed Variables



This diagram shows the standardized estimates (factor loadings) and squared multiple correlations for the indicators, and the correlations between factor variables. *Comorb* = number of comorbid health conditions; *Exercise* = number of physical activities; *Health* = perceived health status; *Group* = number of group activities; *Helping* = number of activities helping others; *Network* = number of social ties.

Table 1: Descriptive Statistics for the Entire Sample and Subsamples

Variable	Entire Sample (*N*=2,884)		Calibration Sample (*N*=1,446)		Validation Sample (*N*=1,438)	
	n	**Mean (SD) or %**	***n***	**Mean (SD) or %**	***n***	**Mean (SD) or %**
Age	2,884	82.10 (5.12)	1,446	82.03 (5.11)	1,438	82.16 (5.14)
Female, %	2,884	62.34	1,446	64.11	1,483	60.57
Language, %	2,884		1,446		1,438	
English		81.35		80.57		82.13
French		18.65		19.43		17.87
Years of education	2,877	10.94 (3.81)	1,445	10.94 (3.82)	1,432	10.94 (3.81)
3MS score	2,884	88.87 (7.80)	1,446	88.83 (7.94)	1,438	88.92 (7.66)
PADL score†	2,884	13.55 (1.08)	1,446	13.55 (1.05)	1,438	13.55 (3.37)
IADL score†	2,876	12.79 (2.04)	1,442	12.75 (2.08)	1,434	12.84 (1.12)
Comorbid health conditions	2,884	1.92 (1.34)	1,446	1.93 (1.34)	1,438	1.91 (1.34)
Perceived health status, %	2,880		1,443		1,437	
Very good		24.48		24.69		24.27
Pretty good		59.95		60.24		59.67
Not too good		12.62		12.03		13.21
Poor		2.32		2.21		2.43
Very poor		.49		.62		.35
Recent physical health	2,847	4.78 (9.18)	1,422	4.85 (9.18)	1,425	4.70 (9.17)
Recent mental health†	2,842	2.43 (6.61)	1,423	2.34 (6.46)	1,419	2.53 (6.77)
Recent activity limitation†	2,856	2.54 (6.82)	1,431	2.57 (6.82)	1,425	2.52 (6.83)
SHARP score	2,853	3.96 (2.26)	1,435	3.94 (2.21)	1,418	3.98 (2.30)
CESD-10 score	2,840	4.48 (4.75)	1,424	4.48 (4.71)	1,416	4.48 (4.79)
Supportive ties	2,824	3.88 (2.53)	1,422	3.97 (2.58)	1,402	3.78 (2.49)
Social network	2,858	6.13 (3.37)	1,431	6.29 (3.37)	1,427	5.96 (3.37)
Personal hobbies	2,873	1.25 (1.13)	1,442	1.27 (1.13)	1,431	1.24 (1.12)
Helping others	2,873	.64 (.81)	1,442	.62 (.80)	1,431	.65 (.83)
Group activities	2,872	1.29 (1.15)	1,441	1.34 (1.14)	1,431	1.24 (1.14)
Physical activities/exercise	2,873	1.43 (1.08)	1,442	1.47 (1.10)	1,431	1.40 (1.05)

†Distribution of values were non-normal and the variables were log-transformed.
Note: Independent t-tests revealed no statistically significant mean differences on any model variables among the two subsamples (p >.05).

Table 2: Correlations of Successful Aging Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		.303	.065	-.097	-.042	.036	-.123	.151	.096	.123	.146	.146	-.117	-.059	-.092	-.078
2	.311		.101	-.133	-.071	-.074	-.202	.204	.078	.159	.323	.208	-.122	-.095	-.078	-.127
3	.066	.136		-.103	-.082	-.061	-.139	.107	.241	.148	.129	.216	-.077	-.061	-.193	-.295
4	-.132	-.162	-.154		.485	.303	.428	-.438	-.108	-.244	-.120	-.120	.280	.412	.284	.313
5	-.031	-.123	-.107	.423		.222	.428	-.400	-.058	-.195	-.068	-.098	.373	.601	.264	.269
6	-.056	-.100	-.029	.335	.213		.258	-.196	-.026	-.210	-.047	-.119	.139	.207	.180	.261
7	-.133	-.240	-.159	.416	.421	.235		-.702	-.124	-.230	-.119	-.149	.544	.388	.239	.301
8	-.188	.213	.182	-.428	-.386	-.242	-.677		.113	.225	.113	.150	-.501	-.353	-.260	-.288
9	.071	.104	.266	-.097	-.085	-.014	-.124	.131		.121	.108	.162	-.052	-.078	-.092	-.139
10	.133	.193	.220	-.261	-.180	-.182	-.199	.192	.055		.156	.256	-.122	-.164	-.302	-.386
11	.141	.293	.126	-.139	-.087	-.092	-.149	.166	.049	.155		.230	-.037	-.081	-.084	-.099
12	.147	.231	.210	-.142	-.134	-.099	-.137	.157	.124	,247	.238		-.011	-.078	-.183	-.263
13	-.080	-.103	-.051	.223	.273	.123	.511	-.444	.013	-.075	-.042	-.053		.321	.156	.150
14	-.061	-.103	-.064	.361	.628	.217	.374	-.344	-.022	-.146	-.085	-.105	.238		.250	.280
15	-.077	-.153	-.167	.226	.267	.234	.260	-.236	-.018	-.303	-.116	-.146	.093	.272		.637
16	-.095	-.170	-.301	.314	.301	.259	.325	-.299	-.080	-.404	-.134	-.244	.124	.296	.615	

Bivariate correlations for calibration sample (n=1,347, lower diagonal) and validation sample (n=1,337, upper diagonal).
Note: Correlations greater than .084 are significant at the .05/16 = .001 level.

Variables:

1 Supportive Ties
2 Social Network
3 3MS score
4 Perceived Health Status
5 Recent Physical Health
6 Comorbid Health Conditions
7 CESD-10 score
8 SHARP score
9 Personal Hobbies
10 Physical Activities/Exercise
11 Group Activities
12 Helping Others
13 Recent Mental Health
14 Recent Activity Limitation
15 PADL score
16 IADL score

Table 3: Common Factor Analysis: Eigenvalues and Percent of Variance Explained

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.206	26.287	26.287	3.737	23.357	23.357	1.790	11.185	11.185
2	1.663	10.392	36.678	1.114	6.962	30.319	1.649	10.306	21.491
3	1.369	8.556	45.234	.843	5.266	35.585	1.422	8.886	30.376
4	1.145	7.156	52.390	.519	3.246	38.831	1.087	6.793	37.169
5	.967	6.043	58.433	.457	2.854	41.684	.722	4.515	41.684
6	.898	5.613	64.046						
7	.871	5.444	69.490						
8	.781	4.879	74.370						
9	.715	4.470	78.839						
10	.661	4.134	82.974						
11	.635	3.971	86.944						
12	.576	3.599	90.544						
13	.491	3.070	93.613						
14	.364	2.273	95.886						
15	.351	2.194	98.080						
16	.307	1.920	100.000						

Extraction Method: Principal Axis Factoring.

