Feeling healthy versus being healthy: Discrepancies between subjective and objective health in older adults

A dissertation submitted for the degree of
Doctor of Philosophy

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To my family for their unending love and support:

John, Clare, Kate, Michael, Rocky, Minnie & Rosie

Abstract

Background: With increasing age, older adults experience declines in health, often in the form of reduced functionality, increased multimorbidity and waning cognitive capacity. Despite such declines, some older adults provide stable (and sometimes even improving) subjective appraisals of their health over time – even in the face of declining objective health. Growing dissociations between subjective and objective health scores in later life mean that some older adults may provide overly 'health optimistic' or 'health pessimistic' appraisals of their health. However, consensus on how these individuals should be identified is lacking. Additionally, the long-term health implications of being overly health optimistic or pessimistic in later life is considerably underexplored.

Methods: To address this, the present thesis describes a health asymmetry framework, a metric which classifies older adults into groups, based on the level of agreement between their subjective and objective health scores ('health optimistic', 'health pessimistic', 'good health realistic' and 'poor health realistic'). Using four nationally representative, secondary archived datasets across Europe, including one instance of primary data collection, the thesis longitudinally investigates how these health asymmetry categories are associated with mental and functional health sequelae over time.

STUDY 1 utilises data from wave one of the Irish Longitudinal Study of Ageing to create a health asymmetry metric. Self-rated health scores were compared to scores from a Frailty Index, in a sample of n=6907 older adults (aged 50+ years), resulting in the derivation of the following categories: 'health optimistic', 'health pessimistic' and 'health realistic'. Multinomial logistic regressions found that being health pessimistic was associated with psychosocial factors such as increased anxiety, increased loneliness and decreased social connectedness. In contrast, being health optimistic was associated with increased levels of vigorous exercise and alcohol consumption.

STUDY 2 describes how a sample of older English adults transitioned from one health asymmetry category to another, across waves one to three of the English Longitudinal Study of Ageing. Using first-order Markov transition and generalised logit models, health realistic individuals were likely to remain health realistic over time. The prevalence of the health optimistic category increased over two wave transitions, while the health pessimistic category yielded volatile, unstable transition probabilities.

STUDY 3 investigated how baseline health asymmetry status predicted depressive symptoms and change in depressive symptoms over time in European older adults. Using data from the Survey of Healthy Ageing and Retirement in Europe, multilevel growth curve models found that health pessimists consistently had the highest levels of depressive symptoms over time. Health optimists had a gradually declining trajectory of depressive symptoms across a 14-year study period.

STUDY 4 explored whether health asymmetry categories differentially predicted the risk of an injurious fall in older Swedish adults. Data from the Swedish National Study on Ageing and Care in Kungsholmen were utilised. A set of time-varying Cox and Laplace regressions found that health optimists had the most elevated risk of experiencing an injurious fall of all health asymmetry categories, which may be due to their poor OH and optimistic biases which make health pessimists believe they are not at risk of falling.

STUDY 5 involved intensive primary data collection from a sample of n=53 middle aged and older Irish adults, through a smartphone-based Ecological Momentary Assessment design. Health anxiety data were collected over the course of a 6-day study period. Growth mixture modelling found that two latent trajectories of health anxiety evolved over the study period. Health asymmetry categories did not significantly predict health anxiety scores over time.

Conclusions: Health asymmetry appears to be a clinically relevant tool which is significantly associated with depressive symptomatology, injurious falls and mortality. Health asymmetry may be more useful as a summary tool for large-scale population-based studies, given that the metric can be retrospectively constructed using secondary data. Future research should consider exploring the association between health asymmetry and other important physical and functional health outcomes in older adults, such as psychological distress and multimorbidity.

Declaration

I hereby declare that I have produced this manuscript without the prohibited assistance of any third parties and without making use of aids other than those specified.

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- Calvey, B., Maguire, R., de Andrade Moral, R., & McHugh Power, J. (2023). Health asymmetry as a predictor of depressive symptomatology over time among older European adults: A growth curve analysis. *Journal of Psychosomatic Research, 166*, 111158.
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List of Abbreviations

AIC	Akaike Information Criteria
ADL	Activities of Daily Living
B	Unstandardised Beta Estimate
BIC	Bayesian Information Likelihood Criteria
BADL	Basic Activities of Daily Living
CCI	Charlson Comorbidity Index
CSO	Central Statistics Office
ECI	Elixhauser Comorbidity Index
EHR	Electronic Health Record
eFI	Electronic Frailty Index
ELSA	English Longitudinal Study of Ageing
EMA	Ecological Momentary Assessment
EURO-D	EURO-Depression
FI	Frailty Index
GMM	Growth Mixture Modelling
GP	General Practitioner
HA	Health Asymmetry
HADS	Hospital and Anxiety Depression Scale
HAT	Health Assessment Tool
HR	Hazard Ratio
IADL	Independent Activities of Daily Living
ICD-10	International Classifications of Diseases 10th Edition
IR	Incidence Rate
ISCED-97	International Standard Classification of Education 1997

LMR-LRT	Lo-Mendel-Rubin Likelihood Ratio Test
MICE	Multiple Imputation using Chained Equations
MMSE	Mini Mental State Examination
OH	Objective Health
OR	Odds Ratio
PRO	Patient Reported Outcomes
SSBIC	Sample Size Adjusted BIC
SE	Standard Error
SES	Socioeconomic Status
SF-36	Short Form Survey 36
SH	Subjective Health
SHARE	Survey for Healthy Ageing and Retirement in Europe
SNAC-K	Swedish National Study on Ageing and Care in Kungsholmen
TILDA	Irish Longitudinal Study on Ageing
WHO	World Health Organisation
WI-6	Whiteley Index 6
Z	Z-score
α	Cronbach's alpha
β	Standardised coefficient
χ^2	Chi-square
η^2	Partial eta-squared
Λ	Wilk's Lambda for Likelihood-ratio test

CHAPTER 1

Feeling healthy versus being healthy: An introduction

*A*s older adults age, they can experience rapid declines in objective health, often in the form of reduced functionality, increased multimorbidity and waning cognitive capacity. However, older adults tend to provide stable or even improving subjective health scores over time, despite experiencing declines in objective health. As a result, a paradox in subjective versus objective health exists in later life (French et al., 2012; Wettstein et al., 2016), where growing dissociations between subjective and objective health are observed in older populations. These growing dissociations over time mean that older adults have a greater likelihood of becoming overly optimistic or pessimistic about their objective health status. As we will see, health pessimism and optimism may have implications for physical, mental and functional health outcomes.

The present thesis describes a novel approach for quantifying discrepancies between subjective and objective health, using a 'health asymmetry' metric. Previous research identified discrepancies between objective and subjective health using a 2x2 indicator variable, which required researchers to identify somewhat arbitrary cut offs between good and poor subjective health (SH) and objective health (OH). Here instead, older adults are classified into categories ('health optimistic', 'health pessimistic', 'good health realistic' and 'poor health realistic') using a 'distance-based' approach; that is, relying on the quantitative discrepancy between measurements of SH and OH. A set of longitudinal, observational cohort studies using secondary data are conducted, to determine how clinically meaningful a health asymmetry metric may be.

To provide a context for the development of the health asymmetry metric, this chapter will first review various definitions of health from relevant disciplines and describe different approaches to the measurements of health used in research and clinical practice – with a particular emphasis on subjective and objective indicators of health. Then, the paradox inherent in subjective and objective health in later life will be outlined and health asymmetry as a clinically relevant solution to this paradox will be discussed. The chapter will culminate with an overview of the aims and objectives of the thesis.

1.1 What is health?

1.1.1 How conceptualisations of health developed over time

The attempt to define health has a complex history. Ancient conceptualisations of health largely fell under the influence of religion and divine gift (Tountas, 2009). Hippocrates, who posited that disease resulted from bodily imbalances, helped shift the concept of health away from divine notion to tangible observation (Longrigg, 2013). Hippocratic medicine considered health to be a state of balance in four humours (i.e. blood, phlegm, black bile and yellow bile), maintained through behavioural and medicinal actions. Over time, Hippocratic concepts of health morphed into contemporary biomedical models of health (which have viewed health predominantly as the absence of pathology) and formed the basis for all modern health practices in the developed world (Farre & Rapley, 2017). However, biomedical approaches to health came under criticism in the early to mid-20th century. Such approaches are arguably too narrow, since they focus just on the somatic experience and presence or absence of disease, while ignoring psychosocial aspects of health (Guinn, 2001; Leonardi, 2018), such as cognition, mental disorders or sleep.

With increasing knowledge accumulated about psychosocial aspects of health during the 20th Century, contrasting definitions of health arose and the World Health Organisation (WHO) subsequently defined health in a way that would quickly be considered the cornerstone of the health definitions.

In 1948, the WHO defined health as “a state of complete physical, mental and social well-being and not only the absence of disease and illness.” This definition was developed during World War II, when the United Nations created the WHO to spark global health initiatives for individuals all over the world, to achieve “the highest possible level of health” (Jadad & O’ Grady, 2008). The definition was the product of a complicated process before, during and after World War II involving international health diplomats, policymakers from within and outside of health policy and scholars from social medicine (Larsen, 2022). The definition has remained unchanged since its foundation in 1948 and, at the time, was considered a revolutionary way of thinking as it expanded concepts of health beyond the Hippocratic, aetiological approach. The definition encompassed more than mere physical attributes of disease by also recognising the importance of well-being and the role of social determinants which affect an individual’s health outcomes and quality of life. The WHO’s definition challenged political and academic organisations to allocate resources to achieve the lofty goal of universal well-being (Jadad & O’ Grady, 2008), while also being considered a positive step forward in the perception of health (Saracci, 1997).

However, others have criticised the WHO’s definition of health, noting that it is unfit for dealing with the new challenges arising from a rapidly ageing population and the increasing number of people living with chronic illness. Firstly, the WHO’s definition conflates health with well-being (Callahan, 1973; Saracci, 1997). Secondly, the WHO’s definition of health is not entirely measurable (Huber et al., 2011; Saracci, 1997) and has not generated useful health standards (Habersack & Luschin, 2008). “Complete well-being” encompasses a wide range of subjective experiences, which makes it difficult to quantify health in a standardised, objective way. Unlike measurable biomarkers or clinical symptoms, well-being relies heavily on subjective perceptions and social context, which vary across individuals and within individuals over time. This subjectivity challenges establishing concrete criteria for assessing health status. Thirdly, the phrasing surrounding “complete” health and well-being is problematic, as “complete” implies a state that is nearly impossible to achieve. Naturally, achieving a complete sense of well-being for those who are affected by chronic illness and disease is unrealistic, though achieving “complete health and well-being" for those unaffected by chronic illness and disease is unrealistic too. Being symptom free for a long period of time is unlikely: the average adult experiences about four symptoms (i.e. a somatic experience which may or may not manifest disease or illness) in a 14-day period (Wood, 1986). The WHO's definition implies that health, conceived as a complete state, could be only a temporary state, at least for the average individual. Huber and colleagues (2011) also reinforced that the WHO's definition proposes unattainable health standards that make almost all people unhealthy most of the time. Ultimately, the WHO's definition is becoming more unfit with time, as the focus of modern healthcare has shifted towards managing chronic illnesses, promoting functionality, and improving quality of life, rather than achieving a "complete" and permanent state of health (Larsen, 2022).

The WHO's definition of health has largely remained untouched since its inception. The WHO since added that health can be defined as a "resource for every day life" (WHO, 1986), though the vagueness surrounding this definition has caused other definitions to emerge in disciplines such as social science and psychology, where a greater emphasis was placed on psychosocial aspects of health. For example, Baumann (1961) argued that health has a "feeling state orientation", a "symptom orientation," and a "performance orientation". Twaddle (1974) suggested that possible meanings of health include an intrinsic notion of well-being, the absence of adverse, worrying symptoms or identifiable medical conditions, the ability to carry on with normal activities, the ability to recover from serious disease, not expecting to get sick, and being told by a physician that one's health is good. Both definitions straddle a biomedical and a psychological approach to defining health.

In response to the limitations of biomedical models, George Engel adopted a biopsychosocial approach to health, which recognises and integrates biological processes, psychological states and social contexts in shaping an individual's health outcomes (Engel, 1977). This approach to health gained widespread acceptance, addressed reductionistic, medical thinking and shaped contemporary approaches to health. However, similar to critiques of the WHO's definition of health, the biopsychosocial model can be challenging to operationalise in clinical practice. Effectively assessing and measuring the interplay between biological, psychological, and social processes presents notable methodological challenges for researchers and healthcare practitioners (Alvares et al., 2012).

In the late 1970s, social constructivist views of health and illness emerged in the field of medical sociology. These views considered health to be socially constructed, influenced by social norms and values and varying across cultures and historical periods. Kelman (1975) adopted a broad, holistic definition of health, describing it as “the capacity for human development and self-discovery and the transcendence of alienating social circumstances” (p. 634). Shortly after, Lidler (1979) defined health and illness as subjective human experiences or social phenomenon which encompass both wellness and malaise, with an objective and subjective reality. Such constructivist views of health contributed to our understanding of health and illness by providing a counterpoint to deterministic approaches of that medicine adopted (Conrad & Baker, 2010). However, these views may overlook the biological realities and determinants of health and illness, while falling victim to challenges of measurement. It is recognised that social constructivist approaches may be most useful when integrated with biological and psychological perspectives of health (Olafsdottir, 2013).

1.1.2 Towards a modern definition of health

While the variance in health definitions across the scientific literature is, in part, a theoretical issue, this has clear implications for public policy and healthcare practice. Some theorists have attempted to reconcile all approaches to health into one cohesive definition. Bircher (2005) proposed that health should be defined as “a dynamic state of well-being, characterised by an individual’s physical, mental and social potential to meet the demands of life unique to the individual’s age, culture and personal responsibility”. Dunlop et al (2012) recently characterised health as a multidimensional, complex and highly desirable outcome and state of being, attempting to incorporate different biomedical and psychosocial approaches to health. However, this definition, along with many others, may not be sufficiently nuanced for clinical application. For example, defining health solely based on a Western, upper-middle-class standard may lead to cultural biases and underestimations of health among different demographics (Leonardi, 2018).

Leonardi (2018) suggested that health might be more effectively understood by examining the ways in which knowledge about health is constructed and validated, emphasising the need to assess both subjective and objective elements of health. Leonardi argues that an epistemological approach to health may be useful, where it embodies many definitions, depending on its use. Based on recent scientific debate, Leonardi summarises that future health definitions should recognise the following: 1) health should be viewed as an iterative, dynamic process, 2) which extends beyond the absence of disease and biophysical parameters, 3) it should also be conceptualised as a capability, reflecting a cluster of abilities rather than a static state, 4) that is achievable for everyone, 5) while also encompassing both malaise and well-being so to acknowledge that individuals often experience negative emotions without losing their overall health, 6) health definitions must also overcome individualistic views, recognising the influence of social and contextual factors on health, 7) which are independent of moral and ethical discourse, 8) and should consider an individual's priorities and needs, taking subjective experiences of health into account and 9) while also being a measurable and practical concept.

1.1.3 How should health status be measured?

The way in which health is defined subsequently determines the way it should be measured. Since definitions of health have evolved over time, so too have the ways in which health is operationalised. In the early 20th century, an orthopaedic surgeon called Codman proposed an "end result idea", which involved the long-term follow-up of a patient, post-surgery, to determine if their treatment was a success or not (Kaska & Weinstein, 1998). The development of this "end result idea" was largely rejected by health measurement experts (Neuhauser, 1990), as it only determined the extent of post-surgery recovery, and not necessarily providing an indication of an individual's health status. This was also not a feasible method of measuring health on a population level.

After the Second World War, clinical researchers developed scales to measure the outcomes of procedures and to assess overall health status more adequately. Karnofsky (1948) developed the first performance-based measure (a 10-point observer-rated scale capturing the level of physical dependency defined by nursing burden). Katz's Activities of Daily Living Scale improved on this measure, by broadening the focus to aspects of quality of life (Katz, 1970). The development of new scales across medicine arose in the late 20th Century (Herndon, 1997), with increasing recognition of the importance of assessing a broader array of health outcomes when measuring general health status.

In the 1970s, the focus of health evaluation moved from traditional clinical outcomes (i.e., mortality) to the measurement of function (i.e., the ability of individuals to perform activities of daily living) (Stewart & Ware, 1992). This shift from traditional outcome measures to the wider encompassing measurement of health occurred, because of: 1) the introduction of the WHO's broadened definition of health (1948), 2) the rising standards of living, 3) the increasing prevalence of older adults and 4) the development of health technology. This caused a shift in attention from the cure of acute diseases to the management of more complex, chronic conditions (e.g., rheumatoid arthritis, multiple sclerosis, inflammatory bowel disease etc.) (Cano & Hobart, 2011).

Patient Reported Outcome (PRO) instruments, such as the Nottingham Health Profile and the 36-item Short Form Survey (SF-36), were then developed and widely used across clinical populations to assess general health status and quality of life (Hunt et al., 1986; Ware, 1993). More targeted PROs, including dimension-specific (e.g., mood), disease-specific (e.g., cancer), site-specific (e.g., cardiovascular) scales became prominent (Aaronson et al., 1993; Cano & Hobart, 2011; Dawson et al., 1996; O' Boyle et al., 1993; Zigmond & Snaith, 1983) Ultimately, there have been incremental shifts from operationalising health status in terms of long-term post-surgery follow-up to more nuanced instruments which capture wide arrays of patient outcomes.