Table 4: Common Factor Analysis: Rotated Factor Matrix

Rotated Factor Matrix[a]

	Factor				
	1	2	3	4	5
CESD-10 score	.790	.181	.217	-.159	-.116
SHARP score	-.709	-.160	-.210	.199	.149
Recent Mental Health	.575	.028	.137	-.041	.016
IADL score	.131	.835	.140	-.096	-.177
PADL score	.102	.663	.155	-.094	-.014
Physical activities/exercise	-.063	-.407	-.096	.255	.151
Comorbid health conditions	.188	.269	.195	-.117	.050
Recent physical health	.253	.158	.797	-.036	-.096
Recent activity limitation	.235	.196	.664	-.046	.010
Perceived health status	.337	.240	.363	-.179	-.101
Social network	-.112	-.083	-.046	.619	.067
Group activities	-.045	-.090	-.055	.425	.084
Supportive ties	-.107	-.038	.009	.417	.024
Helping others	-.009	-.181	-.080	.360	.226
3MS score	-.053	-.210	-.004	.109	.610
Personal hobbies	-.052	.020	-.034	.094	.418

Extraction Method: Principal Axis Factoring.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Table 5: Maximum Likelihood Parameter Estimates for Hypothesized Model using the Calibration Sample (n=1,347)

Parameter			Unstandardized	SE	CR	Standardized	
			Factor Loadings				**Squared Correlations**
CESD-10	←	Well-being	1.000[a]			.879	.772
SHARP	←	Well-being	-.425	.014	-30.090	-.797	.635
mHRQL	←	Well-being	.059	.003	22.157	.590	.348
IADL	←	Physical	1.000			.882	.777
PADL	←	Physical	.539	.024	22.739	.710	.504
Exercise	←	Physical	-2.061	.124	-16.670	-.485	.235
pHRQL	←	Gen Health	1.000[a]			.789	.623
aHRQL	←	Gen Health	.045	.002	24.997	.751	.564
Health	←	Gen Health	.059	.003	20.850	.605	.366
Comorb	←	Gen Health	.065	.005	12.257	.356	.127
Network	←	Social	1.000[a]			.620	.384
Group	←	Social	.247	.023	10.980	.451	.204
Support	←	Social	.513	.049	10.394	.416	.173
Helping	←	Social	.173	.016	10.998	.453	.205
3MS	←	Cognition	1.000[a]			.784	.614
Hobbies	←	Cognition	.064	.011	6.034	.350	.122
			Factor Covariances				**Correlations**
Cognition	↔	Social	5.032	.618	8.149		.387
Cognition	↔	Gen Health	-9.936	1.732	-5.735		-.219
Cognition	↔	Physical	-.696	.063	-11.137		-.432
Cognition	↔	Well-being	-7.215	.958	-7.533		-.279
Gen Health	↔	Social	-4.897	.648	-7.559		-.322
Physical	↔	Social	-.231	.023	-9.850		-.427
Well-being	↔	Social	-3.742	.374	-10.002		-.431
Physical	↔	Gen Health	.973	.070	13.821		.515
Well-being	↔	Gen Health	20.193	1.210	16.689		.666
Well-being	↔	Physical	.464	.037	12.606		.431

SE = standard error; CR = critical ratio; Gen Health = general health status.
[a] Not tested for statistical significance, p <.001 for all other unstandardized estimates.

Table 6: Comparisons of Alternate Models: Goodness-of-Fit Indexes

Model	CMIN*	df	CFI	TLI	RMSEA	Variation explained	N
1	481	94	.932	.901	.053	42%	1,347
2	384	80	.944	.916	.051	44%	1,347
3	330	67	.950	.922	.052	45%	1,347
4	259	48	.957	.930	.055	47%	1,347
4†	275	48	.954	.925	.057	47%	1,337

†Cross-validation sample; *p-value <.05 for all CMIN values.

Note: Model 1 refers to the conceptual five-factor model with 16 variables; Model 2 removes the comorbid health conditions indicator; Model 3 removes the supportive ties indicator; Model 4 removes factor five, including the 3MS and personal hobbies indicators.

CFI = Comparative Fit index (values above .90 indicate an acceptable fit); *CMIN* = model chi-square (non-significant p-values indicate a good fit); *df* = degrees of freedom; *RMSEA* = root mean square error of approximation (values close to .05 indicate an acceptable fit); *TLI* = Tucker Lewis index (values above .90 indicate an acceptable fit).

Table 7: Maximum Likelihood Parameter Estimates for Revised Measurement Model using the Calibration Sample (n=1,347)

Parameter			Unstandardized	SE	CR	Standardized	
			Factor Loadings				**Squared Correlations**
CESD-10	←	Well-being	1.000[a]			.884	.781
SHARP	←	Well-being	-.420	.014	-29.657	-.791	.626
mHRQL	←	Well-being	.059	.003	22.139	.591	.349
IADL	←	Physical	1.000[a]			.871	.759
PADL	←	Physical	.553	.025	21.925	.720	.518
Exercise	←	Physical	-2.081	.127	-16.330	-.485	.234
pHRQL	←	Gen Health	1.000[a]			.813	.660
aHRQL	←	Gen Health	.044	.002	25.211	.764	.583
Health	←	Gen Health	.055	.003	20.103	.579	.335
Network	←	Social	1.000[a]			.558	.311
Group	←	Social	.293	.029	9.984	.482	.232
Helping	←	Social	.202	.020	9.949	.477	.227
			Factor Covariances				**Correlations**
Social	↔	Gen Health	-4.521	.642	-7.043		-.321
Social	↔	Physical	-.222	.023	-9.522		-.462
Social	↔	Well-being	-3.365	.368	-9.146		-.429
Physical	↔	Gen Health	.948	.071	13.378		.493
Well-being	↔	Gen Health	20.230	1.222	16.550		.645
Well-being	↔	Physical	.463	.037	12.583		.433

SE = standard error; CR = critical ratio; Gen Health = general health status.
[a] Not tested for statistical significance, $p < .001$ for all other unstandardized estimates.

Table 8: Maximum Likelihood Parameter Estimates for Revised Measurement Model using the Validation Sample (n=1,337)

Parameter			Unstandardized	SE	CR	Standardized	
			Factor Loadings				**Squared Correlations**
CESD-10	←	Well-being	1.000[a]			.864	.746
SHARP	←	Well-being	-.453	.015	-30.408	-.813	.662
mHRQL	←	Well-being	.064	.003	23.270	.618	.382
IADL	←	Physical	1.000[a]			.867	.752
PADL	←	Physical	.598	.026	22.854	.752	.565
Exercise	←	Physical	-2.014	.123	-16.308	-.478	.228
pHRQL	←	Gen Health	1.000[a]			.791	.626
aHRQL	←	Gen Health	.042	.002	23.473	.721	.519
Health	←	Gen Health	.062	.003	21.352	.637	.405
Network	←	Social	1.000[a]			.535	.286
Group	←	Social	.329	.034	9.712	.518	.268
Helping	←	Social	.221	.023	9.575	.481	.232
			Factor Covariances				**Correlations**
Social	↔	Gen Health	-3.302	.589	-5.608		-.252
Social	↔	Physical	-.183	.022	-8.469		-.408
Social	↔	Well-being	-2.752	.347	-7.930		-.368
Physical	↔	Gen Health	.889	.068	13.085		.490
Well-being	↔	Gen Health	19.968	1.218	16.399		.661
Well-being	↔	Physical	.452	.036	12.520		.437

SE = standard error; CR = critical ratio; Gen Health = general health status.
[a] Not tested for statistical significance, $p < .001$ for all other unstandardized estimates.

APPENDIX A: Literature Search Strategy

Database: Ovid MEDLINE <1950 to August Week 4 2010>
Search Strategy:
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1 "successful ag?ing".tw. (748)
2 "healthy ag?ing".tw. (1125)
3 "optimal ag?ing".tw. (9)
4 "active ag?ing".tw. (66)
5 "productive ag?ing".tw. (24)
6 "ag?ing well".tw. (51)
7 1 or 2 or 3 or 4 or 5 or 6 (1979)
8 limit 7 to (english language and humans and yr="2000 -Current") (1362)
9 limit 8 to (case reports or clinical conference or comment or consensus development conference or consensus development conference, nih or editorial or letter) (45)
10 8 not 9 (1317)

Database: EMBASE <1980 to 2010 Week 35>
Search Strategy:
---

1 "successful ag?ing".tw. (882)
2 "healthy ag?ing".tw. (1332)
3 "optimal ag?ing".tw. (16)
4 "active ag?ing".tw. (82)
5 "productive ag?ing".tw. (31)
6 "ag?ing well".tw. (71)
7 1 or 2 or 3 or 4 or 5 or 6 (2357)
8 limit 7 to (english language and humans and yr="2000 -Current") (1527)
9 limit 8 to (book or book series or conference abstract or conference paper or "conference review" or editorial or letter) (169)
10 8 not 9 (1358)

Database: PsycINFO<1806 to August Week 5 2010>
Search Strategy:
---

1 "successful ag?ing".tw. (831)
2 "healthy ag?ing".tw. (634)
3 "optimal ag?ing".tw. (35)
4 "active ag?ing".tw. (50)
5 "productive ag?ing".tw. (49)
6 "ag?ing well".tw. (119)
7 1 or 2 or 3 or 4 or 5 or 6 (1633)
8 limit 7 to (english language and humans and yr="2000 -Current") (1150)
9 limit 8 to (book or "authored book" or "edited book" or "column/opinion" or "comment/reply" or "dissertation abstract" or dissertation or editorial or letter) (97)
10 8 not 9 (1053)

Database: CINAHL, Sociological Abstracts, AgeLine
Search Strategy:

Query: KW=(("successful aging") or ("successful ageing"))
Query: KW=(("healthy aging") or ("healthy ageing"))
Query: KW=(("optimal aging") or ("optimal ageing"))
Query: KW=(("active aging") or ("active ageing"))
Query: KW=(("productive aging") or ("productive ageing"))
Query: KW=(("aging well") or ("ageing well"))

APPENDIX B: Features of Studies of Successful Aging Included in Review (n=63)

First Author Year	Sample	Definition	Associations
Almeida 2006	601 community-dwelling males aged 80+ at follow-up	Reaching age 80 years with good mental health status (i.e., preserved cognitive function and preserved mood)	Age, education, and lifestyle behaviours such as physical activity were associated with successful mental health aging at follow-up (mean 4.8 years)
Baker 2009	12,042 community-dwelling adults aged >60 from Canadian Community Health Survey 2.1	Low probability of disease or disease-related disability, high cognitive and physical functional capacity, and active engagement with life	Physical activity involvement significantly predicted successful aging
Bosma 2007	1,211 adults aged 24–81 (at baseline) from prospective cohort study (Maastricht Aging Study)	Self-reported physical, affective, and cognitive functioning as three indicators	Higher baseline intellectual abilities in the high socioeconomic status groups protected these groups from declines in self-reported physical, affective and cognitive functioning at 6-year follow-up
Bowling 2006	999 community-dwelling adults aged 65+ from British Omnibus Surveys	**1** Biomedical model (no chronic conditions, good functioning, no psychiatric morbidity); **2** Broader biomedical model (previous criteria, being socially active); **3** Social functioning model (being socially active, high frequency of contacts, available support); **4** Psychological resources model (high self-efficacy and optimism, playing useful part, facing up to problems, overcoming difficulties, self-confidence, self-worth); **5** Lay model (all previous criteria, income, perceived social capital)	Lay multidimensional model of successful aging was strongest over the unidimensional models in predicting good self-rated quality of life
Britton 2008	5,823 adults aged 35–55 (at baseline) from Whitehall II study	Free from major disease for the duration of the study, and good physical and mental functioning at 17-year follow-up	Midlife socioeconomic position (employment grade) strongly predicted successful aging at follow-up; With adjustment for age and socioeconomic position, height, education (in men), not smoking, diet, exercise, moderate alcohol (in women), and work support (in men) were associated with successful aging
Chaves 2009	345 community-dwelling adults aged 60+	Good health, absence of functional disability and mood changes, and no cognitive impairment	Fewer children, more confidants, and higher family income were strongly associated with successful aging
Cohen 2009	198 schizophrenia patients and 113 community comparison adults aged 55+	Avoiding disease and disability, high cognitive and physical function, and engagement with life, measured **1** Objectively, and **2** Subjectively	Greater percentage of community comparison group met criteria of objective successful aging compared to schizophrenia group; similar pattern found for subjective criteria
Cooper 2009	2,007 cognitively impaired adults aged 60+ from British National Psychiatric Morbidity Survey	Mental and physical components of HRQL as two indicators	Mental HRQL was predicted by affective symptoms, whereas physical HRQL was predicted by ADL score and number of longstanding illnesses