Currie & Madrian (1999) outlined eight types of measures that are used to operationalise health in a practical capacity: (1) self-rated health status; (2) health limitations on the ability to work; (3) functional disability, such as problems with activities of daily living (ADL); (4) disease prevalence and presence of chronic and acute conditions; (5) medical care utilisation; (6) clinical assessments of health constructs (e.g., blood markers, alcoholism assessments, physical performance tests etc.) which may be viewed as surrogate outcomes reflecting underlying health conditions; (7) nutritional status (e.g., height, weight, body mass index (BMI) etc.); and (8) expected or future mortality. The application of each measure of health depends on the context: assessing ADLs may be suitable in older populations, while measuring nutritional status or BMI is relevant in any society, but is particularly relevant for assessing health in developing countries. Currie & Madrian (1999) do not distinguish between between all-cause and cause-specific mortality in their publication. Another consideration is that nutritional status measures (such as weight and BMI) are anthropomorphic measures, which are still clinical assessments of health constructs, yet they are separated here as different health measures.

In practice however, expansions of health definitions beyond aetiological parameters may be discouraged by some. In an insurance-driven system, health coverage is usually tied to measurable, treatable conditions or outcomes. Broadening the definition of health might involve addressing aspects like mental well-being, social support, or preventive care, which may not always have clear, quantifiable outcomes, as opposed to outcomes directly affected by medical expenses, such as hospital admissions, surgeries, and specific disease treatments. For broadened health definitions to be funded in an insurance-driven system, the following needs to be considered: 1) insurers would need to see that investing in broader health measures (e.g., preventive care, mental health support) leads to reduced healthcare costs in the long run (Naylor et al., 2012; Taylor et al., 2016) and 2) there would need to be an integration of the social determinants of health into health insurance (Onwujekwe et al., 2019), which might encourage insurers to fund services that target broader health aspects like nutrition, housing or access to mental health services.

1.2 Objective versus subjective measures of health

1.2.1 Objective and subjective health: how do they differ?

The eight types of health measures that Currie & Madran (1999) outline differ in terms of their objectivity and subjectivity (Ware et al., 1981). Typically, in doctor-centered healthcare practices, the focus is often on medical tests, diagnostics and quantifiable health indicators, often at the expense of understanding the patient's own experience of their health. This focus on objective testing and observation is referred to as an individual's medically determined, objective health (OH) status. Healthcare practitioners rely on indicators of OH to gain insight into one's overall health status and to provide a roadmap for what further objective tests should be conducted, if necessary. The evaluation of OH status for scientific and public health purposes has been the province of healthcare professionals (who are assumed to be the best judge of health, due to their training) and clinical testing (due to their assumed reliability and validity) (Hunt & McEwen, 1980).

In contrast, subjective health (SH) relates to an individual's evaluation of their own health status, which typically encompass physical, cognitive, and psychological aspects of an individual's health (Baron-Epel & Kaplan, 2001). SH is naturally reported by the individual, using comprehensive PROs or briefer single items. In one study of Irish older adults, poorer subjective health responses were attributed to specific conditions and mobility issues, while optimal subjective health responses were attributed to lack of disease, fewer mobility issues and less healthcare utilisation (McHugh Power et al., 2016). Given the strong construct and predictive validity as a general health indicator, measures of subjective health are recommended for inclusion in all major health surveys (De Bruin, 1996). As such, an individual's subjective perception of their own health status differs from their OH status, in that subjective health assessments are reliant on subjective interpretations, requiring inference to interpret them (Ware et al., 1981).

1.2.2 Which measures of objective health are used in research and practice?

Methods of OH measurement vary throughout research and clinical practice. Simple objective indicators of health are the first port of call for clinical practice (e.g. obtaining hypertension, BMI or pulse measurements). For example, if a clinical practitioner detects abnormal or irregular pulse patterns using an electrocardiogram, it may be interpreted as an early indicator of atrial fibrillation or coronary artery disease (Xia & Liao, 2018), but may also be indicative of something more benign. Therefore, further objective testing should be performed to confirm. Within research, OH is sometimes operationalised using physicians' ratings of patient health (Elder et al., 2017; Mossey & Shapiro, 1982) or physical performance tests such as gait speed or grip strength (Bohannon, 2019; Welmer et al., 2014). Similarly, single indicators of OH are utilised within medical and social research, where they are assumed to be an informative indication of OH status (Johnston et al., 2009; Leone & Hessel, 2016; Lundberg, 2006; Sutin et al., 2018).

However, in both clinical practice and research, measures of disease burden are often assumed to be equivalent to an individual's OH status, particularly when assessing OH in ageing populations (Cheng et al., 2020; Schübbe et al., 2023). Measures of disease burden, such as the Charlson Comorbidity Index (CCI) or the Elixhauser Comorbidity Index (ECI) (both of which are weighted count-based indices for measuring comorbidity and tools that are used for risk adjustment), are sometimes used. As disease burden has a pertinent influence on the cognitive, functional and psychological health functions of older adults, these multimorbidity indices are sometimes substituted as proxies for OH and remain a primary focus for public health policy and clinicians (Alfredsson & Alexander, 2016; Barnet et al., 2012; Bray et al., 2021; Charlson et al., 1987; Cheng et al., 2020; Elixhauser, et al., 1998; Gupta et al., 2010; Labaki & Han, 2020; Matcham et al., 2014;

Schübbe et al., 2023; Shimada et al., 2014; Yusuf, 1998).

1.2.3 Self-rated health: A single item measure of subjective health

In contrast to the objective measures described above, subjective measurements of health are multidimensional in nature, reflecting an individual's perception of their physical, functional, mental, cognitive or social health. The use of PROs in obtaining SH assessments often relate to a specific dimension of an individual's health, such as their health-related quality of life or their level of depressive symptomatology. For example, an individual can provide a subjective assessment of their health-related quality of life (using the SF-36 instrument) (Ware, 1993), or a subjective assessment of their levels of depressive symptomatology (using the EURO-D scale) (Prince et al, 1999). However, to obtain an indication of an individual's subjective health status, in general, a single item measure of self-rated health has become prominent within the literature, given its simplicity and strong evidence supporting its relevance as a health measure.

An item of self-rated health typically asks individuals how healthy they believe they are, with responses generally measured using a 5-point Likert scale (e.g. ranging from 'poor' to 'excellent'). This is a useful summary measure of population-level health status. For example, in Ireland's general Census of Population in 2022, 82% of the population reported their self-rated health as being either 'very good' or 'good', with 18% of the population reporting their SH as either 'fair', 'bad' or 'very bad' (CSO, 2022). Self-rated health is an independent predictor of morbidity and mortality, and is strongly associated with healthcare costs, mental health status, disease and functional status (Banerjee et al., 2010; Bierman et al., 1999; French et al., 2012; Idler & Benyamini, 1997; Jylhä, 2009; Meng et al., 2014).

The process of providing a self-rated health response incorporates cognitive (e.g. where an individual constructs and interprets what they know about health and their own health status) and emotional factors (e.g. optimism, pessimism, anxiety) that vary from person to person and form the personal evaluation of SH as an outcome (Jylhä, 2009; Manderbacka, 1998; McHugh & Lawlor, 2016). Jylhä (2009) proposed a model for assessing self-rated health, indicating that self-rated health is influenced by contextual frameworks of evaluation, with three steps involved in the self-appraisal. Firstly, respondents select health-related information that they believe is relevant when describing their health, for example, disease burden or functional health. Secondly, they combine this information with those deemed relevant and view them in reference to other factors to come to an evaluation of their own health, for example whether the individual has been diagnosed with a chronic condition or if they perceive their functional health as good or poor. Finally, they choose a pre-set self-rated health response option that best fits this evaluation.

The first two steps outlined by Jylhä (2009) may be easily influenced by internal and external factors. For example, Idler and Benyamini (1997) argue that self-rated health may internally reflect the full array of illnesses that an individual has, even symptoms of preclinical and prodromal diseases. Idler & Benyamini (1997) also argue that SH reflects external factors, such as family health history or the adequacy of resources to deal with future health problems (e.g. access to healthcare, living arrangements etc). In essence, SH provides a more holistic interpretation of health status than OH measures alone.

A meta-analysis has shown that general SH is moderately to strongly correlated with general indicators of OH (Pinquart, 2001), though it has also been shown to take psychological well-being, subjective comparisons of health to others of similar age groups and physical vitality into account too (Bailis et al., 2003). SH an important predictor of physical wellbeing in older adults (Lundberg & Manderbacka, 1996), with functional health (Idler et al., 1999; Krause & Jay, 1994), physical disorders (Borawski et al., 1996) and mental health (Mossey, 1995) all being vital predictors of SH among older adults. However, the association between SH and OH is complex. This association is influenced by socioeconomic status (Cundiff & Matthews, 2017) and potentially by personality (Elran-Barak et al., 2019). The association between general self-rated health scores and OH scores varies considerably by age, as growing dissociations between SH and OH being observed with increasing age (Chipperfield, 1993; Wettstein et al., 2016).

1.3 Should objective measurements of health be the gold-standard?

1.3.1 The dominance of objective health measures in research and practice

In medically-centered healthcare practices, there has traditionally been a hegemony of OH measures, such as diagnostic tests and clinical observations, over SH measures. The hegemony of OH is often at the expense of understanding a patient's experiences regarding their health which include patients' self-reports of symptoms, feelings, and personal experiences of their health (Bridges et al., 2011; Slevin et al., 1988). Despite the clear utility of SH measures, this hegemony of OH is rooted in a clinician-centered approach, where the clinician's perspective are prioritised over that of the patient in decision-making processes (Rogers & Pilgrim, 2021). OH measures are the first port of call for clinical assessment and allow for comparisons of health across populations. Similarly, OH measures have asserted dominance in health-related literature, due to their supposed reliability, validity and mathematical empiricism (Bourne, 2009). However, traditional OH measures may be too narrow to evaluate the broad spectrum of issues that can affect an individual's health status (Bourne, 2009). SH has been shown to predict mortality to a similar extent as OH, and sometimes being an even stronger predictor in the short-term (Idler & Kasl, 1991; Mossey & Shapiro, 1982). For example, in a Finnish study, poor SH was associated with nearly an eightfold risk of mortality over a 5-year period, compared to a fourfold risk for poor OH. This is despite OH measures often being assumed as gold-standard (Wuorela et al., 2020).

SH measures require inference to interpret them (Ware et al., 1981), while the opposite is often assumed for OH. However, the line between what defines an OH or a SH measure is sometimes blurred, with many health measures being labelled as objective, despite relying on some subjectivity. For example, some functional magnetic resonance images require subjective observations from clinicians, in order to interpret the images. Similarly, laboratory tests become less objective if, for example, the analyst has to judge the colour of a urine sample. Sometimes, so-called "objective" test results rely on subjective assessments from clinicians and are therefore not fully independent from SH (de Vet, 2011). Relatedly, physical performance tests, which are often included as measures of OH, particularly in ageing studies (Saadeh et al., 2020; Welmer et al., 2017), may blur the line between subjective and objective measures of health. Instructions for physical performance tests often need to be given by physiotherapists (Christ et al., 1993), whereby the level of encouragement or quality of instruction may vary greatly. Similarly, in cognitive tests, the instructions and support given by instructors may influence the motivation of the individual who is performing the test. As a result, the influence of the person carrying out the measurement introduces a subjective element in these "objective" performance-based tests (Nascimento et al., 2012). This raises a considerable concern: perhaps OH measures are mistakenly considered to be better than SH measurements (de Vet, 2011).

There are also concerns regarding the ubiquitous use of single indicators of OH across the health literature. By capturing only one indicator of OH or one aspect of an individual's health, there are fears that OH may introduce similar levels of measurement error associated with SH appraisals (Bound, 1989). Firstly, single indicators of OH may oversimplify health, which is now considered a dynamic, complex process (Leonardi, 2018). Indicators of OH such as hypertension or grip strength, while informative, only provide information about one specific domain of health. In addition to this, single indicators are often influenced by contextual factors. Grip strength varies based on age, sex, fatigue and even motivation during tests (Reuter et al., 2011; Vianna et al., 2007), while hypertension is strongly influenced by temporal stress levels (Unchino et al., 2006). These indicators may be limited as OH measures, as they may not be sensitive enough to detect subtle changes in health over time. For example, it may be possible that indicators such as grip strength or hypertension may not change within early stages of a chronic illness, and as such, fail to detect worsening health until the illness is more advanced (Delgado et al., 2018; Park et al., 2006).

Multimorbidity indices such as CCIs or ECIs are likely to be subject to considerable measurement bias too: they are merely estimates with some degree of imprecision of a given health dimension within a target population. While some research has shown that CCIs generated from self-reported data were comparable to data from administrative records in predicting one-year mortality risks (Chaudhry et al., 2005), the self-reporting of chronic conditions that constitute CCIs are still naturally dependent on subjective reporting and have also shown concerning results. Baker et al. (2004) matched a wide range of self-reported chronic health conditions to records of public healthcare usage in Canada. Findings indicated that such conditions are subject to a large amount of systematic reporting error as well, leading to large attenuation biases when used as explanatory variables. In approximately 50% of cases, for most chronic conditions examined, individuals used medical services but did not report their health condition in the survey. Additionally, the variability in coding practices may lead to inconsistencies in the comorbidity scores, while agreement between different multimorbidity indices can vary considerably (Mandelblatt et al., 2001; Silliman et al., 1999). These factors may limit the validity of multimorbidity indices as measures of OH (Denti et al., 2015). Another issue with However, some research argues that instruments like multimorbidity indices are appropriate measures of OH, since they capture the seriousness of chronic health conditions which are pervasive in later life (Ruthig & Chipperfield, 2007). Self-reported indices also have a clear advantage, which is the ease with which these can be collected in non-clinical populations.

Physicians' ratings of patients health should also not represent a gold-standard of health due to some concerns regarding their reliability (Krabbe, 2016). Previous studies found that physicians' ratings of various health outcomes were subject to measurement error and biases (Markides et al., 1993; Marquié et al., 2003). A systematic review even concluded that physicians have a limited ability to accurately self-assess patient health, with self-reports being suboptimal in quality (Davis et al., 2006).

Evidently, existing OH measures do not avoid measurement error and attenuation biases, and may still be reliant on subjective self-reporting in many cases. As an alternative solution to single indicators of OH, multimorbidity indices or physicians' assessments of patient health may be included in more comprehensive and multidimensional indices of health, to: 1) reduce likelihood of measurement error and 2) ensure that a holistic and multidimensional approach to measuring OH is adopted, rather than focusing on only one facet of health.

1.3.2 Attempts to rectify measurement issues regarding objective health

Some research has attempted to compile indices of OH which capture its multidimensionality. Jürges (2007) complied a comparable health index which captures 'true' health on a scale from 0 to 1, with a score of 1 representing 'perfect' health. This index defined so-called perfect health as the absence of any health conditions, and therefore adopts concerns regarding biomedical definitions of health. Borawski et al (1996) created a composite score of OH, which accounted for number of chronic medical conditions, polypharmacy, pain intensity and presence of shortness of breath. They noted that capturing multiple indicators of OH provides better estimations of the severity of health conditions alone, while capturing those respondents who do not present themselves often to physicians (Liang, 1986). In a similar manner, Araújo et al (2018) created a composite score of OH, based on the number of self-reported diseases per individual and their functional capacity, measured by basic activities of daily living (BADL) and instrumental activities of daily living (IADL). These studies provided more comprehensive measures of OH, which included disease counts, functional capacity and some measures of general physical wellbeing, though are still absent of mental and psychosocial health indicators.

Johnston et al (2009) attempted to eliminate reporting bias from SH measures using other measures of health, typically available in survey data, using an approach referred to as a “purging method”. This method replaces actual reported SH values with predicted values of SH. These predicted values are derived from latent variable models that estimate SH as a function of other OH measures (as explanatory variables), such as presence of chronic conditions or gait speed for example. Demographic variables are included with the aim of purging further subjectivity and endogeneity in individuals’ self-reports. Johnston et al (2009) found that there was a weak positive correlation between these predicted and the associated raw values. This approach has been used in previous studies too (Disney et al., 2006; Zucchelli et al., 2007). However, it is not fully clear that these predicted OH values are void of subjective reporting errors. Johnston et al (2009) also noted that this purging approach is problematic if the demographic variables used to inform the prediction are directly associated with the measurement error of SH, which often is the case (Butler et al., 1997; Jürges, 2007; Mackenbach et al., 1996). Overall, difficulties arise when collecting OH data on a large scale, as in order to approximate OH status, researchers may have to rely on some form of subjective reporting of health.

Alternative health measures have emerged in health economics, such as Quality-Adjusted Life Years (QALY) and Disability-Adjusted Life Years (DALY), which indicate health outcome measurements that combine duration and quality of life (Zeckhauser & Shepard 1976) and duration and disability (Murray & Acharya, 1997), respectively. The intent for both these measures is in cost-effectiveness analyses in healthcare, however the theoretical underpinnings of the two metrics differ (Neumann et al., 2018).

QALY is a measure that combines both the length of life (in years) and the quality of life (measured by utility values, ranging from 0 for death to 1 for perfect health). The product of these two factors gives a single value that reflects both how long an individual lives and the quality of their life during that time. Utility values in QALY represent an individual’s preferences or perceived well-being in different health states, based on the "welfarist" economic view that individuals are the best judges of their own welfare. However, QALYs also incorporate "extra-welfarist elements", which may include considerations beyond individual preferences, such as the impact of health states, functionality, and broader societal perspectives on well-being (Brouwer et al., 2008). A QALY score of 1 represents one year of life in perfect health, while values less than 1 indicate years lived in less-than-perfect health, with the score adjusted based on the quality of life during those years.

In contrast, DALYs serve as a summary measure of the burden of disease, which helps inform healthcare resource allocation decisions. DALYs assess disease burden at a population level, capturing both the years of life lost due to premature mortality and the years lived with disability, accounting for both the severity and duration of such disability (Gore et al., 2011). The disability weights used in DALYs are the inverse of the utility weights used in QALYs. These weights, which range from 0 (no disability) to 1 (death), are assigned to different health conditions to quantify their impact on an individual's quality of life. DALYs do not explicitly integrate extra-welfarist concepts. The disability weights are defined based on expert opinion, not individual surveys. This results in a standardised set of weights anchored to specific health conditions, which facilitates cross-cultural comparisons of disease burden, but may not fully reflect individual preferences or values.