Dodge 2008	303 community-dwelling adults aged 65–96	Frequency of engagement with life (physical hobby, nonphysical hobby, and social activity) as three summary activity index scores	Frequency of engagement in nonphysical hobbies was significantly associated with all cognitive domains examined
Driscoll 2008	64 adults aged 75+ from AgeWise study	Avoiding disease (general health and HRQL), maintaining mental health and cognitive function, and staying engaged with life and others	Better physical and mental HRQOF were associated with better sleep quality
Engberg 2009	39,945 adults aged>70 from Danish 1905 birth cohort	Hospitalizations and length of stay in hospital as two indicators	Centenarians were hospitalized substantially less than shorter-lived contemporaries at same point in time during the years 1977–2004
Evans 2009	140 community-dwelling adults aged 65+	Level of life satisfaction and depressive symptoms as two indicators	Subjective level of social support was a positive predictor of life satisfaction and a negative predictor of depressive symptoms
Ferri 2009	53 community-dwelling adults aged 60+	Self-rated successful aging	Successful aging was positively related to social support, life satisfaction, and subjective health
Flood 2006a; 2006b; 2010	57 community-dwelling adults aged 56–97; 152 community-dwelling adults aged 56–97; 209 adults from the two above samples combined	Life satisfaction and purpose of life as two indicators	Creativity was not significantly predictive of either indicator, but functional performance significantly predicted purpose in life; Presence of depressive symptoms moderated the relationship between creative personality types and successful aging; With number of chronic diseases as a covariate, purpose in life scores accounted for a considerable portion of the variance in life satisfaction scores
Friedman 2010	720 adults aged~70s (at follow-up) from Terman Life Cycle Study	Four-factor measure consisting of physical health, subjective well-being, social competence, and productivity components at follow-up	Neuroticism in midlife predicted worse old-age physical health and well-being; Extraversion in midlife predicted old-age social competence; Conscientiousness predicted old-age productivity (in men)
Gilhooly 2007	200 survivors aged 70–90 from Paisley/Renfrew (MIDSPAN) longitudinal study	Survivors with little or no hospital morbidity	Compared to unhealthy agers, healthy agers were less neurotic, more likely to endorse an internal locus of control belief, and reported a greater sense of coherence; no differences between groups on extraversion/introversion, psychoticism, or optimism
Gjonca 2008	11,234 community-dwelling adults from English Longitudinal Study of Ageing	Physical functioning, cognitive functioning, and health as three indicators	Parental, especially mother's, lifespan was positively associated with cognitive functioning and a decreased likelihood of some chronic diseases and poor health at older age
Gondo 2006	304 community-dwelling or institutionalized adults aged 100–107	'Exceptional' functional status phenotype (i.e., excellent sensory, physical, and cognitive functions)	Classified centenarians into 4 categories according to their functional status, of which only 2% were classified as 'Exceptional'
Gow 2007	550 adults aged 79–80 from Lothian 1921 Birth Cohort	Cognitive ability and satisfaction with life as two indicators	Social network/support factors were associated with life satisfaction and later life cognition, with level of loneliness as the largest predictor

Gregory 2010	70 community-dwelling adults aged 74–90	Memory and independence in everyday life as two indicators	Successful aging was associated with openness to experience, and was most strongly correlated with the facet of openness to fantasy (active imagination)
Gruenewald 2007	1,189 community-dwelling adults aged 70–79 from MacArthur Study of Successful Aging	Feelings of usefulness to others	Adults who never/rarely felt useful to others, compared with those who frequently felt useful, were more likely to experience an increase in disability or death over a 7-year period after adjustment for demographic, health status, behavioural, psychosocial factors
Habib 2007	1,463 community-dwelling adults aged 50–85 from Betula project	High (cognitive and non-cognitive) functioning older adults that remained high functioning after 5 years	Years of education was a significant predictor of remaining successful over time
Hank 2008	27,297 adults aged 50+ from 2004 Survey of Health Ageing and Retirement in Europe	Engagement in volunteering, informal helping, or caregiving	Engagement in volunteering, informal helping, or caring was negatively correlated with functional limitations; Propensity to volunteer was significantly lower among those who reported depressive symptoms
Hoppmann 2008	1,130 community-dwelling adults aged 70+ (at baseline) from Australian Longitudinal Study of Ageing	Social activities	11-year social activity trajectories depended on both individual and spousal cognitive, physical, and affective resources at baseline
Hsu 2009	3,155 community-dwelling adults aged 60+ from Survey of Health and Living Status of the Elderly in Taiwan	Emotional health (absence of depressive symptoms) and subjective well-being (life satisfaction) as two indicators	An increase in physical function disability was associated with increased depressive symptoms and reduced life satisfaction
Jang 2009	1,825 community-representative sample of adults aged 65–103	Satisfied the following criteria: physical function, mental function, social function, subjective well-being	Education was significantly associated with physical functioning, mental functioning, and subjective well-being; personal income with social functioning and subjective well-being; and household income with subjective well-being
Jopp 2006	156 adults aged 71–91 from Berlin city registry	Subjective well-being	Personal resources were important determinants of subjective well-being; and selection, optimization, and compensation life-management strategies had considerable protective effect when resources were constrained, particularly in very old age
Jung 2010	1,072 community-dwelling adults aged 70–79 from MacArthur Study of Successful Aging	Engagement in productive activities (volunteering, paid work, and childcare)	Only volunteering was associated with lower cumulative odds of frailty after adjusting for age, disability, and cognitive function

Kaplan 2008	2,432 adults aged 65–85 (at baseline) from Canadian National Population Health Survey	Maintained exceptional health with no or only mild disability over 10 years(i.e., 'Thrivers' group)	Thrivers were more likely to be younger, female, married, non-smokers, moderate alcohol users, with lower psychological distress and higher self-rated health than the three comparison groups
Knappe 2009	110 patients with internal diseases, 196 cancer patients and 80 healthy controls aged 60+	Health locus of control and subjective well-being (positive/negative affect) as two indicators	Differences between internal diseases and cancer patients on health locus of control and well-being scales were less pronounced than differences between patients and controls; Higher levels of education, more social support, higher self-esteem, internal health locus of control, and daily functioning predicted positive affect
Ko 2007	287 community-dwelling adults	Successful aging profile consisting of cognition, physical health, personality, and social support	Profiles of successful aging discriminated on external measures of well-being
Lamond 2009	1,395 females aged 60–91 from Women's Health Initiative	Self-rated successful aging, social engagement, physical functioning, emotional health/well-being, cognitive functioning, and optimism as six indicators	Higher emotional well-being, optimism, self-rated successful aging, social engagement, and fewer cognitive complaints were predictors of greater resilience
Lawler-Row 2006; 2010	425 adults aged 50–95; 253 community-dwelling adults aged 52–87	Six subscales of psychological well-being (environmental mastery, self-acceptance, purpose in life, autonomy, personal growth, positive relations with others) as indicators	High trait forgiveness compared to low forgiveness was significantly associated with higher scores on all six subscales; Trait forgiveness fully mediated the relationship between prayer and intrinsic religiosity with all subscales of successful aging except autonomy
Lee 2009	109 community-dwelling adults aged 60+	Self-rated successful aging	Predictors of self-reported successful aging in older adults with relatively low socioeconomic status included life satisfaction, sex, self-reported health status, satisfaction with living environment, and major source of income
Li 2006	1,516 community-dwelling adults aged 65–99 from Shanghai Successful Aging project questionnaire	Meeting criteria across four domains (cognitive function, ADL, mood status, physical disability)	Higher life satisfaction, higher leisure activities level, sleeping 7–8 hours per day, a self-satisfied economic evaluation, and being currently married were related to successful aging
Litwin 2006	Community-dwelling adults aged 60+ from Israel national survey	State of well-being (morale)	Morale was negatively associated with functional disability and positively associated with social network and activity level
Livingston 2008	224 community-dwelling or institutionalized Alzheimer disease patients aged 55–98 from LASER-AD study	Self-rating of life as a whole (well-being in adversity)	The most important predictors of successful aging were mental health and social relationships, which fully mediated the relationship between health perception and wellbeing at 18-month follow-up

McLaughlin 2009	Adults aged 65+ from Health and Retirement Study	No major disease including depression, no ADL disability, high physical functioning, high cognitive functioning, and being actively engaged	Age, gender, race-ethnicity, and socioeconomic status (education, income, and wealth) predicted successful aging
Meisner 2010	12,042 community-dwelling adults aged 60+ from Canadian Community Health Survey 2.1	Low probability of disease or disease-related disability, high cognitive and physical functional capacity, and active social engagement with life as three indicators	Physical inactivity was significantly associated with higher odds of reporting less desirable conditions for all three indicators
Mjelde-Mossey 2009	1,502 adults aged 60–94	Self-rated health and depression as two indicators	Engagement in productive activities and satisfaction with family relations were predictors of both self-rated health and depression
Montross 2006	205 community-dwelling adults aged >60	Self-rated successful aging, independent living, positive adaptation, active engagement with life, mastery/growth, life satisfaction/well-being, freedom from disability, absence of disease	Subjective ratings of successful aging were significantly correlated with higher HRQL (physical and mental health functioning), resilience, greater activity, number of close friends, days per week reading, days per week listening to radio, days per week visiting family, but not with age, mother/father's age at death, gender, ethnicity, current marital status, living situation, level of education, or income
Moore 2007	182 community-dwelling adults aged 58–99	Self-rated successful aging	Self-rated successful aging was positively correlated with level of education, income, mental/cognitive functioning
Ng 2009	Epidemiological-based cohort of 1,281 community-dwelling adults aged 65+ from Singapore Longitudinal Aging Study cohort	Summary composite measure across six domains (physical health, functional well-being, cognitive well functioning, emotional well-being, social functioning and active engagement in life activities, positive life satisfaction)	Successful aging was significantly associated with age, female gender, 6+ years of education, better housing, religious or spiritual beliefs, physical activities and exercise, and low or no nutritional risk
Ostbye 2006	Population-based sample of 3,413 community-dwelling adults aged 65+ from Cache County Memory Study	Independent living, vision, hearing, ADL, IADL, absence of physical illness, cognition, healthy mood, social support and participation, and religious participation and spirituality as ten indicators	All indicators except cognition, and religious participation/spirituality were significant predictors of self-reported excellent/good health, whereas all except excellent/good vision and hearing and independence in ADL were predictors of mortality
Oswald 2007	1,918 community-dwelling adults aged 75–89 from ENABLE-AGE survey wave 1	ADL independence, perceived functional independence, and subjective well-being (life satisfaction, environmental mastery, positive and negative affect, depression) as seven indicators	Greater independence in ADL and better sense of well-being were associated with both objective and perceived aspects of housing
Park 2010	761 community-dwelling adults aged 65–84 from Hallym Ageing Study wave 3	High levels of physical and social functioning	Socioeconomic status (income, education) had a greater gender-specific effect on physical functioning than on social functioning

Perrig-Chiello 2006	442 independent-living adults aged 65–95 from Basle Inter-Disciplinary Study on Aging	Functional autonomy	Physical strength (mobility) was a significant predictor of PADL, whereas memory (free recall, working memory, perceptual speed) was the strongest predictor of IADL
Puig-Domingo 2008	Population-based cross-sectional study of 313 non-institutionalized adults aged 70+ from Mataro Aging Study	Optimal function and cognitive capacities with absence of disease	Successful aging was associated with greater hand grip strength
Ramage-Morin 2006	1,711 institutionalized adults aged 65+ from Canadian National Population Health Survey	Positive self-perceived health	Successful aging was associated with independence, absence of chronic conditions, absence of pain, daily social involvement in activities, feeling close to at least one staff member, and lower odds of mortality over a 6-year period, but not with having close friends or relatives outside the institution
Robson 2007	201 community-dwelling adults aged 40–72	Perceived successful aging at work, based on 8 items	Security, relationship development, continuous learning, and career management strategies were predictive of successful aging at work, above and beyond characteristics of the individual or employing organization
Steca 2010	735 adults aged 65–95 from 2007 national survey	Well-being, quality of interpersonal relationships, and leisure activities as three indicators	Resilient, over-controlled and under-controlled personality prototypes differentiated in terms of life and health satisfaction, positive affectivity, interpersonal trust, civic and social engagement and leisure activities
Steptoe 2006	120 community-dwelling adults aged 65–80 from two general practices	Physical health status and self-rated health as two indicators	The relationship between dispositional optimism and indices of healthy aging was partially mediated by health behaviours
Tyas 2007	678 females aged 75–102 from The Nun Study	Meeting at least the minimum requirement for three performance-based measures of cognitive and physical function, and participants' self-rated function	Survival curves showed significantly greater longevity with higher levels of healthy aging
Vahia 2010	1,979 community-dwelling females aged 60 –91 from Women's Health Initiative study	Subjective assessment of successful aging, physical functioning, mental/emotional functioning, quality of life, attitude toward aging, personal mastery, self-efficacy, optimism, resilience, subjective cognitive complaints, test-based cognitive performance, anxiety, and hostility as thirteen indicators	Mild-moderate levels of depressive symptoms were associated with worse functioning on virtually every component of successful aging
Warburton 2008	387 community-dwelling adults aged 65+ with/without fall-related hip fracture	Volunteering as a productive activity in later life	Volunteer activity was significantly protective of hip fracture independent of social and physical activity, social support and health status