However, there are some drawbacks to the interpretation of DALYs and QALYs as health measures. Firstly, the weights assigned to health states in QALYs and DALYs may not accurately reflect the actual well-being or health levels of individuals, leaving out important issues like fairness and equality, and discriminating against disabled people (Mosquera, 2023). Secondly, DALYs may not align with the definitions of disability according to WHO's International Classification of Functioning, Disability, and Health, ultimately leading to suboptimal indicators of public health interventions' effects on people with disabilities (Mont, 2007). Thirdly, these measures are also not easy to retrospectively construct using secondary archived datasets, which prohibits their use in this thesis.

1.3.3 Are subjective assessments any better?

SH measures can be extremely informative when compared to OH measures (Abrams et al., 2006; Sullivan, 2003) and can sometimes be even more informative than objective measures themselves (Hyland & Shevlin, 2024). However, SH measures are not independent of measurement and reliability issues. Despite its usefulness in both clinical and general populations, SH is still poorly understood – even after extensive research. Lawton et al (1967) suggested that SH is limited in its use due to defence mechanisms such as denial, somatisation distort and hypochondriasis (which is now referred to as severe health anxiety). Most notably, considerable measurement error exists with the estimation of SH (Sokol et al., 2017), which challenges interpretations of the measure. While OH measures may be subject to certain response errors and attentuation biases when used as explanatory variables (Baker et al., 2001), SH measures can be prone to biases due to personal and social factors (Kerhofs & Lindeboom, 1995). Additionally, there is vagueness around what SH actually measures for each individual (Jylhä, 2009).

There has been debate if SH reflects solely a physical perspective of health status or a more global, holistic interpretation of health. Some individuals may base their SH response on a specific health problem they are currently dealing with, while others may think more generally in terms of their health and functionality (Krause & Jay, 1994). The format or phrasing in which SH is obtained may also impact SH responses (Bonnesen & Hummert, 2002; Cape & McCulloch, 1999). Open-ended question formats may allow older adults to generate free responses and define the context in which they view their health rather than being restricted to prescribed categories (Bangerter et al., 2017), yet research has been mainly restricted to collecting responses on a five-point Likert scale.

Some argue that a problem with SH is that it may be an endogenous explanatory variable (Bound, 1989), making it a construct that is largely influenced by other factors. For example, the latent emotional and cognitive processes that underlie SH challenge the reliability of SH responses as an outcome (Layes et al., 2012). Cognitive or emotional reporting tendencies such as optimism and pessimism could trigger measurement error and bias in the reliability of SH, particularly in older adults. SH has also been found to correlate with both state and trait levels of positive and negative affect (Casten et al., 1997). Inducing negative affect has led individuals to perceive themselves as being in poor health (Croyle & Uretsky, 1987). Evidently, self-appraisals of health and emotional well-being are bidirectionally associated with one another (Abma et al., 2021).

Jylhä (2009) argues that there is no “gold-standard” measure of “true” health (that SH can be compared to). However, clinical practice and research has often pinned OH measures as not necessarily a gold-standard but perhaps a benchmark, which SH can be compared to (Ruthig & Chipperfield, 2006). By assuming that OH represents a gold-standard way of measuring health status, it devalues other measures. In fact, some research found that SH reflects a greater sensitivity in detecting changes in well-being than OH measures (Bailis et al., 2003; Saw et al., 2015), partially because SH allows individuals to access critical internal information (Idler & Benyamini, 1997). There is convincing evidence to suggest that measures of OH should not be considered “gold-standard”, but instead, simply what it is – a medically determined indication of health status – which may still carry measurement error and biases.

1.4 Subjective versus objective health in later life: A paradox

1.4.1 Trajectories of objective and subjective health in later life

SH is generally considered a reliable indicator of health status. However, early gerontologists noted inconsistencies between SH and OH indicators in older populations (Maddox & Douglass, 1973; Mossey & Shapiro, 1982), where these scores can often be paradoxically different (Abma et al., 2021; Brissette et al., 2003). SH and OH follow different trajectories throughout the life course, which results in growing dissociations between SH and OH over time (particularly in later life). As adults age, clear deteriorations in OH markers are noted (e.g., changes in bone density, cardiovascular health, gait speed etc.) (Burge et al., 2007; Guralnik et al., 1995), with the likelihood of developing chronic conditions increasing (Vetrano et al., 2018). However, such trends of deterioration are not mirrored in most SH indicators (Cohen-Mansfield et al., 2013, Wettstein et al., 2016). As a result, a paradox in subjective versus objective health arises; while we may become objectively less healthy over time, we do not always rate ourselves as less healthy, to match such OH changes.

SH shows some decline in older adults (Anstey et al., 2007; Chen et al., 2007; Pinquart, 2001). Such declines in SH are associated with waning functioning capacity and physical activity (Hirosaki et al., 2017; Leinonen et al., 2001), memory decline (Bendayan et al., 2017), increasing number of illnesses and medical appointments (Rodin & McAvay, 1992) and polypharmacy (Fillenbaum, 1979). However, SH does not decline with the same rate of change as would be expected from age-related OH decline (Ferraro, 1980; Henchoz et al., 2008). In Ireland’s Census of Population in 2022, all age groups reported a noticeable shift from good health to less than good health since the previous population census, except for older adults aged 75 years or older (CSO, 2022), whose SH remained stable. Older adults aged 75+ typically experience more health decline than their younger contemporaries, yet such declines were not self-reported in the nationwide census, providing descriptive evidence for relative stability in SH ratings. Cohen-Mansfield et al. (2013) found that older adults comprising different age groups (75– 84 years, 85–94 years and 95+ years) significantly varied in terms of OH indicators (e.g. comorbidities, activities of daily living, and instrumental activities of daily living) but not in terms of their SH scores. In some cases, SH can even improve in very old populations (Dening et al., 1998; Heller et al., 2009; Liang et al., 2005; Vogelsang, 2018). Nybo et al. (2001) reported that more than 50% of Danish nonagenarians rated their health as 'excellent' or 'good' despite high levels of disability and functional limitations. And similarly, centenarians tended to report 'good' health, despite high multimorbidity and functional restrictions (Jopp et al., 2016). Such discrepancies between SH and OH in older adults have casually been attributed to cognitive difficulties, recording errors, physiological dysregulation, emotional well-being, and social comparisons (Henchoz et al., 2008; Idler & Benyamini, 1997; Jylhä et al., 2006).

There is worth in examining SH changes from two perspectives: 1) changes in the nature and determinants of SH with older cohorts and 2) longitudinal within-person changes in SH over the life course. Firstly, SH may be experienced differently at different ages and may depend on determinants that vary according to age (Wolff et al., 2012). For example, with increasing age, the association between SH and various OH factors (particularly functional health) weakens, whereas the association between SH appraisals and psychosocial constructs such as depressive symptoms and positive affect strengthens (Benyamini et al., 2000; Spuling et al., 2015). Additionally, each age cohort might have different expectations of and attitudes towards health, which might affect their SH appraisals. These changes in the determinants of SH observed in later life, may explain why SH follows a different trajectory to OH.

Secondly, it is important to observe how an individual's perception of health might change over the life course. Assessing within-person change in SH over time may reveal patterns in how subjective assessments of health might adapt, possibly becoming more positive and less connected to an individual's objective declines in health. In previous years, various theoretical explanations have been proposed regarding within-person change in SH in later life. The following section will consider these theoretical explanations which may explain why SH may follow a less clearly defined trajectory of decline, specifically in older cohorts.

1.4.2 Some theoretical explanations for the paradox

A paradox in objective and subjective health in later life captures the idea that people's expectations surrounding their health co-evolve with the health norms surrounding one's age, and where growing dissociations between SH and OH scores are observed over time. Some explanations for this paradox have been proposed. Response shift theory posits that individuals reconceptualise and reprioritise internal standards and self-appraisals over time, which may result in older adults assessing SH to a different standard than younger individuals (Sprangers & Schwartz, 1999). It may be that older adults have capabilities for a self-protective adaptation to irreversible declines of OH and functioning in very old age, and that they may experience "response shifts" of such internal health standards (Sprangers & Schwartz, 1999), particularly when their concept of what constitutes good health changes.

It may also be that older adults revisit and reconsider their health standards and priorities as they grow older, when comparing themselves with similarly-aged peers, when accepting the ageing process and growing presence, or more importantly, after a significant decline in OH status (Kurpas et al., 2013; Robinson-Whelen & Kiecolt-Glaser, 1997; Sharpe & Curran, 2006; Spini et al., 2007; Ubel et al., 2005). Thus, older adults might be forced to adjust their SH perceptions to lowered standards and expectations (Galenkamp et al., 2012), to avoid suboptimal quality of life. These points are considered a sort of 'scale recalibration', in the context of age-adjusted health expectations (e.g. "I'm relatively well off, considering my age"; Moser et al., 2013) and temporal and social comparisons (particularly downward comparisons), which contributes to positive SH responses in old age (Albert, 1977; Frieswijk et al., 2004; Suls et al., 1991).

Spuling et al (2017) found evidence for an SH response shift in older adults, where SH responses were maintained by utilising two response shifts: a recalibration (retrospectively overestimating baseline health relative to concurrent ratings) and reprioritisation (re-evaluating SH after a serious health event). Evidence for response shifts exists in other areas of wellbeing research too: patients with life-threatening diseases or disabilities were found to report a stable quality of life (Andrykowski et al., 1993; Bach & Tilton, 1994). Some research however claims that this response shift and reconceptualisation of health standards may not entirely be a desirable adaptive psychological response to worsening OH, but may also be interpreted as a form of measurement bias (Galenkamp et al., 2012; Visser et al., 2000), where the outcome measure, a change in SH, is not fully determined by the variable of interest, a change in OH.

An age-related positivity effect regarding SH appraisals could explain relative stability of SH in older age. This positivity effect in older adults has been defined as a relative preference for positive information over negative information during cognitive processing (Charles et al., 2003; Reed & Carstensen, 2012). According to socioemotional selectivity theory, emotional goals are increasingly prioritised later in life (Carstensen, 2006). Consistent with this motivational shift, an age-related positivity effect has been documented, showing that older adults process a greater proportion of positive information relative to negative information, compared with younger adults (Mather & Carstensen, 2005). An age-related positivity effect is present when older adults exhibit a memory bias for positive stimuli over negative stimuli (Sanders et al., 2021). Perhaps a similar effect is noted when older adults provide SH appraisals in later life.

While an age-related positivity effect and selective information processing may seem an adaptive psychological response to deteriorating OH, failing to process negative information in certain medical contexts may also be maladaptive in nature. Perhaps when rating health status, older adults may focus on their still healthy and physically intact functions, rather than focusing on aspects of health decline and suboptimal objective functionality which they should also be aware of (Carstensen & DeLiema, 2018). Despite this, recent research has concluded that an age-related positivity effect may only be at play when goal-directed cognitive processing is operating or, in other words, if negative health information which is processed by older adults is goal-relevant, a positivity effect may not be observed (English & Carstensen, 2015; Juang & Knight, 2016).

Selective survivorship may also explain the increasingly strong association between age and optimistic health perceptions (Idler, 1993). The oldest-old may be better able to adapt to declines in health and down-regulate negative psychological responses to such decline (Wettstein et al., 2016), causing gradual increases in dissociations between SH and OH, with increasing age. In other words, long-term survival against declining health and functionality may result in a later-life dissonance between worsening OH, but stable SH.

Wettstein et al (2016) reasoned that the absence of considerable SH decline in older adults can be attributed to building resilience and expertise after life and health-related events. These types of comparisons and changes in expectations are desirable adaptive responses to health decline, but they make it challenging to interpret SH across different age groups. Also, the accumulation of health problems over time may overburden very old individuals' capabilities to maintain positive attitudes toward their health and functioning.

However, very old age may provide conditions for older adults to adapt to worsening health and to down-regulate negative psychological responses to such changes. Considering that the capacity of humans to interpret and judge their bodily states positively may not end late in life, very old adults could be forced to increasingly use this capacity when faced with health and functioning. As a result, old age may come with an increasing dissociation between OH and SH scores. Theoretically, a lifelong capacity of optimistic health perceptions may exist, with positive reframing of health problems and protective illusions. Specifically, living into very old age may be accompanied by expertise and resilience (Staudinger et al., 1995), as discussed previously. Therefore, long-term survival to very old age may result in an increased ability to psychologically adapt to accumulating health deficits, which would result in a "late-life ambiguity" of worsening objective functioning, but relatively stable SH appraisals (Wettstein et al., 2016).

1.4.3 The role of personality and cognitive impairment

SH ratings arise from multidimensional, complex, dynamic cognitive evaluation processes (Knäuper & Turner, 2003; Simon et al., 2005; Jylhä, 2009). Therefore, there may be various predictors that are of importance for varying trajectories of SH, including some that might work against worsening perceptions of health and functioning even when OH declines occur. Personality may play a pertinent role regarding health in older populations because certain personality traits may help or hinder adaptation to the onset of health problems (Sprangers & Schwartz, 1999). As an example, individuals with higher neuroticism scores tend to use less adaptive coping strategies when stressors occur, as compared to individuals with low neuroticism (Gunthert et al., 1999). Personality traits, particularly neuroticism (McCrae & Costa, 1987) seem to be more strongly associated with indicators of subjective functioning (such as perceiving and reporting symptoms) as compared with indicators of objective functioning (Friedman & Kern, 2014; Löckenhoff et al 2012), where the association strengthens with age (Duberstein et al., 2003). Perhaps, personality contributes to the slower decline of SH when compared to OH decline.

Additionally, severe cognitive impairment in older age may impair the utility of SH responses. SH is an independent predictor of mortality, through the knowledge of past and current health experiences, implicit comparisons with people of similar age and health status. These mechanisms rely considerably on the cognitive processes of the respondent. This raises questions about the reliability of an SH measure in respondents with varying degrees of cognitive impairment. Previous research reported that, in the presence of severe cognitive impairment, SH responses no longer remain a predictor of mortality (Walker et al, 2004; Park & Chung, 2021), and that cognitive alteration may make SH appraisals unreliable, particularly in patients with dementia (Hickey & Bourgeois, 2000). Essentially, the utility of SH may be impeded in cases of severe cognitive impairment and the reduced ability to integrate necessary data to assemble an SH appraisal. As cognitive impairment is more prevalent in very old adults, it may result in gradual increasing dissociations between SH and OH over time.

1.5 A Health Congruence framework: Discrepancies between health measures

1.5.1 What is health congruence?

Discrepancies between SH and OH were hypothesised to be associated with mortality in older adults (Chipperfield, 1993; Peterson & Bossio, 1991), similar to SH scores being an independent predictor of mortality. To identify those whose SH is at odds with their OH status, and to test their association with mortality, Chipperfield (1993) proposed a 'health congruence' framework. This framework classified individuals into groups, based on the level of agreement between their SH score (self-rated health estimation) and their OH score (which was originally based on a simple count of diseases and chronic illnesses).

Chipperfield (1993) identified two forms of incongruence: 1) optimistic appraisals of poor health and 2) pessimistic appraisals of good health. Essentially, four groups of individuals were identified: 'health optimists' (those who provide positive SH estimations despite poor OH), 'health pessimists' (those who rate their SH as poor despite good OH), 'good health realists' (those whose good SH aligns with their good OH score) and 'poor health realists' (those whose poor SH aligns with their poor OH score). Findings indicated that cases where SH was better than OH (i.e health optimism) led to health benefits and resulted in longer survival over an eight and 12-year follow-up, when compared to those who had congruent SH and OH scores. However, it was only in those older adults who exhibited an "extreme" overestimation of OH which resulted in health optimism-related survival benefits. Those whose SH scores were worse than their OH (i.e health pessimism) experienced more rapid declines in health and mortality after an eight and 12 year follow-up.

Chipperfield used terms such as congruence and incongruence rather than 'overestimations' or 'underestimations', to challenge the underlying assumption that OH is a gold standard of health (Markides et al., 1993) and that SH reflects a distortion of reality. The health congruence framework also allows for distinguishing between health optimists and good health realists (who have similarly good OH levels), and between health pessimists and poor health realists (who have similarly poor OH levels), yet different SH appraisals.

1.5.2 What are the implications of health incongruence?

Since the development of Chipperfield's health congruence framework, research has investigated how the alignment between SH and OH is associated with an array of physical and mental health outcomes in older populations. Health congruence categories have been associated with functional status and healthcare usage, with health pessimists having the lowest functional health status and utilising healthcare services more than other health congruence groups (despite their relatively good OH) (Hong et al., 2004). Health incongruence has also been associated with well-being, depressive symptomatology and health behaviours, with health optimists showing lower levels of depressive symptomatology and greater engagement in exercise than other health congruence categories (Hong et al., 2004; Hong et al., 2005).

Other health congruence research relates to aging (Kunzmann et al., 2000), physical activity (Ruthig & Chipperfield, 2007), sense of control (Ruthig & Chipperfield, 2007), social engagement (Ruthig & Allery, 2008) and cognition (Abma et al., 2021). There is a consistent link between SH/OH discrepancies and general well-being and health outcomes, even considering that many methods of operationalising OH have been used (Ruthig &

Chipperfield, 2007), ranging from simple counts of chronic health conditions (Chipperfield, 1993) to comorbidity indices (Hong et al., 2005) to physician ratings (Maddox & Douglass, 1973).

1.5.3 Limitations within the literature on health congruence

However, previous health congruence studies are limited in four manners. Firstly, using comorbidity indices or simple counts of chronic conditions as a proxy for OH is not entirely suitable for older populations. While multimorbidity is of great concern in older populations, limiting the measurement of OH to a simple disease count is insufficient, as the multidimensionality of health is clearly being ignored (Cacioppo & Berntson, 2011; Currie & Madran, 1999; Leonardi, 2018; Shaw & Mackinnon, 2004;) and reduces health to a traditional/historical biomedical model which is questioned by theorists (Guinn, 2001; Leonardi, 2018). Declining health in older adults is also marked by functional, psychosocial and cognitive health decline (Colón-Emeric et al., 2013; Diehr et al., 2013; Lin et al., 2013; Pronk et al., 2014), which is ignored by biomedical approaches to health. While some health congruence research has attempted to reconcile multidimensional approaches to measure OH, such as disease prevalence along with IADLs/BADLs (Araújo et al., 2018; Borawski et al., 1996), they still do not account for a fully holistic interpretation of health status.

Secondly, most health congruence research relies on cross-sectional analyses (Elder et al., 2017; Hong et al., 2004; Ruthig & Allery, 2008). This reliance on cross-sectional studies to date mean that studies are limited in their ability to infer causal relationships between health congruence and various health sequelae. For example, discrepancies between SH and OH are associated with depressive symptoms (Hong et al., 2004; Rai et al., 2019), however, it remains unclear whether discrepancies between SH and OH predict future levels of depressive symptoms or even predicting change in depressive symptoms over time. Such questions could be answered using, prospective, longitudinal designs, however, few have been conducted in the health congruence literature (Borawski et al., 1996; Chipperfield, 1993; Ruthig & Chipperfield, 2006). A goal of this thesis is to conduct a set of longitudinal, cohort studies to fill in subsequent gaps in the literature, and to determine whether discrepancies between SH and OH have longitudinal, causal implications.

Thirdly, past research has not considered a breadth of outcome variables in relation to health congruence. Although health congruence is associated with depression (Hong et al., 2004), it also may be linked to other aspects of psychological functioning, such as health anxiety or generalised anxiety, which have not been previously explored. The gap between feeling unwell subjectively, while simultaneously being told by medical assessments that one's health is fine, or vice versa, may have implications for broader psychological distress. Additionally, it is possible that health congruence shares a common factor with other aspects of psychological functioning, such as health anxiety – where underestimating an individual's OH status (i.e. health pessimism) may result in increased health anxiety to some degree. There is also insufficient evidence surrounding the stability of these categories over time. It is worthwhile exploring whether states of health optimism or health pessimism are more stable/unstable than others. For example, if health pessimism is found to be a more unstable category than health optimism, it is possible that health pessimism could be a beneficial therapeutic or intervention target.

Relatedly, research has also shown that discrepancies between SH and OH are associated with functional decline and functional status (Maddox & Douglass, 1973; Ruthig & Chipperfield, 2006). When individuals perceive their health to be better than it objectively is, they may engage in riskier behaviours, and it might affect how individuals adapt their environment or activities to match their physical capabilities. Those who perceive themselves as healthier than they are, might not use mobility aids or fail to make lifestyle adjustments, which increases physical decline. Discrepancies between SH and OH may also be relevant to everyday physical activity or to functional decline outcomes, such as the risk of injurious falls – however these outcomes have not been explored yet. Ultimately, a broader range of health sequelae need to be considered, as the literature thus far is considerably limited.

Finally, past studies have not considered whether different forms of health congruence play differential roles depending on the type of outcome. It may be that the protective effects of health optimism are limited to psychological well-being, but the adverse outcomes of health pessimism are broader and relate to well-being, functionality and health care. This would be consistent with past findings that optimism and pessimism relate differently, not diametrically, to health outcomes (Kivimäki et al., 2005). This issue cannot be addressed by examining the linear effects of SH while adjusting for OH. Applying a health congruence framework permits examination of the two forms of health incongruence (optimism and pessimism) and their potentially different relations with well-being. However, the limitations of the health congruence framework merit an extension of the framework, which considers a more appropriate method of operationalising OH.

1.6 Are multidimensional indices of objective health a suitable solution?

1.6.1 Can a frailty index act as a proxy for objective health?

Given that modern characterisations of health and well-being reflect physical, functional, cognitive and psychosocial and disease-related components of health, one potential construct that would be worth exploring in ageing populations is frailty, a clinically pertinent geriatric condition (van Kan, 2008). Frailty has been defined in varying ways; as a physical disability which results in impairment in IADLs/BADLs and as a clincally recognisable state of increased vulnerability, resulting from age-associated decline in reserve and function across multiple physiologic systems (O'Halloran et al., 2014; Sternberg et al., 2011). However, more recent research has focused on cognitive and social factors associated with frailty (Ávila-Funes et al., 2009; Fisher et al., 2005; Rothman et al., 2008). An operational definition of frailty is important for clinical care, research, and policy planning (Ferucci et al., 2004; Walston et al., 2006). Fried's definition of frailty includes three or more of the following: weight loss, weakness, exhaustion, low activity level, and slow gait speed, which forms the basis of Fried's Frailty Phenotype (Fried et a., 2001). This syndrome of frailty, however, ignores the cognitive and psychosocial aspects of frailty which have received attention in recent years (Ruan et al., 2015; Navarro-Pardo et al., 2020).

The Frailty Index (FI) is a commonly deployed instrument in older populations (Mitnitski et al., 2001). A typical FI counts deficits in health (which may be symptoms, diseases, disabilities, or objective health abnormalities) that may be present within an older adult (Searle et al., 2008). The FI reflects a global health-related structure, as different health deficits which can be considered in the index cover physical, cognitive, functional, psychosocial health and disease diagnoses. Given that the FI has a global health-related structure, it may have relevance as an OH measure in older populations (Rockwood et al., 2014). The interpretation of an FI as a measure of health status in older populations is apt, as it incorporates different facets of health as outlined by Currie & Madran (1999). The FI has been interpreted as a measure of OH in previous investigations (Cheung et al., 2023; Hosseini et al., 2022; Wu & Zhang, 2023; Wuorela et al., 2020), as it forms a holistic indication of a participant's frailty and relative functionality, physical, and cognitive health status.

Some research indicated that there are no considerable differences between self-reported and test-based FIs (Theou et al., 2015), despite concerns of self-reporting health information introducing measurement error. Some studies even purport that an electronic Frailty Index (eFI) has usefulness as a health measure and can be used in risk stratification in older adults (Abassi et al, 2019; Boyd et al., 2019; Mak et al., 2022). Although there is some inconsistency regarding the agreement between a traditional measurements of frailty and eFIs, with some research proposing that eFIs are suitable replacements for traditional methods of measuring frailty (Lin et al., 2023), while others argue that eFIs have the propensity to overestimate the prevalence of frailty in community-dwelling older adults (Broad et al., 2020).

1.6.2 An objective Health Assessment Tool

Other efforts to create a comprehensive OH measure for older populations have reconciled measures of functionality, morbidity burden, disability, and physical markers such as gait speed. For example, an objective Health Assessment Tool (HAT) was developed using data from the Swedish National Study on Aging and Care in Kungsholmen (SNAC-K), Stockholm using nationally representative data (Santoni et al., 2017). HAT summarises OH status in the study population, by integrating 5 objectively tested health indicators into a composite score, using nominal response models: 1) gait speed (measuring physical function), 2) count of chronic diseases (measuring multimorbidity), 3) a Mini-Mental State Examination (measuring cognitive function), 4) number of IADLs an individual could not perform independently (measuring mild disability) and 5) number of BADLs an individual could not perform independently (measuring severe disability). HAT has been touted as an appropriate method to assess and track health changes in older adults, that has the potential to detect unexpected health decline and new care needs, while also accurately predicting cases of mortality and unplanned hospitalisation over 3 and 5 year follow-ups (Santoni et al., 2017; Santoni et al., 2020; Zucchelli et al., 2019), matching the prognostic value of other health measures such as FIs, Frailty Phenotypes etc.

1.7 Health Asymmetry: An extension of the Health Congruence framework

1.7.1 Borrowing from other asymmetry typologies

This thesis compares SH and OH scores in older adults using a type of asymmetry metric which has been implemented in different corners of the psychological literature. A 'social asymmetry' metric was developed to identify discrepancies between social isolation and loneliness, two constructs which are often conflated, despite social isolation reflecting an objective, measurable phenomenon, while loneliness captures subjective appraisals of insufficient social engagement (McHugh Power et al., 2017). Social asymmetry calculates the standardised scores of social isolation and loneliness measures and then subtracts loneliness scores from social isolation scores to derive a discrepancy score. A one standard deviation cut off of this discrepancy score is used to identify 'concordant' individuals (displaying matching levels of loneliness and social isolation) and 'discordant' individuals (experiencing either greater loneliness than expected given their social isolation (i.e. social vulnerability or less loneliness than expected (i.e. social resilience) (McHugh Power et al., 2019).

The categorical variable which results from this asymmetry framework has been touted as a clinically meaningful metric: it is associated with cognitive functioning, all-cause mortality, and generativity (i.e. internal beliefs and motivations towards contributing to future generations) (McHugh Power et al., 2019; Ong et al., 2024; Ward et al., 2021). Social asymmetry borrows also from similar typologies used to describe premorbid and cognitive functioning (Benke, 2011; Bondi et al., 2008). A similar approach to identifying discrepancies between SH and OH may also be appropriate.

1.7.2 The potential utility of a health asymmetry metric

Risk stratification is an important public health priority that is central to clinical decision making and resource allocation. Identifying older adults who may be at risk of adverse physical, functional, mental health outcomes should therefore be a primary concern for healthcare practitioners and for public policy. A health asymmetry metric, that compares SH and OH scores in older adults may be a useful addition in this context. As a clinical tool for healthcare practitioners, identifying those who may be more health optimistic or pessimistic than their peers may be useful in assessing risk in a variety of different health contexts, such as attempts to reduce risk of injurious falls, or identifying older adults who may experience increased depressive symptoms.

The research described in this thesis presents a new approach for quantifying discrepancies between SH and OH. Previous research derived health congruence categories using an unflexible 2x2 indicator variable. Borrowing from other asymmetry metrics, this thesis will nclassify older adults into potentially clinically meaningful categories using a distance-based approach (which refers to quantifying the "distance" or discrepancy between standardised SH and OH scores), where older adults may be classified as health optimistic, pessimistic or realistic, based on how far their standardised SH and OH scores are apart. Additionally, by quantifying the discrepancy between SH and OH scores, we will be left with a raw discrepancy score which provides more flexibility and granularity for statistical analyses than previous 2x2 indicator variables, while also leading to larger effect sizes.

There are considerable gaps that exist within the health congruence literature that could be addressed by health asymmetry. Health asymmetry will introduce a slight paradigm shift in the interpretation and subsequent measurement of OH in older adults, by introducing multidimensional indices of health (such as FIs, HATs etc) as proxies for OH. These OH indices capture different facets of health in older populations such as disease prevalence, physical and cognitive functioning along with mental health quality. This is in direct contrast to previous health congruence research which failed to account for all facets of health decline experienced by older adults. However, a health asymmetry metric would account for the the synergistic combination of OH and SH, which makes a health asymmetry metric an interesting measure. The complex interplay between SH and OH (and how they shift over time) in later life means that older adults may be differentially at risk for various adverse health outcomes, depending on whether they display a more optimistic, pessimistic or realistic perception of their own health status. Additionally, this thesis will extend previous health congruence research by conducting a set of longitudinal, observational cohort studies using archived secondary datasets and one instance of intensive primary data collection, to determine how clinically meaningful a health asymmetry metric may be, over longer and shorter timeframes. The thesis primarily incorporates different nationally representative datasets from across Europe, to ensure the generalisability of our findings across older European adults.

1.7.3 Overview of Thesis Structure and Objectives

The present thesis explores how health changes over time, how our perceptions of our health change over time and how these health perceptions in later life are predictive of critical geriatric outcomes over short and long time periods. To address prevailing gaps in the health congruence literature, three objectives were identified: 1a) to develop a 'health asymmetry' metric which quantifies discrepancies between SH and oH scores in older adults, 1b) to investigate the stability of these health asymmetry categories over time and 2) to conduct a set of observational, longitudinal studies to determine whether health asymmetry is a clinically useful metric in predicting various health sequelae over time.

Chapter Two outlines the framework for a health asymmetry metric, which derives three categories ('health optimists', 'health pessimists' and 'health realists') using secondary data from the Irish Longitudinal Study of Aging (TILDA). This chapter also investigates the sociodemographic, psychosocial and health behaviour factors associated with being health optimistic or health pessimistic, using multinomial logistic regressions, to pinpoint what areas of health in older adults that future health asymmetry research should focus on.

Chapter Three extends this further by introducing a fourth health asymmetry category. The study further divided the 'health realistic' category into two groups ('good health realists' and 'poor health realists'). Using data from the English Longitudinal Study of Ageing (ELSA), a prospective, observational study was conducted, where older English adults were tracked across three waves of data collection, to identify how they transitioned from one health asymmetry category to another. First-order Markov transition models (to estimate transition probabilities) and generalised ordinal logit models (to identify trends in health asymmetry change over time) were conducted.

Chapter Four utilises data from the Survey for Healthy Ageing and Retirement in Europe (SHARE) to track depressive symptomatology in older European adults across a 14-year follow-up period. Using multi-level growth curve models, it is estimated whether baseline health asymmetry predicts depressive symptoms or change in depressive symptom trajectories over time, accounting for country of origin.

Chapter Five assesses whether health asymmetry categories differentially predict the risk of injurious falls in Swedish older adults. Using data from the Swedish National of Aging and Care in Kungsholmen (SNAC-K), community-dwelling older adults were followed over a ten-year time period. Time-varying Cox proportional hazard and Laplace regression models estimated injurious fall risk.

Finally, in Chapter Six, an Ecological Momentary Assessment (EMA) study tracked health anxiety in older Irish adults over a 6-day period. The study aimed to determine whether baseline health asymmetry status, SH and OH scores predict health anxiety for the remaining study period. Finally, Chapter Seven critically evaluates the overall clinical utility of health asymmetry in light of the five empirical studies conducted. The chapter also outlines public health and policy implications of the present thesis, providing a roadmap for future health asymmetry research.

CHAPTER 2

Expecting the best or fearing the worst? Describing a health asymmetry framework

Bill Calvey, Joanna McHugh Power, Rebecca Maguire

Abstract

Older adults have the propensity to rate their subjective health (SH) score incongruently with their objective health (OH) status. As a result, we: (1) devised a health asymmetry metric which categorises older adults into groups based on the discrepancy between their SH and OH scores, and (2) investigated which factors predict group membership. Data from the Irish Longitudinal Study of Ageing (TILDA) were utilised in our cross-sectional study. A health asymmetry metric categorised n = 6907 participants (aged 50+ years) into three groups: 'health pessimistic' where participants rated their SH worse than their OH, 'health realistic' where participants' SH and OH were congruent and 'health optimistic' where participants rated their SH better than their OH. A Frailty Index was used as a proxy for OH. A multinomial logistic regression modelled the ability of a set of sociodemographic, psychosocial, and health behaviour variables in predicting membership of health asymmetry categories. Approximately 69% - of the study population were categorised as 'health realistic'. The prevalence rates of health optimistic individuals increased in older age groups, and conversely, health pessimistic rates decreased in older age groups. Most notably, psychosocial factors significantly predicted being health pessimistic: such as anxiety (OR = 1.03), loneliness (OR = 1.04), and decreased social connectedness (OR = 0.87). However, less clear sociodemographic, psychosocial, and health behaviour associations were found for being health optimistic. Health asymmetry is a useful method of identifying at-risk individuals of discrepancies between SH and OH. The ability of this metric to predict clinical mental health outcomes should be investigated further.

2.1 Introduction

As discussed in Chapter One, self-rated health, or subjective health (SH) is a multi-dimensional and complex health construct, which relates to the subjective perception of an individual's own health status. This can simply be measured by asking an individual how healthy they think they are, with five potential response options, typically ranging from 'poor' to 'excellent'. Interestingly, SH reveals a considerable amount of information about an individual's disease, functional status and mental health (French et al., 2012; Meng et al., 2014). SH is considered a reliable proxy for objective health (OH) status and has been shown to independently predict mortality (Bath, 2003; Falk et al., 2017; Idler, 2003). As a result, SH is an interdisciplinary measure, ubiquitously deployed in many fields of research, including psychology, epidemiology, and economics. Despite its usefulness however, the subjective measure is undoubtedly complex and still poorly understood – even after extensive research. Most notably, considerable individual variability exists in the estimation of SH (Sokol et al., 2017), which leads to some difficulties with interpreting SH as a health measure.

Gaps in understanding of SH are not due to a lack of empirical evidence, but rather vagueness around what SH actually measures (Jylhä, 2009). This includes inconsistent operational definitions, latent, unobservable processes and response biases. For example, there has been contestation over whether SH solely measures physical health or a more global perspective on an individual's health. Krause and Jay (1994) note that, in response to an SH item, some participants base their rating on specific health problems they suffer from, whilst others think more generally in terms of their health behaviours and functionality. This highlights the importance for consistency and accuracy in phrasing and response options when collecting SH ratings (Cullati et al., 2020). The WHO (1996) recommended that SH responses included five worded responses, preferably ranging from ‘very good’ to ‘very bad’. Few changes have been recommended since, though the phrasing of SH has still varied internationally. For example, responses in some European studies have ranged from ‘very good’ to ‘bad’, with other variations of this too (Jylhä et al., 1998; Robine & Jagger, 2003). Another explanation for the lack of understanding surrounding SH is that a latent process underlies the process of providing an SH appraisal (Layes et al., 2012). Cognitive or emotional reporting tendencies such as optimism and pessimism could trigger measurement error and bias in the accuracy of SH, particularly in those aged 80+. Consequently, such biases along with other measurement intricacies and individual differences may result in unexplained discrepancies between an individual’s SH and OH status.