Weir 2010	14,749 community-dwelling adults aged 60+ from Canadian Community Health Survey 2.1	Low probability for disease or disease-related disability, high cognitive and physical functional capacity, active engagement with life as three indicators	Age was a significant predictor of disease-related disability and impaired physical functioning, but had little impact on active engagement
Wiesmann 2008	170 community-dwelling adults from Health and Physical Activity in Old Age project	Subjective well-being	Sense of coherence mediated the relationship between generalized resistance resources and subjective well-being
Windsor 2009	240 (120 couples) aged 52–90 from Aging Well Together study	Self-rated mental health, physical health, subjective well-being, availability of social networks, and social engagement as five indicators	Individuals' positive reappraisal was positively related to all successful aging indicators, whereas persistence in goal striving was associated with only better mental health; Spouses' goal persistence and reappraisal tendencies were not related to individuals' aging well outcomes
Woloski-Wruble 2010	127 community-dwelling females aged 45+ from a menopause clinic	Life satisfaction	Life satisfaction and sexual satisfaction were positively correlated
Young 2009	1,732 females aged 65+ from Women's Health and Aging Studies (WHAS) I and II or Continuing care retirement community (CCRC) study	A construct with physiology (disease, impairment), psychology (cognition, emotional vitality), and sociology (engaging with life) components	The successful aging construct discriminated participants with regard to ADL and IADL function and self-reported health status (CCRC data); predicted functional ADL and IADL change over time; and predicted hospitalizations (WHAS-I)

APPENDIX C: Measurement of Components of Definitions of Successful Aging Included in Review

Domain	Operationalization (First Author, Year)
Well-being and Life Satisfaction	Life Satisfaction Index (LSI) (Woloski-Wruble, 2010)
	Life Satisfaction Index-A (LSI-A) total score (Flood, 2006a; 2006b; 2010)
	Life Satisfaction Index-Z (LSI-Z) score (Evans, 2009)
	Satisfaction With Life Scale (SWLS) score (Gow, 2007; Windsor, 2009)
	Life Satisfaction Rating (LSR) total score (4 items) (Hsu, 2009)
	Life Satisfaction Scale score in lowest decile (i.e., score <11) (Ng, 2009)
	Life Satisfaction Scale score based on 5 self-rated items (Steca, 2010)
	Satisfaction with health status (Steca, 2010)
	Life satisfaction, single item (Oswald, 2007)
	SF-12 Physical and Mental component scores (health-related quality of life) (Cooper, 2009)
	MOS SF-36 Physical and Mental subscales (health-related quality of life) (Driscoll, 2008)
	MOS SF-36 Emotional health/well-being subscale (Lamond, 2009)
	MOS SF-36 Emotional health/well-being subscale score ≥73 (Montross, 2006)
	MOS SF-36 Mental/emotional functioning subscale score (Vahia, 2010)
	MOS SF-36 Social functioning subscale score (health-related quality of life) (Vahia, 2010)
	SF-36 Mental Health Index score (Windsor, 2009)
	Quality of Life-Alzheimer's Disease Scale (QoL-AD) scores (Livingston, 2008)
	Ryff Scale of Psychological Well-Being (Lawler-Row, 2010)
	Ryff Scale of Psychological Well-Being abbreviated version (Lawler-Row, 2006)
	Subjective well-being composite variable (Friedman, 2010)
	Psychological Well-Being Questionnaire-Environmental Mastery subscale (sense of mastery, competence in managing the environment) (Oswald, 2007)
	Philadelphia Geriatric Center Morale Scale (PGCMS) sum score (Wiesmann, 2008)
	Philadelphia Geriatric Center Morale Scale (PGCMS) score ≥10 (median) out of 17 (agitation/attitude toward aging/lonely dissatisfaction) (Jang, 2009)
	Philadelphia Geriatric Morale Scale (PGMS) score from 0 to 5 (attitude toward aging) (Vahia, 2010)
	Philadelphia Geriatric Center Morale Scale (PGCMS) aging satisfaction subscale (Jopp, 2006)
	General Health Questionnaire–Short Form (Israeli version) summary scale score (morale) (Litwin, 2006)
	Positive and Negative Affect Schedule (PANAS) positive and negative affect scores (Oswald, 2007)
	Positive and Negative Affect Schedule (PANAS) (German version) positive and negative affect scores (Knappe, 2009)
	Positive and Negative Affect Schedule (PANAS) daily frequency of positive affect in relation to quality of interpersonal relationships (Steca, 2010)
	CES-D score (Hsu, 2009; Mjelde-Mossey, 2009)
	CES-D score <4 out of 8 (McLaughlin, 2009)
	Geriatric Depression Scale (GDS-15) score (Evans, 2009; Oswald, 2007)
	Geriatric Depression Scale (GDS-15) score ≤5 (Almeida et al., 2006)
	Geriatric Depression Scale (GDS) score <5 (Ng, 2009)

	Geriatric Depression Scale (GDS) score ≤10 out of 30 (Young, 2009)
	Hamilton Rating Scales for Depression (HRSD) and Anxiety (HRSA) (Driscoll, 2008)
	Symptom Checklist depression subscale (Bosma et al., 2007)
	≤1 negative item on Hopkins Symptom Checklist Anxiety subscale (shortened 4-item version) (Young, 2009)
	Brief Symptom Inventory (BSI) anxiety scale score (Vahia, 2010)
	Excellent to good range on Self-Evaluation of Economic and Mood Status scale (Li, 2006)
	No reported sadness, loss of interest, or irritability at present or in preceding interval (Ostbye, 2006)
	Happiness rating ≥8 out of 10 (Young, 2009)
	GHQ-12 score ≥5 (no psychiatric morbidity) (Bowling, 2006)
	No self-reported mental diseases (Jang, 2009)
Physical Functioning and Ability	Barthel index score=100 (Gondo, 2006; Puig-Domingo, 2008)
	ADL (Bosma et al., 2007)
	Independent in all ADL (Ostbye, 2006)
	No disabilities in basic ADL (Cohen, 2009)
	No/little difficulty performing ADL (score <10) (Bowling, 2006)
	No difficulty performing 6 ADL items (McLaughlin, 2009)
	ADL items from health-assessment questionnaire (score of 0 versus ≥1 out of 6) (Gjonca, 2008)
	Perceived independence in ADL using Neuropsychological Aging Inventory (Oswald, 2007)
	Ability to perform ADL and IADL (Weir, 2010)
	Performed all ADL (Korean version) with no difficulty (Jang, 2009)
	Absence of difficulties with ADL or IADL (Korean versions) items (Park, 2010)
	ADL and IADL (Chinese version) total score of ≤15(Li, 2006)
	Self-reported level of assistance required with instrumental and general ADL (Meisner, 2010)
	Adapted ADL/IADL scales consisting of 11 items (6 ADL, 5 IADL items) (Perrig-Chiello, 2006)
	ADL score=5 and IADL score=5, or ADL score=5 and IADL score ≥4, or ADL score ≥4 and IADL score≥3 (excellent/very good/good) (Tyas, 2007)
	ADL Staircase (extension of Katz's ADL Index) comprising 5 PADL and 4 IADL items (Oswald, 2007)
	Independent in all IADL (Ostbye, 2006)
	Independent in IADL (Ng, 2009)
	IADL score ≥25 out of 28 (Cohen, 2009)
	No difficulty on Nagi's 7 physical performance variables (Young, 2009)
	Maximum of 1 difficulty with any of 7 physical functioning measures (McLaughlin, 2009)
	No physical disability (Li, 2006)
	Excellent/very good/ good self-rated function (Tyas, 2007)
	Moderate/very satisfied with ability to care for self without help, believes health does not affect activities (Cohen, 2009)
	MOS SF-36 Physical functioning subscale score (Lamond, 2009; Vahia, 2010)
	MOS SF-36 Physical functioning scale score reflecting no limitation in ability (Montross, 2006)
	MOS SF-36 Physical Component Summary score (physical function, role limitations due to physical problems, pain, general health perception) (Steptoe, 2006)
	RAND-12 Physical Health Component score (levels of disability caused by physical health problems) (Windsor, 2009)

	No assistance required as a result of poor health on the Restriction of Activities Scale (Baker et al., 2009)
	Mean walking speed (8-foot course), lung function (forced expiratory volume),SF-36 physical component (Britton, 2008)
	Everyday Problems Test (EPT) 21-item version (Gregory, 2010)
	Living independently (Montross, 2006; Ostbye, 2006)
	Not institutionalized at any time during the follow-up (Kaplan, 2008)
General Health Status	*Do you feel healthy?* (Habib, 2007)
	Good/excellent self-rated health{326} (Cohen, 2009)
	Good/very good/excellent self-perceived health (Gjonca, 2008; Ramage-Morin, 2006; Steptoe, 2006)
	How would you rate your overall health at this time (Mjelde-Mossey, 2009)
	Reported no long-term conditions expected to last or have already lasted ≥6 months that have been diagnosed by health professional (Baker et al., 2009; Weir, 2010)
	Self-report of clinician-diagnosed long-term illnesses expected to last, or having already lasted, ≥6 months (Meisner, 2010)
	Self-report of whether doctor had ever told them that they suffered from various diseases (Gjonca, 2008)
	No more than the median (≤2) of self-reported number of chronic conditions (Jang, 2009)
	No diagnosed chronic medical conditions (Bowling, 2006)
	None of 17 chronic conditions (Young, 2009)
	No incidence of coronary heart disease, stroke, cancer, diabetes mellitus, depression, or Adult treatment Panel III metabolic syndrome (Britton, 2008)
	Absence of cancer, heart/lung/diabetic disease, or symptoms of stroke, no untreated hypertension (Cohen, 2009)
	Absence of cancer, chronic lung disease, diabetes, heart disease, or stroke (McLaughlin, 2009)
	Absence of self-reported cancer, diabetes, high blood pressure, heart attacks, other heart disease, stroke, osteoporosis, Parkinson's disease, or respiratory disease (Montross, 2006)
	No diagnosis of cancer, stroke, cardiovascular or pulmonary chronic diseases (Puig-Domingo, 2008)
	Absence of self-reported Parkinson's disease, stroke, cardiovascular disease, diabetes mellitus, or other serious physical illness (Ostbye, 2006)
	Proportion of the total number of chronic health conditions divided by the total number of conditions assessed (Ko, 2007)
	Cumulative Illness Rating Scale–Geriatric (burden of medical co-morbidity) (Driscoll, 2008)
	Self-rated intact visual and hearing functions (sensory functioning) (Gondo, 2006)
	Self-reported hearing and vision functions (Ostbye, 2006)
	Physical health composite variable (not being sick, no major morbid conditions, functioning well physically) (Friedman, 2010)
	Hospitalization (Engberg, 2009)
	Either no hospital admissions or no mental health hospital discharges/cancer registrations, and number of acute hospital bed days ≥25th percentile value for whole group of resident survivors (Gilhooly, 2007)
	Mean number of hospital days per year during specified period (Engberg, 2009)
Social Functioning	Visiting friends/family ≥1 day per week (Montross, 2006)
	Sum of number of days per week respondent reported visiting family/friends (Lamond, 2009)
	High frequency of social contacts (Bowling, 2006)
	Being married, having good friends living in neighbourhood, or getting together with neighbours for social visit at least once per week (McLaughlin, 2009)
	Sum of ratings on positively interacting with others, engaging in activities with others, having suitable social network (Friedman, 2010)

	Lubben Social Network Scale (LSNS-6) Friends and Relatives subscales (Windsor, 2009)
	≥3 confidants or close friends (Cohen, 2009; Montross, 2006)
	How much one trusts their native and actual family members, partner, friends, neighbours, and colleagues (Steca, 2010)
	Locke-Wallace Marital Adjustment Test (social support) (Ko, 2007)
	Social Relationship Index score (likelihood rating of going to 5 categories of people for support) (Ko, 2007)
	Support/help available in all 5 areas of life enquired about (Bowling, 2006)
	Interpersonal Support Evaluation List (perceived social support) (Driscoll, 2008)
	Moderate/very satisfied with emotional support from family/friends, being useful to others (Cohen, 2009)
	Self-rated frequency of feeling useful to family and friends (Gruenewald, 2007)
	Provided help to family, friends or neighbours external to respondent's household; cared for sick or disabled adult (Hank, 2008)
	Social participation in ≥1 activity (Jang, 2009)
	Engaged in ≥3 different social activities during past month (Bowling, 2006)
	Self-rated frequency of social engagement (Windsor, 2009)
	Participation in >1 social or productive activity at least once per week (Ng, 2009)
	Mean score of ≥8 on 5 engaging with life items (Young, 2009)
	Actively engaged in voluntary or charity work during previous month (Hank, 2008)
	Engaging in voluntary unpaid work on a regular basis after turning age 65 (Warburton, 2008)
	Habitual participation in political, cultural, or recreational public events (Steca, 2010)
	Usual participation in activities organized by volunteer, cultural, religious, or recreational associations (Steca, 2010)
	Summary activity index score on each of physical hobbies, nonphysical hobbies, and social activity (Dodge, 2008)
	Self-ratings on four items from Adelaide Activity Profile (Hoppmann, 2008)
	Volunteered in past 12 months, currently working, spend time caring for children younger than 18 years (Jung, 2010)
	Doing work for pay at present time, any volunteer work in previous year, or caring for grandchildren >100 hour during prior two years (McLaughlin, 2009)
	≥3 instrumental linkages, or working, or does heavy and light housework (Cohen, 2009)
	Participation in job activities, religious gatherings, or volunteer service (Park, 2010)
	6 items adapted from Religious Background and Behaviour Scale reflecting public religious participation or private spirituality (Ostbye, 2006)
	Self-report of living with someone else, having someone to trust/confide in, being able to see relatives/friends as often as wanted, currently Employed (Ostbye, 2006)
	Sum of ratings on having concrete goals to contribute to society, remaining active in work activities (paid/unpaid), continuing to accomplish things (Friedman, 2010)
	<35 hours/week in leisure-time sedentary activities and *very strong/somewhat strong* sense of belonging to community or member of voluntary organization or association (Baker et al., 2009; Meisner, 2010; Weir, 2010)
	Frequency of reading newspapers/books, navigating internet, performing sports (Steca, 2010)
Mental Status and Cognitive Functioning	MMSE score (Driscoll, 2008)
	MMSE score ≥28 (excellent), ≥26 (very good), or ≥24 (good) (Tyas, 2007)
	MMSE (Chinese version) score ≥26 (Ng, 2009)
	MMSE (Korean version) score ≥26 (Jang, 2009)
	MMSE score ≥24 (Almeida et al., 2006; Young, 2009)
	MMSE score >23 (Puig-Domingo, 2008)