Despite the difficulties in interpreting SH as a measure of health, it is undoubtedly useful. SH is considered to be a reliable indicator of an individual’s OH status (Lundberg & Manderbacka, 1996). However, comparing the agreement of an individual’s SH to their OH status is not a straightforward process. Given the multi-dimensional nature of health, a gold-standard OH scale is unrealistic. Previous studies have operationalised OH as the amount of disease diagnoses a patient has received, combined with measures of functional capacity, such as Instrumental Activities of Daily Living (IADLs) and Basic Activities of Daily Living (Araújo et al., 2018). An issue with such measures, however, is that health is more complex than just disease and functional status. Other aspects of health, such as cognitive and mental health, seem to be ignored. Similarly, research in economics has merely focused on single indicators of OH, for example hypertension, rather than an index or more extensive measures of OH (Johnston et al., 2009; Suziedelyte & Johar, 2013).

As discussed in Chapter 1, one potential measure that may be used to estimate OH status, is the Frailty Index (FI), which is commonly deployed in ageing populations (Mitnitski et al., 2001). Frailty has been defined as the susceptibility to decreased reserve, decreased response to stressors, and reduced functionality (O'Halloran et al., 2014), and has also been recognised as a pertinent and clinically relevant geriatric condition (van Kan et al., 2008). The FI measures global health-related structures and covers a range of measures of health, such as cognitive, functional, physical health, and illness diagnoses (Searle et al., 2008). For example, the FI can include health deficits such as whether an individual has had joint replacement surgery, or whether they experience chronic pain. Given its global health-related structure, the FI has the potential to be interpreted as a health measure in older patients (Rockwood et al., 2014). The application of FI as a potential health indicator is also suitable in the context of an older population (Wuorela et al., 2020), as it forms a holistic indication of a participant's frailty and relative functionality, physical, and cognitive health status.

Nielsen (2016) argues that, when rating their own health status, individuals not only assess their current health but also anticipate severe health outcomes which may occur in the future. This may lead to unfounded fears and anxieties around health in some, who may be categorised as 'health pessimistic', and could be fearing the worst for their health. Conversely, it is also possible that a cohort of individuals may have an overly hopeful view and are expecting the best in terms of their health, being 'health optimistic'. While considerable research has been conducted on predictors of SH generally in terms of sociodemographic, psychosocial, and health behaviour variables (Chow et al., 2018; Svedberg et al., 2006; Vingilis et al., 2002), little is known about the factors that may predict discrepancies between SH and OH – this will be addressed in this chapter.

Age is the main risk factor for decline of SH. A steady decline of SH is noticed from mid-to-late life, whilst being an independent predictor of mortality (Idler & Benyamini, 1997). However, in later life, such SH decline is not as pronounced as the age-related decline associated with OH (Ferraro, 1980; Henchoz et al., 2008). Some counter-intuitive trends in SH have been noted where older individuals may underestimate their health decline (Henchoz et al., 2008). This suggests that discrepancies between SH and OH may be more prevalent in older age, and a greater understanding of the predictors of such discrepancies is merited.

Other sociodemographic factors such as marital status are predictive of lower SH, perhaps due to married individuals sometimes being less isolated and socially restricted (Meadows & Arber, 2015). Aspects of work life are often included in models of SH decline. Verity et al (2018) found that employees who work more hours per week are more likely to be categorised as the 'worried well' – where individuals possess health concerns about illnesses that are typically absent. Other sociodemographic factors – such as having a close family member who suffers from an illness – are generally known to increase health anxiety levels, leading to an increase of the utilisation of health care services (Bilani et al., 2019). Ultimately, this may have implications for health discrepancies.

Additionally, there are psychosocial factors which can be linked to SH. Most notably, an anxiety diagnosis, in particular health anxiety, is strongly associated with low levels of SH (Lodin et al., 2019). Therefore, higher anxiety levels could be predictive of more distorted health ratings. Other psychosocial factors, including loneliness and social connectedness, may similarly be indicative of SH and OH discrepancies. For example, in their longitudinal investigation into the implications of loneliness on SH, Nummela et al (2011) found that no or low experience of loneliness was highly predictive of good SH. Lower levels of loneliness yielded slower SH decline, which indicates that loneliness is associated with the decline of SH. Within the SH literature, what constitutes as good/bad SH or high/low SH tends to fluctuate from study to study. However, for consistency, 'poor' or 'fair' SH responses were considered to be bad or lower levels of SH, while 'good', 'very good', or 'excellent' SH responses were considered as being generally good or higher levels of SH.

Finally, a collection of health behaviours are repeatedly associated with SH, particularly in individuals who suffer from chronic pain and have been diagnosed with chronic diseases (Reyes-Gibby et al., 2002; Yang et al., 2021). Persistent smoking is associated with extremely low SH levels (Wang et al., 2012). Interestingly, while alcohol consumption has been associated with suboptimal SH levels, a linear relationship is rarely obtained between the two. Instead, often a 'J-shaped' relationship is noted with suboptimal SH being more frequent in non-drinkers and binge drinkers, than in moderate drinkers (Grønbæk et al., 1999; Theobald et al., 2003; Van Dijk et al., 2004). A potential explanation for this is that the benefits of moderate drinking may be artificially increased by confounding variables such as education, socioeconomic and marital status, social network and psychological health (Emberson & Bennett, 2006; Fillmore et al., 1998). Additionally, the SH literature in relation to alcohol consumption remains contradictory in nature, as more recent research has refuted an association between consumption and low SH (Frisher et al., 2015). Regardless, the daily actions which people consciously undertake have the propensity to be indicative of the consistency between their SH and OH scores.

This chapter aims to create a new metric for the identification older adults whose SH and OH scores are at odds. Using data from the Irish Longitudinal Study of Ageing (TILDA), a framework for a health asymmetry metric was outlined, which identifies the following categories: 'health pessimists', those whose SH levels are considerably lower than their OH scores, 'health realists', those whose SH appraisals are relatively consistent with their OH scores and 'health optimists', those whose SH score is considerably higher than their OH score. Given the lack of empirical evidence which identifies predictors for discrepancies between SH and OH, a secondary aim of this study is to assess whether a collection of sociodemographic, psychosocial, and health behaviour variables significantly predict group membership within the health asymmetry metric.

2.2 Method

Participants and design

A nationally representative and longitudinal dataset called The Irish Longitudinal Study of Ageing (TILDA) was utilised, which collates social, economic, and health data from older adults, resident in the Republic of Ireland. We draw on the data from Wave 1 (2009 – 2010), of which 6907 independently living and ageing adults were included in analyses. All participants provided informed consent prior to their participation in TILDA. The project was ethically approved and assessed by the ethics board (Kenny et al., 2010).

Measures

Self-rated health

SH was measured on a 5-point scale, with the responses: ‘excellent’, ‘very good’, ‘good’, ‘fair’, and ‘poor’. Participants were asked how they would rate their health generally, in terms of one of the above responses.

Frailty Index

A number of health measures collected within the TILDA study were used to compile a unique FI, following guidelines from Searle et al. (2008), including aspects of functional health, physical health, cognitive health, and disease prevalence. Specifically, the FI is computed through the combination of health deficits across these domains (see Appendix 1). The items in the index remain unweighted, as long as they cover each fundamental aspect of health and frailty, assuming that the frailty scores increase over time. Inclusion of a health deficit is warranted if the health deficit becomes more prevalent with age and does not saturate too early (e.g., reduced eyesight). Each health deficit is computed into a binary variable: in this study, they were labelled as either 1 (deficit not observed yet) or 2 (deficit observed). For example, the measure of chronic pain within this study was dichotomised into whether the participant experienced chronic pain (=2) or not (=1). Continuous variables were converted in a similar manner, whilst being informed by the relevant literature. For example, results from the mini mental state examination were computed as follows: a score of less than 10 indicates severe dementia (=2), a score between 10 and 17 indicates moderate dementia (=1.75), a score between 18 and 20 indicates a diagnosis of mild dementia (=1.5), a score between 21 and 23 reveals a diagnosis of mild cognitive impairment (=1.25), and a score of +24 implies no cognitive impairment (=1), as indicated by Cullen et al. (2005). Overall, each binary deficit is computed together to reveal a whole FI score; a higher score implies a more frail individual.

Health Asymmetry

To identify discrepancies between an individual's SH and OH score, a categorical health asymmetry variable was derived, consisting of three categories. We borrowed from previous asymmetry typologies, such as 'social asymmetry' and asymmetry metrics used to describe premorbid and cognitive functioning (Benke, 2011; Bondi et al., 2008; McHugh Power et al., 2017; McHugh Power et al., 2019).

Firstly, since SH ratings and OH scores were not measured on similar scales, both were standardised, by converting both scales into Z scores. SH ratings were then subtracted from OH scores, giving rise to a discrepancy score for each participant. One standard deviation of this discrepancy score was used to determine the cut-off points for this new categorical 'health asymmetry' variable. An older adults whose discrepancy score was one standard deviation below the mean was categorised as a 'health pessimist', as their SH score was considerably lower than their OH score. Participants with a discrepancy score of within one standard deviation of the mean were categorised as 'health realists', as their SH and OH scores were in relative agreement with each other. Finally, those whose discrepancy score was one standard deviation above the mean were classified as 'health optimists', as their SH ratings were considerably higher than their OH score.

As is noted in previous asymmetry metrics, the derivation of a new categorical variable from continuous variables can reduce statistical power; however, it is a beneficial way to categorise at-risk individuals (McHugh Power et al., 2017). Additionally, the 'health realist' category could be further dichotomised into two groups ('good health realist' and 'poor health realist'), as health realists may have entirely contrasting health profiles. However, our goal was to identify predictors for health optimistic and health pessimistic individuals only, with health realists as a reference point, so the 'health realist' category was not dichotomised as such.

Covariates

A set of sociodemographic, psychosocial and health behaviour variables were identified, which were potential predictors of health asymmetry status. We controlled our analyses for a set of categorical factors, such as gender, marital status, educational attainment, work status, relative with a cancer diagnosis or other serious illness, smoking status, vigorous exercise level, sleep quality, and cancer screening participation. A set of continuous variables were also adjusted for: anxiety was measured using the Hospital Anxiety and Depression scale (HADS) (Zigmond & Snaith, 1983); loneliness was measured using the UCLA loneliness scale (Russell, 1996); social connectedness was measured using a derived variable which accounted for whether an individual was a member of church, was married or living with a partner, was a member of a non-religious organisation, and had at least one close relative. Alcohol consumption was a count-based measure, accounting for how many days a week an individual would consume alcohol.

Data analysis

All data analyses were completed in R Studio. There were few missing datapoints across the entire dataset (2.34)%, though a significant amount of this missingness was contained within four of the variables to be entered into the multivariate model (loneliness, alcohol consumption, intimate relationship, and social connectedness). Multiple imputation was conducted to fill in these missing values. The R package 'Multiple Imputation by Chained Equations' (MICE) was utilized to conduct the imputation (Van Buuren & Groothuis-Oudshoorn, 2011). Continuous data were imputed using predictive mean matching, whilst categorical data were imputed using polytomous regression.

Prior to modelling, preliminary analyses were run to ensure that there was no violation of model assumptions, particularly multicollinearity. A multinomial logistic regression was conducted to predict health asymmetry group membership, based on a set of sociodemographic, psychosocial, and health behaviour variables. The multinomial logistic regression model can be generalised as follows:

$$\log\left(\frac{p(X)}{1-p(X)}\right) = \alpha_0 + \beta_1 x_1 + ... + \beta_l x_k$$

where X = () are k predictors. Maximum likelihood estimation was utilised in the model to estimate the coefficients β1 . . . βk predictors. The quantity p(X)/1 − p(X), which is exponentiated, is the log odds: the probability of a respondent being categorised in a health asymmetry category, in relation to the reference category. The log odds or 'logit' were interpreted to assess how the sociodemographic, psychosocial, and health behaviour variables predict categorisation within the health asymmetry metric:

health pessimist, health realist, and health optimist. Probabilities of group membership were calculated in relation to a reference category, which was set as health realistic in this model. The logit model was conducted using the 'nnet' package in R (Venables & Ripley, 2002).

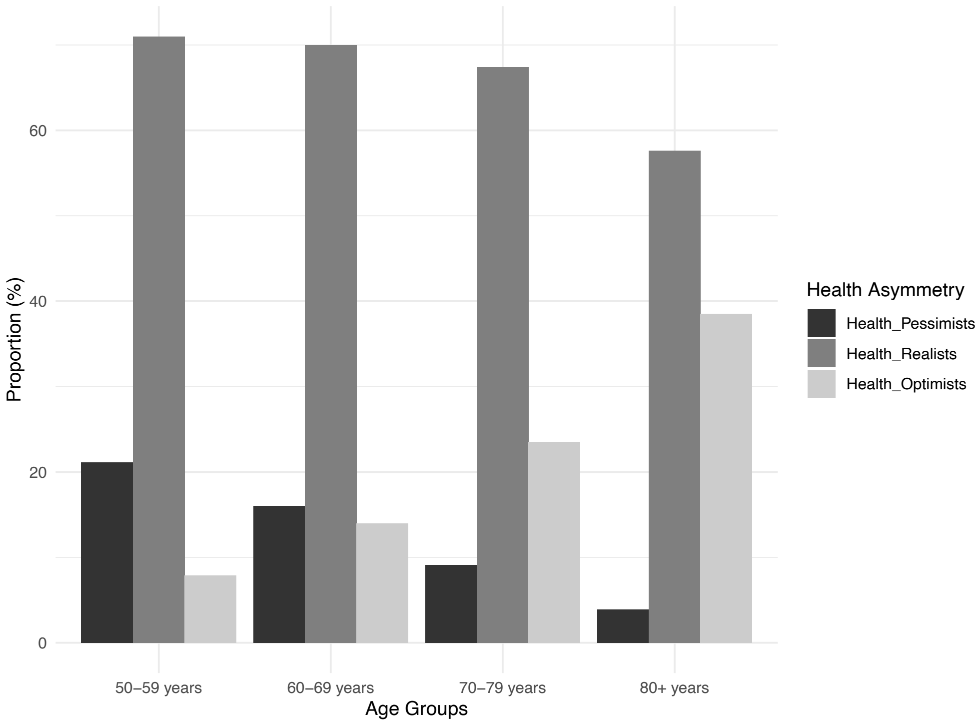
2.3 Results

In total, 6,907 participants were included in the analysis, of which 45.84% of participants were male (n=3,166), with all participants aged 50+ years: 50–59 years (n=2,858), 60–69years (n=2,250), 70–79 years (n=1,363), and 80+ years (n=436). The health asymmetry metric was derived and prevalence rates for the health status categories were obtained: 16% of participants were health pessimistic (n=1,104), 69.1% of participants were health realistic (n=4,776), and 14.9% were health optimistic (n=1,027). Most notably, the number of participants who were classified as health optimistic increased with older age groups, and conversely, the prevalence of health pessimistic individuals declined with an increase in age (see Figure 2.1). Table 2.1 includes the descriptive statistics for the categorical and continuous variables were also tabulated.

The full multinomial logistic model ($\chi 2$ (48, n=6,907) = 6.45, p=.17) explained between 7.3% (Cox and Snell) and 9.1% (Nagelkerke) of the variance in health asymmetry status. Table 2.2 displays the results for likelihood of membership in the health pessimistic category. Males were less likely to be categorised as health pessimists (OR=0.62, $p<.001$). Those who were retired were significantly less likely to be classified as health pessimists, when compared to those who were employed (OR=1.28, $p<.001$) or unemployed (OR=1.62, $p<.001$).

Figure 2.1

Proportions of health asymmetry groups across age varying groups in TILDA wave one.



The higher the educational attainment, the lesser likelihood of being categorised as a health pessimist: relative to those with no education, having a secondary level education was linked with a 18% lesser likelihood of being categorised here (OR=0.82, p=.02), while those with a postgraduate degree had a 32% lesser likelihood of being categorised as a health pessimist (OR=0.68, p=.02).

Table 2.1

Valid percentages for health asymmetry categories prior to imputation (n = 6907).

	Health Pessimist (n = 1104; 16%)	Health Realist (n = 4776; 69.1%)	Health Optimist (n = 1027; 14.9%)
Sex			
Male	19.7	69	11.3
Female	12.9	69.3	17.8
Age			
50-59	21.1	71	7.9
60-69	16	70	14
70-79	9.1	67.4	23.5
80+	3.9	57.6	38.5
Marital Status			
Married	15.7	70.7	13.6
In a Relationship	19.6	73	7.4
Single	21.5	66.8	11.7
Widowed	10.2	63.4	23.4
Employment Status			
Retired	12.2	66.9	20.9
Employed	17.8	73.9	8.3
Unemployed	18.6	65.5	15.87
Educational Level			
Primary	18.3	65.2	16.5
Secondary	15.9	70.5	13.6
Certificate	14.8	69.2	16
Undergraduate	13.2	71.7	15.1
Postgraduate	12.9	74.8	12.3
Relative w/ Cancer			
Yes	15.6	69.5	14.9
No	16.1	69	15.9
Relative w/ Illness			
Yes	16	68.8	15.2
No	15.9	70	14.1
Cancer Screening			
Yes	15.2	69.7	15.1
No	17.8	68	14.2
Smoking Status			
Smoker	18	67.6	14.4
Non-smoker	13.4	71	15.6
Sleep Quality			
Good	15.7	69.9	14.4
Fair	16.4	68.3	15.3
Poor	16.9	66.4	16.7

In terms of being a health optimist, males had a 50% increased likelihood of being a health optimist, in comparison to females (OR=1.50, p<.001) (see Table 2.3). Notably, being a widow was linked with a 72% greater likelihood of being a health optimist (OR=1.72, p<.001). Each additional day of alcohol consumption per week was significantly associated with a 6% increased likelihood of being a health optimist (OR=1.06, p=.01). Additionally, belonging to the health optimistic category was significantly and negatively associated with: being employed (OR=0.39, p<.001) or unemployed (OR=0.74, p<.001), relative to retirement. Finally, both occasional vigorous exercise (OR=0.69, p<.001) and regular vigorous exercise (OR=0.68, p<.001) were linked with a decreased likelihood of being health optimistic.

The set of psychosocial variables yielded some significant associations with the health pessimistic category: a one-point increase on the HADS anxiety scale was associated with a 3% increase in likelihood of being in health pessimistic (anxiety (OR=1.03, p=.02). Similarly, a one-point increase on the UCLA loneliness scale was associated with a 4% increased chance of being categorised as a health pessimist (OR=1.04, p=.05). In terms of social connectedness scores, a one-point increase was associated with a 13% lesser likelihood of being classified as a health pessimist (OR=0.87, p=.003). Additionally, being a smoker (OR=1.22, p=.003), engaging in regular vigorous exercise (OR=1.34, p<.001), and occasional vigorous exercise (OR=1.07, p<.001) were significantly associated with health pessimism.

Table 2.2

Multinomial logistic regression predicting the likelihood of being a 'health pessimist'.

	B	SE	OR (95%)
Health Pessimists			
Sex:			
Female	-.47***	.08	0.62 (0.53 / 0.73)
Marital Status:			
In a Relationship	.06	.21	1.06 (0.71 / 1.6)
Single	.13	.1	1.14 (0.93 / 1.4)
Widowed	-.36***	.13	0.7 (0.54 / 0.9)
Education:			
Secondary	-.2*	.09	0.82 (0.7 / 0.97)
Certificate	-.17	.11	0.85 (0.68 / 1.05)
Undergraduate	-.3*	.14	0.74 (0.56 / 0.97)
Postgraduate	-.39*	.17	0.68 (0.49 / 0.94)
Hours of Work per Week	.0003	.002	1 (1 / 1.01)
Work Status:			
Employed	.25**	.1	1.28 (1.07 / 1.53)
Unemployed	.48***	.1	1.62 (1.34 / 1.95)
Relative w/ Cancer:			
Yes	-.01	.08	0.99 (0.86 / 1.16)
Relative w/ Illness:			
Yes	.07	.08	1.07 (0.92 / 1.25)
Intimate Relationship	-.02	.07	0.98 (0.85 / 1.12)
Loneliness	.04*	.02	1.04 (1 / 1.07)
Social Connectedness	-.14**	.05	0.87 (0.79 / 0.95)
Anxiety	.02*	.01	1.03 (1 / 1.05)
Smoker:			
Yes	.21**	.07	1.22 (1.07 / 1.42)
Alcohol Consumption	-.02	.02	0.98 (0.94 / 1.02)
Vigorous Exercise:			
Occasional	.07***	.09	1.07 (0.90 / 1.28)
Regular	.29***	.09	1.34 (1.13 / 1.59)
Sleep Quality:			
Fair	.06	.13	1.06 (0.83 / 1.35)
Good	-.02	.12	0.98 (0.78 / 1.24)
Cancer Screening:			
Yes	-.01	.08	0.99 (0.85 / 1.15)

*Note. B = unstandardised Beta value; SE = standard error for B; OR (95% CI) = odds ratio with 95% confidence interval; *significant at p < 0.05, **significant at p <0.01, ***significant at p < 0.001. Reference categories: Sex (Male), Marital Status (Single), Education (Primary), Work Status (Retired), Relative w/ Cancer (No), Relative w/ Illness (Yes), Smoker (No), Vigorous Exercise (Rare), Sleep Quality (Poor), Cancer Screening (No)*

Table 2.3

Multinomial logistic regression predicting the likelihood of being a 'health optimist'.

	B	SE	OR (95%)
Health Optimists			
Sex:			
Female	.41***	.09	1.50 (1.27 / 1.78)
Marital Status:			
In a Relationship	-.58	.31	0.56 (0.3 / 1.03)
Single	.-.05	.12	0.95 (0.75 / 1.21)
Widowed	.54***	.11	
1.72 (1.39 / 2.12)			
Education:			
Secondary	-.11	.09	0.89 (0.75 / 1.06)
Certificate	.07	.11	1.07 (0.86 / 1.34)
Undergraduate	-.04	.14	0.96 (0.73 / 1.25)
Postgraduate	-.21	.17	0.81 (0.58 / 1.14)
Hours of Work per Week	.003	.002	1 (1 / 1.007)
Work Status:			
Employed	-.93***	.1	0.39 (0.33 / 0.48)
Unemployed	-.31***	.1	0.74 (0.62 / 0.88)
Relative w/ Cancer:			
Yes	-.03	.08	0.98 (0.84 / 1.13)
Relative w/ Illness:			
Yes	.12	.08	1.12 (0.96 / 1.32)
Intimate Relationship	.04	.07	1.04 (0.9 / 1.21)
Loneliness	-.03	.02	0.97 (0.94 / 1.01)
Social Connectedness	.03	.05	1.03 (0.94 / 1.14)
Anxiety	-.02	.01	0.98 (0.95 / 1)
Smoker:			
Yes	-.03	.01	0.97 (0.84 / 1.12)
Alcohol Consumption	.06***	.02	1.06 (1.03 / 1.14)
Vigorous Exercise:			
Occasional	-.37***	.09	0.69 (0.59 / 0.82)
Regular	-.39***	.09	0.68 (0.57 / 0.81)
Sleep Quality:			
Fair	-.07	.13	0.93 (0.73 / 1.19)
Good	-.05	.12	0.95 (0.76 / 1.20
Cancer Screening:			
Yes	.05	.08	1.05 (0.9 / 1.23)

*Note. B = unstandardised Beta value; SE = standard error for B; OR (95% CI) = odds ratio with 95% confidence interval; *significant at p < 0.05, **significant at p <0.01, ***significant at p < 0.001. Reference categories: Sex (Male), Marital Status (Single), Education (Primary), Work Status (Retired), Relative w/ Cancer(No), Relative w/ Illness (Yes), Smoker (No), Vigorous Exercise (Rare), Sleep Quality (Poor), Cancer Screening (No)*

2.4 Discussion

In this study, a useful health asymmetry framework was introduced, which classifies older adults according to the discrepancy between their SH and a more OH score (as measured by a FI). This satisfied the primary aim of the study. While our results illustrate that a considerable majority of the study population were 'health realistic', a significant minority were found to exhibit discrepancies in their self-assessment of health, being either overly 'health pessimistic' or 'health optimistic'. Interestingly, the prevalence rate of health optimists increased incrementally with age, while, conversely, the prevalence of health pessimists decreased with age. This supports the claim that very advanced ageing can lead to the overestimation of healthiness, compared to younger groups (Henchoz et al., 2008).

The secondary aim of this study was to investigate potential associations between health asymmetry categories and a set of sociodemographic, psychosocial, and health behaviour variables. Meaningful results were obtained which helps fill a prevailing gap in the literature surrounding discrepancies between SH and OH in older populations. Specifically, this study found that some sociodemographic and health behaviour variables were relatively useful in predicting membership of the health pessimists. Females were more likely to be categorised here than males, which supports the SH and frailty literature: females typically self-report worse health than males (Idler, 2003), and tend to score higher on the FI (Gordon et al., 2017; Gordon & Hubbard, 2020). Generally, lower levels of education obtained led to a greater likelihood of being categorised as health pessimistic compared to those with no education. This is unsurprising as education has strong associations with health, self-rated health (Volken et al., 2017) and preventable mortality (Grytten et al., 2020). However, associations between education and health must be interpreted with caution: educational attainment can often act as a proxy for socioeconomic status (SES) and wealth (Ware, 2019) and can be influenced by an individual's ability to access health care (McMaughan et al., 2020). Current smokers were more likely to be categorised as health pessimistic, providing underestimations of SH, which aligns with findings from Wang et al. (2012). Though a noteworthy, and seemingly paradoxical, finding was that individuals who engage in more regular vigorous exercise were more likely to be categorised as health pessimistic relative to health realistic individuals. A potential explanation for this may be that individuals who assume that they are unhealthier may engage in physical exercise more than regular to combat this perceived ill health. This is also a finding which warrants further exploration.

Psychosocial factors – including loneliness, anxiety, and social connectedness – were also useful in predicting a health pessimistic classification. Associations between anxiety and underestimated SH are perhaps not surprising here, given the intrinsic links between SH and health anxiety (Hedman-Lagerlöf et al., 2017). Therefore, there is merit in investigating whether health asymmetry could predict clinical outcomes, such as health anxiety, depression, or quality of life, for example.

In addition, our study's findings strengthen the link between loneliness and SH: Nummela et al. (2011) found that little or no experience of loneliness yielded high SH. Our findings show how higher levels of loneliness increase the probability of being categorised as a health pessimist, leading to an underestimation of SH. Although nuanced theoretical differences exist between loneliness and social connectedness, being more socially connected also decreases the probability of being a health pessimist.

In contrast, sociodemographic, psychosocial, and health behaviour variables became less relevant in predicting the health optimistic category. Males were more likely to be classified as health optimists than females, which fits in line with existing SH and frailty literature, discussed previously. Varying levels of educational attainment were not significant in predicting health optimists, unlike predicting health pessimistic individuals. Alcohol consumption was linked to an increased likelihood of being categorised as a health optimist. This adds to the counterintuitive body of literature of the associations between alcohol and SH (Grønbæk et al., 1999; Theobald et al., 2003; Van Dijk et al., 2004). Despite psychosocial variables being intrinsically linked to health pessimism, no psychosocial variable that was accounted for significantly predicted membership of the 'health optimistic' category. Perhaps there is a lack of psychosocial impairment associated with health optimists that explains this finding. Future research could examine trajectories of psychological health of health optimists, pessimists and realists to explicate this finding more (See Chapter Four).

However, there are limitations to our study design. The cross-sectional design of the study is limiting, in that the associations between sociodemographic, psychosocial, and health behaviour variables with health asymmetry were at one specific time-point: important longitudinal associations remain to be assessed. As discussed previously, the derivation of a categorical variable from continuous data comes at a cost: information is lost as the statistical power is reduced. Though, the benefits of categorising at-risk individuals were considered pertinent in this instance.

Additionally, in constructing our unique FI using TILDA data, only 26 theoretically appropriate health deficits were included in our analyses, whereas a minimum of 30 are recommended when deriving a FI (Searle et al., 2008). Although the FI was distributed as expected and FI scores increased with age, further investigation into health asymmetry should rectify this by including a minimum of 30 deficits. Next, alcohol consumption was perhaps ill-defined in TILDA. Alcohol consumption was measured based on how many days in a week a participant consumed alcohol, whereas it would have been more appropriate to measure the weekly consumption of alcohol units instead. Therefore, alcohol consumption associations are to be interpreted with caution. While the study's general findings are relevant for the discrepancy of SH and frailty in ageing populations, they cannot be generalised to all age groups. It must be flagged that the FI is not a suitable OH measure for younger age groups, as the index compiles frailty deficits typically observed in advanced ageing populations. Since the FI computed age-related deficits, age was not included as a factor in the predictive model; age is known to have a significant influence on the reliability of SH. Proceeding models should incorporate age, if alternative OH measures can be found, instead of the FI.

There is potential for the discrepancies between SH and OH to be clinically meaningful. Nielsen (2016) argued that when individuals assess their own SH that they are not only measuring their own global health status based on previous experiences, but also in anticipation of severe health events that are likely to occur to them in the future. As a result, the psychometric properties of the health asymmetry should be investigated further, with the ultimate view to assess its utility in predicting health decline. Given the association between anxiety and health pessimism, there is potential for the health asymmetry metric to be useful in predicting of pre-clinical and clinical levels of health anxiety, or depressive symptomatology. Future longitudinal research could assess the clinical relevance of these health asymmetries in terms of the psychosocial health of older adults.

A further investigation into the link between health optimists and quality of life would be of particular interest, for older populations. Chapter 3 will investigate if older adults shift from one health asymmetry category to another, over time. This would yield much needed evidence regarding the rigidity of these classifications, and whether older adults are likely to change group membership, based on the discrepancy between SH and OH measures.

A novel and potentially clinically meaningful metric has been derived here, which creates categories based on the discrepancies between SH and OH. The metric is a parsimonious and less burdensome way of identifying discrepant health perceptions in older adults – a group of adults who are known to appraise their health more incongruently with their OH status, than their younger counterparts. This metric deals with the potential cognitive and emotional reporting tendencies of individuals (health optimistic and health pessimistic) and categorises individuals accordingly. Based on the above findings, sociodemographic factors, psychosocial factors, and health behaviours play a useful role in the predicting health pessimists. It may be useful to further assess the use of health asymmetry as a proxy for clinical constructs, as it may indicate those who are at-risk for adverse physical health and mental health outcomes. Ultimately, this study provides further clarity on the identification of older adults who – in terms of their health – may be expecting the best or fearing the worst.

CHAPTER 3

Do discrepancies between subjective and objective health shift over time in later life? A Markov transition model

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Abstract

Subjective health (SH) deteriorates less rapidly than objective health (OH) in older adults. However, scant evidence exists regarding if discrepancies between SH and OH shift in the same individuals over time. This study explored whether such discrepancies change over time in a sample of older adults living in England, through a prospective, observational cohort study design. Using data from the English Longitudinal Study of Ageing, a sample of 6,589 older adults, aged 60+ years at baseline, were tracked over three waves of data collection (2002 – 2007), yielding two wave transitions. A 'health asymmetry' metric classified older adults into four categories at each wave, based on the level of agreement between their SH and OH scores ('health pessimist', 'health optimist', 'good health realist' and 'poor health realist'). First-order Markov transition and generalised logit models yielded estimated transition probabilities and odds ratios for health asymmetry transitions over time. At baseline, 35.91% of the sample were 'good health realists', 33.09% were 'poor health realists', 15.93% were 'health optimists', and 15.07% were 'health pessimists.' Good and poor health realists were likely to remain health realistic over time. Good health realists who did transition however, were likely to become health optimists. The proportion of health optimists in the sample subsequently increased over time. Health pessimists had a high probability of being lost to study attrition. In conclusion, health optimism (i.e. where SH is rated better than OH scores) becomes more prevalent over time, in later life. Future research should ascertain if implementing cognitive or community-based social participation interventions may be helpful in promoting positive SH appraisals among older adults (particularly for those with poor OH).

3.1 Introduction

As mentioned in the previous two chapters, subjective health (SH), an individual's appraisal of their own health status, is a commonly implemented and reliable health measure. This is typically measured by a single item, with individuals asked how healthy they believe they are, ranging from 'poor' to 'excellent'. SH is an independent predictor of morbidity and mortality (DeSalvo et al., 2006; Idler & Benyamini, 1997; Jylhä, 2009) and is associated with mental and functional health status (French et al., 2012). SH responses typically reflect an individual's knowledge of their health, social norms, illness expectations and illness acceptance (Bailis et al., 2003; Layes et al., 2012; Singh-Manoux et al., 2005; Whitmore et al., 2022). As a result, a measure of SH is recommended for inclusion in all major health surveys (De Bruin, 1996).

However, older adults' SH appraisals are often paradoxically different to their medically defined, objective health (OH) status (Abma et al., 2021). As adults age, a deterioration in OH is often observed (e.g., changes in bone density, cognitive decline, waning cardiovascular function and slowing gait speed etc.) and the likelihood of developing acute or chronic conditions increases (Burge et al., 2007; Calderón-Larrañaga et al., 2018; Speh et al., 2024; Vetrano et al., 2018). Despite clear evidence for OH decline in later life, such trends of deterioration are not mirrored in SH. SH scores do show some decline in some older adults (Chen et al., 2007; Idler 1993), but not with the same rate of change as would be expected from age-related OH decline (Graf & Hicks Patrick, 2016; Henchoz et al, 2008; Kunzmann et al., 2000). Among the oldest-old (generally those aged 85+ years), SH has the propensity to remain stable or even improve (Heller et al., 2009; Vogelsang, 2018). Ultimately, a paradox in self-rated versus objective health exists in later life (French et al., 2012; Hansen & Blekesaune, 2022; Wettstein et al., 2016), which leads some older adults to be more health optimistic than their OH would indicate.

Idler (1993) argued that a relatively optimistic view of health is attributable to selective survivorship. The oldest-old may be better able to adapt to declines in health and down-regulate negative psychological responses to such decline (Wettstein et al., 2016), causing gradual increases in dissociations between SH and OH with increasing age. In essence, long-term survival against declining health and functionality may result in a later-life dissonance between worsening OH, but stable SH. In addition, the association between SH appraisals and various OH factors (particularly functional health) weakens with increasing age, whereas the association between SH appraisals and psychosocial constructs such as depressive symptoms and positive affect strengthens (Benyamini et al., 2000; Spuling et al., 2015). These changes in the determinants of SH that are observed in later life, may explain increasing discrepancies between SH and OH among old and very old adults.

Another explanation points towards the response shift theory, which argues that individuals reprioritise internal standards across time. It is possible that response shifts occur, where SH changes as the value of its contributors change (Schwartz & Sprangers, 2000). This may explain why older adults assess their health against different standards than their younger counterparts and why SH tends to remain relatively stable in later life (Galenkamp et al., 2012; Ruthig et al., 2011). For example, older adults may appraise their SH based on somatic symptoms or a transient health problem they are dealing with. Yet upon interacting with others who are in worse health, they may downgrade their expectations regarding health (Tornstam, 1975), essentially comparing themselves to others who are worse off (Cheng et al., 2007; Henchoz et al., 2008). This may contribute to a positive shift in SH. These types of changes in expectations may be desirable adaptive responses to health decline, but they make it challenging to interpret SH across different age groups.