	MMSE score ≥21 (Gondo, 2006)
	MMSE score > education-adjusted cut-off (Chaves, 2009)
	MMSE (Chinese version) score ≥4 points above educational specified cut-off (Li, 2006)
	Education- and sensory-adjusted MMSE score ≥78 (Ostbye, 2006)
	Global cognitive index score (learning and memory, word-finding ability, executive function, speed and processing, numerical ability) (Gjonca, 2008)
	Cognitive Failures Questionnaire (CFQ) score (Lamond, 2009)
	Cognitive Failures Questionnaire (CFQ) score (subjective complaints) (Vahia, 2010)
	Cognitive Assessment Screening Test (CAST) score (test-based performance) (Vahia, 2010)
	Cognitive Abilities Screening Test-Revised (CAST-R) score (Lamond, 2009)
	≥median score on tests based on Telephone Interview for Cognitive Status (McLaughlin, 2009)
	WMS-III subtest (logical memory, faces, verbal paired associates, family pictures, letter-number sequencing, spatial span) scores (Gregory, 2010)
	Logical Memory Test–immediate and delayed recall (episodic memory) (Driscoll, 2008)
	Number-Letter Sequencing Test (working memory) (Driscoll, 2008)
	Digit Span Forward and Backward scores (memory) (Ko, 2007)
	Delayed Word Recall ≥7, ≥6 or ≥5 (excellent/very good/good) (Tyas, 2007)
	Test of Nonverbal Intelligence-III (TONI-III) (Driscoll, 2008)
	Age-79 IQ score, converted from raw Moray House Test (MHT) score (Gow, 2007)
	Verbal Meaning test and Advanced Vocabulary test scores (crystallized intelligence) (Ko, 2007)
	Letter and Pattern Comparison Test of Salthouse, Primary Mental Abilities Spatial Relations, Letters series test scores (fluid intelligence) (Ko, 2007)
	Alice Heim 4-I cognitive test (verbal, mathematical reasoning) (Britton, 2008)
	23 items covering episodic, semantic and general memory (Habib, 2007)
	Able to keep mind on things (Cohen, 2009)
	Bother due to forgetfulness in daily life (Bosma et al., 2007)
	Cognitive Dementia Rating score=0 (Gondo, 2006)
	Dementia Rating Scale score ≥130 out of 144 (Cohen, 2009)
Psychological Functioning	Connor-Davidson Resilience Scale (CD-RISC) score (Vahia, 2010)
	Often true/true nearly all of the time on 4 CD-RISC items measuring positive adaptation and mastery/growth (Montross, 2006)
	Revised NEO Personality Inventory (NEO-PR-R) score (neuroticism) (Ko, 2007)
	Aggression Questionnaire (AQ) summed score (Ko, 2007)
	Brief Symptom Inventory (BSI) hostility scale score (Vahia, 2010)
	Life Orientation Test-revised summed score of 3 items (optimism) (Ko, 2007)
	Life Orientation Test score (optimism) (Lamond, 2009; Vahia, 2010)
	Best optimism score <6 on Scheier and Carver's optimism-pessimism scale (Bowling, 2006)
	Self-rated happiness ≥8 out of 10 (Young, 2009)
	Self-Efficacy Scale (SES) score (Vahia, 2010)
	Schwarzer's Self-Efficacy Scale best score <11 (Bowling, 2006)
	Personal Mastery Scale (PMS) score (Vahia, 2010)

	Strongly agree/agree and *strongly disagree/disagree* with 2 personal mastery items (Young, 2009)
	Purpose in Life (PIL) total score (Flood, 2006a; 2006b; 2010)
	Multidimensional Health Locus of Control Scales (MHLC) (Knappe, 2009)
	Life Experience Survey (number and severity of stressful life events) (Driscoll, 2008)
	Perceived Stress Scale (subjective stress associated with on-going events) (Driscoll, 2008)
	The Brief COPE instrument (individual coping strategies for a given stressor) (Driscoll, 2008)
Self-rated Successful Aging	*How successfully do you think you are aging?* (Ferri, 2009)
	Self-rated on 10-point scale (Lamond, 2009; Montross, 2006; Moore, 2007; Vahia, 2010)
	Categorized as 'successful' based on response to *Do you think your aging has been successful?* (Lee, 2009)
	Agreement with *I am aging well* (Montross, 2006)
	Perceived successful aging at work as a sum score across 8 items (Robson, 2007)
Risk Factors	No smoking (Cohen, 2009)
	BMI score (Driscoll, 2008)
	BMI score <30 (Cohen, 2009)
	Systolic and diastolic blood pressure (Ko, 2007)
	Median exercise, as reflected in diary-based reports (Driscoll, 2008)
	Dental status (false teeth) (Habib, 2007)
	Years of education (Driscoll, 2008; Habib, 2007)
	Chronological age (Habib, 2007)
Longevity	Alive at follow-up (Britton, 2008)
	Age ≥70 years, and age ≥75 years (Habib, 2007)
	Age ≥80 years (Almeida et al., 2006)
Environment	Annual gross income >£7,280 (Bowling, 2006; Jang, 2009)
	Very good/good area facilities (Bowling, 2006)
	Very good/good environment to go for walk (Bowling, 2006)
	Feels very safe walking alone in am/pm (Bowling, 2006)
	Few reported problems in area (score 24-30) (Bowling, 2006)
Other	Health Utilities Index Mark 3 (HUI3) score ≥0.89 (vision, hearing, speech, ambulation, dexterity, emotion, cognition, pain/discomfort) (Kaplan, 2008)