A growing body of research points towards the value of identifying those older adults whose SH appraisals do not align with OH measures, such as physician ratings (Hong et al., 2004), comorbidity (Rai et al., 2019; Ruthig & Chipperfield, 2007) and frailty indices (Calvey, et al., 2022). A 'health congruence' framework categorises older adults into one of four groups ('health optimistic', 'health pessimistic', 'good health realistic' or 'poor health realistic'), based on the agreement between SH and OH scores and on the valence of the health status (i.e. good or bad) of the participant (Chipperfield, 1993). Discrepancies between SH and OH precipitate adverse health outcomes in later life. Those whose SH is rated better than their OH scores (i.e., health optimists) tend to live longer, have fewer depressive symptoms, experience slower functional decline and use healthcare services less than others (Calvey et al., 2023; Chipperfield, 1993; Ruthig & Chipperfield, 2007; Viljanen et al., 2021). In contrast, those whose SH scores are worse than their OH would indicate (i.e., health pessimists) are more likely to die (during a 12-year follow-up), experience higher levels of depressive symptoms, make more negative health attributions, while having longer and more frequent hospital visits (Borawski et al., 1996; Calvey et al., 2023; Chipperfield, 1993; Ruthig & Chipperfield, 2007). Health pessimists are also more likely to make poorer health attributions (i.e. providing explanations as to why an individual has rated their health in an unfavourable manner) (Borawski et al., 1996). For example, some health pessimists might attribute milder physical symptoms such as fatigue or temporary pain as causes of their underlying health issues.

However, much 'health congruence' research uses OH measures such as comorbidity indices (Chipperfield, 1993; Hong et al., 2004) or physicians' ratings (Elder et al., 2017), which may not fully capture the physical, psychological, functional and cognitive health decline that is observed in later life (Black & Rush, 2002; Diehr et al., 2013). Most health congruence research focuses on older adults, though some use of the metric has been on younger populations too (Chiavarino et al., 2019). To respond, a 'health asymmetry' framework was developed in Chapter Two, which conceptualises OH using multidimensional indices of health, such as a Frailty Index (FI) (Calvey et al., 2022) or an objective Health Assessment Tool (Calvey et al., 2024). These indices capture more facets of health decline than comorbidity indices alone, and thus allowing for the appropriate identification of health incongruence in older populations. The health asymmetry classification enables the prognostication of health outcomes that cannot be considered by examining the predictive effects of SH (while holding the effects of OH constant).

Despite a paradox in self-rated versus objective health emerging in later life, scant evidence exists regarding how discrepancies between SH and OH change in the same individuals over time. In other words, few studies investigated if older adults transition to and from health optimistic, pessimistic or realistic states. Ruthig et al (2011) descriptively examined the stability of health congruence categories over a 5-year follow-up. Findings showed that most health realists remained health realistic: 53% of poor health realists remained poor health realistic after five years, while 63% of good health realists remained good health realistic after the same amount of time. Findings also indicated that 26% of poor health realists and 16% of good health realists transitioned to health optimists five years later, reflecting relatively stable SH and/or declining OH. However, these were merely descriptive observations of health congruence transitions, with OH being measured using a count of chronic conditions (while accounting for the severity of such conditions). It would be valuable to identify transition trends to and from these categories, using a model-based approach, rather than relying solely on descriptive observations. It would also be valuable to observe transition trends over time, when OH is captured more broadly than previous studies.

Chapter Two concluded that it may be useful to explore whether discrepancies between SH and OH shift over time, alluding to the stability of health asymmetry categories throughout later life, over time. Particularly, it may be of public health and clinical importance to know if one health asymmetry category is more or less stable than another. If health optimism or health pessimism is more temporary than health realism, promoting positive SH appraisals to counteract health pessimism and to encourage health optimism may be viable. To address gaps in the literature, we track longitudinal change in health asymmetry status over a four-year follow-up period. Based on previous evidence, it was hypothesised that: 1) health realists (both 'good health realists' and 'poor health realists') will have a high probability of remaining health realistic after two wave transitions, and 2) both good and poor health realists who transition to another health asymmetry category, will likely become 'health optimistic', thus contributing to an increasing prevalence of health optimists over time.

3.2 Methods

Study Design and Population

Archived secondary data were used to respond to our objectives. Data from a multi-wave, prospective cohort study called the English Longitudinal Study of Ageing (ELSA) was utilised. ELSA includes longitudinal measurements of multidimensional aspects of health, occupation, economic status and retirement (Steptoe et al., 2013). Older adults were eligible to participate in ELSA if: 1) they had participated in the Health Survey for England (HSE) in 1998, 1999 and 2001 and agreed to follow-up, 2) were born before 1 March 1952 and 3) lived in a private household in England at baseline (2002/2003). ELSA data are collected every two years, with ten waves of ELSA data currently archived (https://doi.org/10.5255/UKDA-Series-200011). The baseline assessment consisted of electronic, self-reported questionnaires, while nurse-led interviews collecting physical and medical data are conducted every two waves, starting at wave two. Participants provided written informed consent prior to data collection.

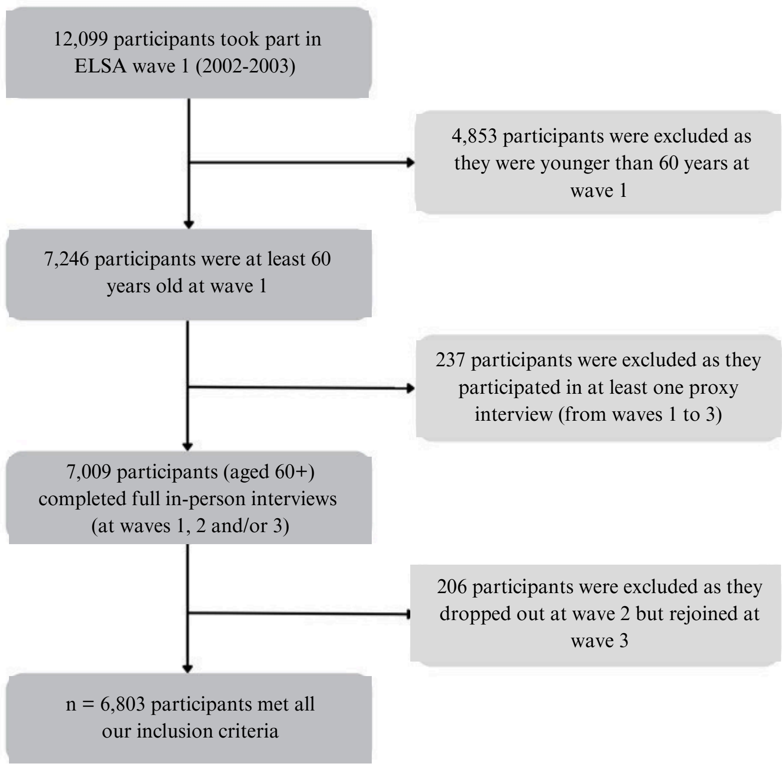
We followed STROBE reporting guidelines for longitudinal cohort studies (Vandenbroucke et al., 2007). We analysed data from ELSA waves one (2002/2003), two (2004/2005), and three (2006/2007). Earlier ELSA waves were utilised, since they have a comprehensive amount of measures appropriate for computing an OH index (Marshall et al., 2015). We also wanted to leverage the larger sample sizes in these earlier waves (Stubbings et al., 2021). From the initial 12,099 participants who participated at wave one, participants who were younger than 60 years old (n=4,853) were excluded. Participants who completed a partial or proxy interview during waves one, two and/or three (n=237) were also excluded, to remove the possibility of proxy respondents providing an SH response for another individual. Finally, those who dropped out at wave two but returned at wave three (n=206) were excluded from analyses, to ensure a parsimonious interpretation of transition probabilities in our models.

Ultimately, a final sample size of n=6,803 individuals was obtained (see Figure 3.1). A total of n=5,298 participants were present in our analyses at wave two and n=4,458 participants were present at wave three. Refreshment cohorts introduced at ELSA wave three were not included in our analyses. ELSA participants aged 60+ years old, who were excluded from our analyses based on the above criteria (n=514), were older ($p<.001$, Cohen's d=.35), had lower levels of educational attainment ($p<.001$, Cramer's V=.06), higher depressive symptoms ($p<.001$, Cohen's d=.13), poorer OH ($p<.001$, Cohen's d=.33) and poorer SH ($p<.001$, Cohen's d=.48), when compared to those who were included in our study. Those excluded from our analyses did not differ from study participants in terms of sex (see Appendix 3.1).

ELSA participants who were present at all three waves (n = 4252), were younger (p<.001, Cohen's d=.33), had a higher proportion of female participants (p<.01, Cramer's V=.04) had higher levels of educational attainment (p<.001, Cramer's V=.14), fewer depressive symptoms (p<.001, Cohen's d=.18), better OH (p<.001, Cohen's d=.31) and better SH (p<.001, Cohen's d=.34) than those lost to attrition during from ELSA waves two to three (n=2551) (see Appendix 3.2).

Figure 3.1

A flow chart illustrating the exclusion criteria chosen for Chapter Three.



Measures

Subjective Health

To measure SH, participants were asked "Would you say your health is excellent, very good, good, fair or poor?", with responses ranging from excellent (coded as 1) to poor (coded as 5). Self-rated health items show good reliability (DeSalvo et al., 2006) and good construct and convergent validity with other health constructs (Cullatti et al., 2018).

Objective Health

A frailty index (FI) was used as a proxy for OH in this study. As mentioned previously, frailty can be defined as the susceptibility to decreased reserve and response stressors, along with reduced functionality (O'Halloran et al., 2014). An FI constitutes an index of physical, cognitive, functional and mental health-related data (termed 'deficits') and is considered to have a global health-related structure (Searle et al., 2008). As a result, an FI has the potential to be interpreted as a suitable OH measure in older populations (Laan et al., 2014; Rockwood et al., 2014), forming a holistic approximation of an older adult's physiological, functional, mental and cognitive health status. The FI has been successfully interpreted as a proxy for OH in recent investigations (Calvey et al, 2022; Calvey et al., 2023; Hosseini et al., 2022; Wuorela et al., 2020).

Different attempts at indexing frailty have different ways of coding deficits (Fried et al., 2001), but for the most part, a health deficit can be included in a FI if it becomes more prevalent with age and does not saturate too early (for example, reduced eyesight which develops in younger populations, would not typically be included). At least 30 health deficits are recommended for inclusion in a FI. Each deficit is coded into a binary variable, either 1 (deficit is present) or 0 (deficit is absent). For example, in this study, a formal cancer diagnosis was coded as '1' (patient received formal cancer diagnosis) or '0' (participant did not receive formal cancer diagnosis). Health deficits that were positive continuous variables were also converted in a similar manner. Overall, the summed total of present deficits is divided by the total number of measured deficits, revealing a FI score which ranges from 0 to 1; a higher score implies a frailer individual. Health deficits within the index can remain unweighted, provided they cover different facets of health and frailty, assuming that the frailty scores increase over time.

A unique FI was compiled using ELSA waves one, two and three, following guidelines from Searle et al. (2008), including aspects of functional health, physical health, cognitive health, mental health and disease prevalence. We aimed to include 36 health deficits in our FI (see Appendix 3.3). However, the health deficit which accounted for walking and balance issues (included in waves one and two) was not measured at wave three. Therefore, our FI scores from wave three were based on 35 health deficits, instead of 36 health deficits. However, Searle et al (2008) noted that at least 30 deficits included across multiple domains of health should provide stable estimates. In this chapter, the FI was computed using more health deficits than in Chapter Two. Here, health deficits were coded as being either 1 (present) or 0 (absent), in contrast to 1 (absent) and 2 (present), in Chapter Two.

Health Asymmetry

Our main outcome of interest was health asymmetry status. Similar to previous asymmetry metrics (Bondi et al., 2008; McHugh Power et al., 2017) and similar to Chapter 2, health asymmetry derives a categorical variable from continuous data. Health asymmetry categorises older adults into groups based on the level of agreement between an older adult's SH and OH score. Chapter Two derived three health asymmetry categories: 'health optimist', 'health pessimist' and 'health realist'.

However, in this chapter, the health realist category was further dichotomised based on the valence of the participant's OH. Health realists are now categorised as being either a 'good health realist' or a 'poor health realist'.

Categorising participants into one of four groups is achieved by standardising both SH and OH scores, by converting them into Z scores. Although SH and OH scores are not normally distributed, converting them into Z scores should still be possible, as converting to Z scores does not carry the typical assumption of normality, but merely scales these scores. This should still make it suitable for comparison purposes, similar to previous research (Andres et al., 1988; Capitani & Laiacona, 2017). SH scores were subtracted from OH scores, deriving a discrepancy score for each participant. A one standard deviation of this discrepancy score was used as the cut-off point for categorisation within health asymmetry. The distribution of our baseline SH and OH scores were visualised (see Appendix 3.4).

An older adult whose discrepancy score was one standard deviation above the mean was considered a 'health optimist', as their SH score was rated better than their OH. Conversely, an older adult whose discrepancy score was one standard deviation below the mean was considered a 'health pessimist', as their SH was worse than their OH score. Those whose discrepancy score was within ±1 standard deviations from the mean were considered 'health realists', i.e. rated their SH similar to their OH scores. The 'health realist' category was further dichotomised to reflect two different health profiles (Calvey et al., 2023). Specifically, the population median OH score at each wave was used to differentiate between health realists who were in poor health ('poor health realists') and health realists who were in good health ('good health realists'). The baseline health asymmetry status acted as a reference point (Manderbacka et al., 2003; Sargent-Cox et al., 2010). SH and OH scores from waves two and three were converted into Z scores based on the means and standard deviations from wave one. Without this standardisation relative to baseline scores, assigning the same proportion to each health asymmetry category at each wave would simply reflect the raw scores, potentially ignoring individual shifts in health status. This would lead to similar proportions of participants in each category at each wave, regardless of actual health changes and would impede detecting transitions in health status over time.

This ensured that health asymmetry categories were assigned at waves two and three were relative to their baseline status (Calvey et al., 2024).

Confounders

Our analyses were adjusted for a set of confounders based on their established associations with SH and OH. We controlled for age, sex, educational attainment and depressive symptoms (Calvey et al., 2023; Calvey et al., 2024; Hong et al., 2004; Ruthig & Chipperfield, 2007). Educational attainment was categorised into 5 groups, similar to previous investigations (Tsimpida et al., 2019; Tsimpida et al., 2022): no qualifications, foreign/other, O levels CSE (Certificate of Secondary Education), A levels (Level 3 of the National Qualifications Framework) and degree/higher education. Depressive symptomatology was assessed using an eight-item version of the CES-D (Center for Epidemiological Studies Depression), with scores ranging from 0 to 8 (Karim et al., 2015; Steptoe et al., 2013). The CES-D showed good internal consistency at baseline (α=.78).

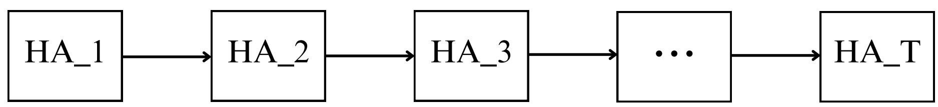
Data Analysis

All analyses were implemented in R (R Core Team, 2024). There were few missing datapoints across our data. most of which were missing at random. In the OH index, 0.75% of data were missing at wave one, 0.21% at wave two, and 0.40% at wave three. Most missingness within our baseline covariates occurred in the education variable (8.9%). Little's Missing Completely at Random (MCAR) test indicated that our data were not missing completely at random. The 'naniar' package was used to visualise of the extent and pattern of missingness in the data (Tierney et al., 2019). The 'missing_compare' function from the 'finalfit' package established the mechanism of missingness, testing the associations between missing and observed data (Harrison et al., 2020). Patterns in the missing data that were explained by our covariates and other missing variables were identified, thus satisfying the assumption of the data being 'missing at random'. Therefore, this missingness was imputed using the R package 'Multiple Imputation by Chained Equations' (Van Buuren & Groothuis-Oudshoorn, 2011). Continuous data were imputed using predictive mean matching and categorical data were imputed via polytomous regression. The chained equation process was ran for 10 cycles, creating 100 imputed datasets. The results from each individual dataset were combined into one final imputed dataset, using Rubin's rules (Rubin, 2004).

To identify trends in changing health asymmetry status over time, a first-order Markov model was utilised (Diggle, 2002). Such Markov models are based on stochastic processes, which describe how individuals transition between a finite number of pre-defined categorical states. This enables us to estimate the probability of transitioning from one health asymmetry category to another over time. In its basic formulation, the health asymmetry category of an older adult at time t1 depends only on the current health asymmetry category at the previous time t0. This is known as the Markovian property, which defines a first-order Markov chain (see Figure 3.2).

Figure 3.2

A visual representation of a first-order Markov chain, where HA represents categorical health asymmetry status, and T represents timepoint.



However, there are some additional assumptions to our Markov model. Here, we assume a discrete-time and discrete-state process (Agresti, 2012), where the probability of transitioning from category a to category b, from time t1 to time t, depends only on the previous state. Mathematically, this can be written as:

$$\pi_{ab}(t-1,t) = \pi_{ab}(t) = P(Y_t = b|Y_(t-1) = a), t = 1,2,3$$

with a, b S = 1, 2, 3, 4, 5 representing the five mutually exclusive categories of the study; i.e., 1) good health realistic, 2) health pessimistic, 3) health optimistic, 4) poor health realistic and 5) death/dropout (which is an absorbing state, i.e. once an individual reaches this state, they cannot transition back to any other state), and t = 1, 2, 3 are the specific ELSA waves when health asymmetry categories were derived. Death and dropout were considered as one singular category (loss due to attrition) within the Markov model for the sake of a parsimonious interpretation of transition probabilities.

To determine if a set of confounders had a significant effect on health asymmetry transitions, an extension of a generalised logit model was implemented where the effects of age, sex, educational attainment, depressive symptoms, and previous state (also referred to as the 'Markov covariate') are included in the linear predictors for the logits:

$$\eta(t) = \log\left(\frac{\pi_{ab}(t)}{\pi_{a1}(t)}\right) = \lambda_b(t) + \beta_b(t)\,x + \alpha_b(t)\,y_{(t-1)}, \quad a,b \in S$$

where λb(t) represents the intercept, βb(t) is the vector of parameters for the effects of our confounders, here represented by the vector x, αb(t) is the vector referring to the stochastic parameters that measure the effect of the previous health asymmetry category, y(t1), on the current health asymmetry category. Since health asymmetry is a nominal outcome, all parameters depend on b = 2, 3, 4, 5. 'Good health realists' (category 1) and females were set as our reference categories for the estimation processes. Good health realists were set as the reference category as they typically have optimal health outcomes (due to both good OH and SH).

To evaluate the condition of homogeneity of transition probabilities (stationarity of the Markov process), the likelihood-ratio test (Lara et al., 2020) was used. The significance of the confounders on health asymmetry transitions was also assessed using the likelihood-ratio test for nested models. Once the effects are estimated, for a stationary model the transition probabilities from state a to state b are estimated by the equation:

$$\hat{\pi}_{ab}(t) = \frac{\exp\left(\hat{\lambda}_{b(t)} + \hat{\beta}'_{b(t)}x + \hat{\alpha}_{b(t)}y_{(t-1)}\right)}{1 + \sum_{b=1}^{4} \exp\left(\hat{\lambda}_{b(t)} + \hat{\beta}'_{b(t)}x + \hat{\alpha}_{b(t)}y_{(t-1)}\right)}$$

where $\hat{\lambda}_b$, $\hat{\beta}_b$, and $\hat{\alpha}_b$ are the estimated parameter vectors under the null hypothesis of a stationary process, and $\hat{\lambda}_{b(t)}$, $\hat{\beta}'_{b(t)}$, and $\hat{\alpha}_{b(t)}$ are the estimated parameters for time transition t.

Chi-square tests and ANOVAs were conducted to compare the distribution of our baseline covariates across the four health asymmetry categories. Pearson's correlation tests were conducted to investigate how SH and OH scores were correlated across each ELSA wave, how their changes are correlated with one another, and how stable both measures were in terms of their autocorrelations over time (see Appendix 3.5). Finally, a sensitivity analysis was carried out to determine whether self-reported data in our OH index was biasing our health asymmetry categorisations and therefore our transition probabilities. In this sensitivity analysis, five health indicators (most of which were objectively measured) were inputted into a latent factor analysis model to yield a latent OH score for each individual. Using the 'lavaan' package in R (Rosseel, 2012), generated latent OH scores were calculated based on: 1) smoking status, 2) memory function, 3) executive functioning, 4) CES-D scores and 5) confirmed diagnoses of chronic illnesses. Participants were categorised into health asymmetry groups and yielded transitions probabilities, to compare with our main results (see Appendix 3.6).

3.3 Results

In a sample of 6,803 English adults aged 60 years or older, 54.6% were female (n=3714), with a mean sample age of 70.85 years (±7.42) (see Table 3.1). At baseline, 36.84% of the sample was categorised as 'good health realist', 33% as 'poor health realist', 14.54% as 'health optimist' and 15.62% as 'health pessimist'. Chi-square tests and ANOVAs revealed that health asymmetry categories significantly differed in terms of their age ($p<.001$, $\eta^2=.06$), sex ($p<.001$, Cramer's V=.11), education ($p<.001$, Cramer's V=.11), depressive symptoms ($p<.001$, $\eta^2=.11$), SH ($p<.001$, $\eta^2=.44$) and OH scores ($p<.001$, $\eta^2=.56$). Post hoc analyses revealed that health optimists and poor health realists were significantly older than health pessimists and good health realists. Poor health realists had the highest level of depressive symptoms at baseline, while good health realists had the lowest levels of depressive symptoms at baseline (see Table 3.1). The distribution of sex and education levels were visualised across health asymmetry categories, incorporating post hoc analyses to identify significant group differences (see Appendix 3.7). Health optimists and poor health realists had significantly greater proportions of females, while health pessimists and good health realists had significantly greater proportions of males. The poor health realistic category had a significantly greater proportion of participants with no educational qualification, while the good health realistic category had a significantly higher proportion of participants with a higher level education qualification.

Table 3.2 includes the frequencies and estimated transition probabilities (in parentheses) of the first health asymmetry transition (from wave one to two) and the second health asymmetry transition (from wave two to three), which accumulated to a total of 13,606 transitions over time. These estimated transition probabilities are unconditioned, i.e. they do not take the effects of confounders into account. Figure 3.3 visualises these health asymmetry transitions using a river diagram (including an additional outcome of 'Death/Dropout' at waves two and three).

Table 3.1

Baseline descriptives (mean and standard deviation or percentage and frequency) for the study sample and stratified by health asymmetry category

	Full Sample	Good Health Realist	Health Pessimist	Health Optimist	Poor Health Realist	p	Effect Sizes
Age	70.85 ± 7.44	69.02 ± 6.72	69.52 ± 6.98	73.1 ± 7.94	72.55 ± 7.52	p <.001	0.06
Sex							
Male	45.4% (n = 3089)	40.42% (n = 1493)	52.40% (n = 557)	38.82% (n = 384)	40.36% (n = 906)	p < .001	0.11
Female	54.6% (n = 3714)	59.58% (n = 1264)	47.60% (n = 506)	61.13% (n = 605)	59.64% (n = 1339)		
Education							
None	50.29% (n = 3421)	39.23% (n = 983)	51.18% (n = 544)	57.43% (n = 568)	59.06% (n = 1326)	p < .001	0.11
Foreign/other	9.20% (n = 626)	9.26% (n = 232)	8.84% (n = 94)	9.20% (n = 91)	9.31% (n = 209)		
GCSE/O	18.05% (n = 1228)	21.79% (n = 546)	18.63% (n = 198)	14.16% (n = 140)	15.32% (n = 344)		
A-level	4.34% (n = 295)	4.91% (n = 123)	3.57% (n = 38)	4.45% (n = 44)	4.01% (n = 90)		
Higher	18.12% (n = 1233)	24.82% (n = 622)	17.78% (n = 189)	14.76% (n = 146)	12.93% (n = 276)		
CES-D	1.62 ± 1.96	0.84 ± 1.35	1.6 ± 1.96	2.04 ± 2.14	2.33 ± 2.12	p <.001	0.11
Objective Health	0.2 ± 0.13	0.1 ± 0.03	0.14 ± 0.07	0.34 ± 0.16	0.29 ± 0.10	p <.001	0.56
Subjective Health	2.89 ± 1.12	2.11 ± 0.67	3.84 ± 0.68	2.38 ± 1.22	3.55 ± 0.87	p <.001	0.44

Note CES-D scores (Centre for Epidemiological Studies – Depression) range from 0 to 8, with higher scores implying higher levels of depressive symptoms. Objective Health scores range from 0 to 1, with higher scores implying poorer health. Self-rated health scores range from 1 (excellent) to 5 (poor), with higher scores indicating poorer self-rated health. Chi-square and ANOVA tests were conducted to investigate potential significant baseline group differences among health asymmetry categories, reporting p values, Cramer's V effect and partial eta-squared effect sizes (where relevant).

Table 3.2

Frequencies (and transition probabilities, as estimated by the first-order Markov model) of health asymmetry transitions from ELSA Wave 1 to Wave 2 and ELSA Wave 2 to 3.

	Health	**Asymmetry**	**Wave 2**		
Health Asymmetry (Wave 1)	Good Health Realist	Health Pessimist	Health Optimist	Poor Health Realist	Death/Dropout
Good Health Realist	1183 (0.47)	194 (0.08)	381 (0.15)	317 (0.13)	431 (0.17)
Health Pessimist	315 (0.30)	256 (0.24)	25 (0.02)	219 (0.20)	248 (0.23)
Health Optimist	129 (0.13)	105 (0.10)	136 (0.14)	404 (0.41)	215 (0.22)
Poor Health Realist	181 (0.08)	355 (0.16)	60 (0.03)	1038 (0.46)	611 (0.27)
	Health	**Asymmetry**	**Wave 3**		
Health Asymmetry (Wave 2)	Good Health Realist	Health Pessimist	Health Optimist	Poor Health Realist	Death/Dropout
Good Health Realist	814 (0.45)	39 (0.02)	418 (0.23)	223 (0.12)	314 (0.18)
Health Pessimist	176 (0.19)	182 (0.20)	16 (0.02)	271 (0.30)	265 (0.29)
Health Optimist	114 (0.19)	6 (0.01)	311 (0.52)	82 (0.13)	89 (0.15)
Poor Health Realist	216 (0.11)	126 (0.06)	142 (0.07)	1116 (0.57)	378 (0.19)
Death/Dropout	0 (0)	0 (0)	0 (0)	0 (0)	1505 (1)

Figure 3.3

River diagram showing transitions from health asymmetry categories at ELSA waves one, two and three.

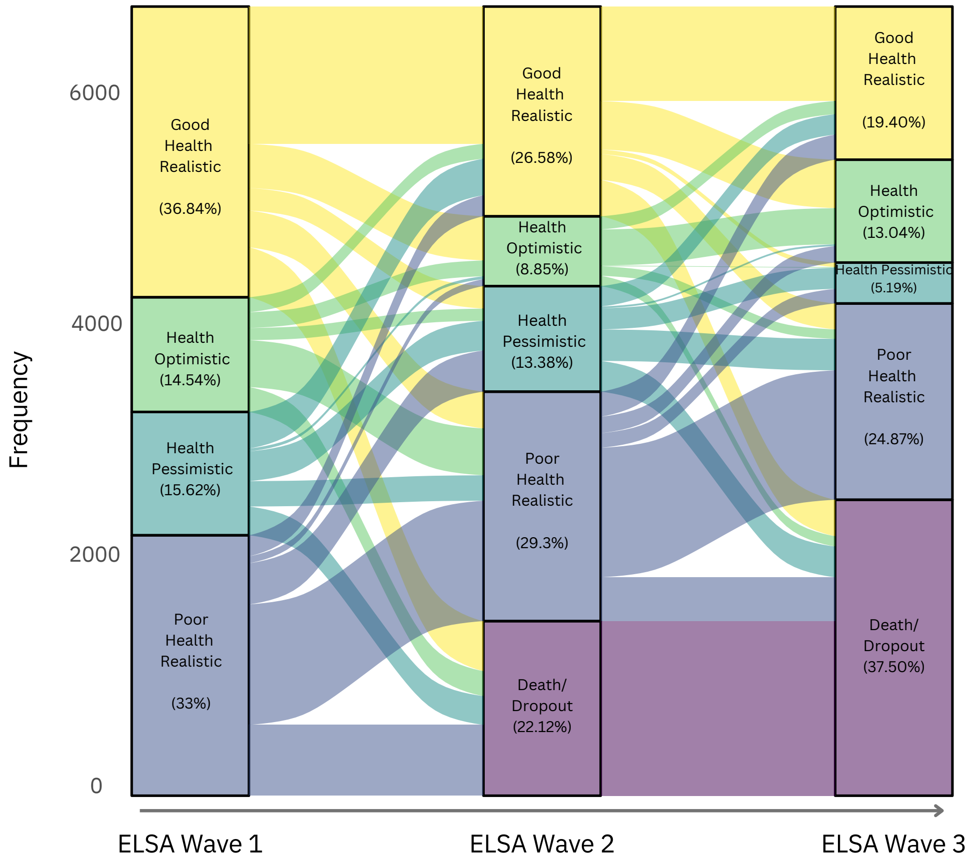


Table 3.3

Model 1: Odds ratios (95% Confidence Intervals) of transitioning from the 'good health realist' category to the other categories, calculated using generalised logit models - ELSA wave one to wave two

Health Asymmetry (Wave 2)	Intercept	Sex	Age	Depressive Symptoms	Education: Foreign/other	Education: O levels CSE
Health Pessimistic	0.03*** (0.01, 0.06)	1.16 (0.93, 1.40)	1.01 (0.78, 1.24)	1.40*** (1.20, 1.60)	0.78*** (0.58, 0.97)	0.78 (0.35, 1.21)
Health Optimistic	1.13 (0.73, 1.08)	0.70 (0.21, 1.19)	0.99 (0.67, 1.30)	0.93*** (0.88, 1.72)	1.18*** (1.17, 1.20)	1.23 (0.98, 1.47)
Poor Health Realistic	0.15*** (0.16, 0.18)	0.57*** (0.31, 0.83)	1.01 (0.76, 1.25)	1.24* (1.03, 1.46)	1.15 (0.70, 1.49)	0.97 (0.89, 1.09)
Death/Dropout	0.01*** (0.01, 0.02)	1.12*** (1.07, 1.17)	1.04 (0.04, 2.04)	1.27* (1.03, 1.51)	0.77*** (0.51, 1.03)	0.68 (0.26, 1.11)

Health Asymmetry (Wave 2)	Education: A levels	Education: Degree/higher	Health Pessimistic	Health Optimistic	Poor Health Realistic
Health Pessimistic	0.39*** (0.11, 0.67)	0.54*** (0.53 0.55)	3.95*** (3.74, 4.16)	3.17*** (2.90, 3.44)	7.41*** (7.37, 7.46)
Health Optimistic	1.25*** (0.93, 1.57)	1.46*** (1.21, 1.72)	0.22*** (0.19, 0.27)	3.70*** (3.50, 3.91)	1.18 (0.98, 1.39)
Poor Health Realistic	0.91 (0.16, 1.65)	1.14 (0.94, 1.34)	2.41*** (2.26, 2.56)	9.15*** (8.77, 9.52)	16.55*** (16.30, 16.81)
Death/Dropout	0.49*** (0.33, 0.64)	0.54*** (0.19, 0.88)	1.84*** (1.83, 1.85)	2.90*** (2.69, 3.12)	5.93*** (5.72, 6.14)

Table 3.4

Model 2: Odds ratios (95% Confidence Intervals) of transitioning from the 'good health realist' category to the other categories, calculated using generalised logit models - ELSA wave two to wave three

Health Asymmetry (Wave 2)	Intercept	Sex	Age	Depressive Symptoms	Education: Foreign/other	Education: O levels CSE
Health Pessimistic	0.01*** (0.01, 0.02)	0.96 (0.60, 1.31)	1.02 (0.62, 1.42)	1.35** (1.12, 1.56)	0.54 (0.19, 1.50)	0.73** (0.49, 0.97)
Health Optimistic	0.70** (0.43, 0.97)	0.82 (0.21, 1.44)	1.00 (0.11, 1.88)	0.98 (0.58, 1.38)	1.16 (0.98, 1.35)	1.05 (0.61, 1.48)
Poor Health Realistic	0.05*** (0.03, 0.07)	0.76 (0.38, 0.15)	1.02 (0.63, 1.42)	1.20 (0.97, 1.42)	1.15*** (1.14, 1.17)	0.89 (0.66, 1.12)
Death/Dropout	0.02*** (0.01, 0.05)	1.02 (0.95, 1.08)	1.04*** (1.04, 1.04)	1.16*** (1.11, 1.21)	0.87 (0.54, 1.20)	0.69*** (0.62, 0.76)

Health Asymmetry (Wave 2)	Education: A levels	Education: Degree/higher	Health Pessimistic	Health Optimistic	Poor Health Realistic	Death/Dropout
Health Pessimistic	1.58 (1.05, 2.11)	0.44 (0.28 0.69)	14.40*** (14.16, 14.65)	1.13 (0.24, 2.02)	8.71*** (8.47, 8.94)	1.19*** (1.12, 1.31)
Health Optimistic	1.13 (0.88, 1.37)	1.26** (1.09, 1.42)	0.19*** (0.14, 0.51)	5.19*** (5.01, 5.37)	1.28 (0.86, 1.70)	2.54*** (2.38, 3.01)
Poor Health Realistic	1.46*** (1.22, 1.12)	0.89*** (0.88, 0.90)	4.52*** (4.30, 4.73)	2.60*** (2.59, 2.61)	14.84*** (14.60, 15.08)	4.42*** (4.40, 4.44)
Death/Dropout	1.03*** (1.03, 0.76)	0.60*** (0.31, 0.90)	3.07*** (3.07, 3.07)	2.08*** (1.77, 2.39)	3.66*** (3.61, 3.71)	NA

The first-order Markov model indicated that health asymmetry transitions over time were non-stationary (i.e. not homogeneous) (Λ = 539.29, df=48, $p<0.01$), that is, the likelihood of transitioning from one health asymmetry category to another was not constant at each wave. Thus, to estimate transition probabilities while accounting for confounders, two separate generalised logit models were fitted, one for each wave transition (from wave one to two, and from wave two to three) (see Table 3.4 and 3.5).

The effects of depressive symptomatology, educational attainment and previous health asymmetry category were significant in both logistic models. Those who had higher levels of depressive symptoms were more likely to become health pessimists at wave two (OR = 1.40, $p <.001$) and at wave three (OR=1.35, $p<.001$), when compared to good health realists. Those who had higher levels of depressive symptoms also had an increased likelihood of being lost to death/dropout at wave two (OR=1.27, $p = .03$) and at wave three (OR=1.16, $p<.001$). Older adults with higher educational attainment were less likely to become health pessimistic at wave two (OR=0.54, $p<.001$), when compared to good health realists. Having higher educational attainment was associated with an increased likelihood of becoming health optimistic at wave two (OR=1.46, $p<.001$) and at wave three (OR=1.23, $p<.01$). However, the effects of sex were only significant in the first transition, where males had a decreased likelihood of becoming poor health realists (OR=0.57) and an increased likelihood of being lost to death/dropout (OR=1.12, $p <.001$), compared to good health realists. The effect of age was only significant in the second transition, with an increase in age being associated with a greater odds of being lost to death/dropout (OR=1.04, $p <.001$). Estimated transition probabilities were stratified by sex and age (as visualised in Figures 3.4 and 3.5) and across varying levels of depressive symptoms (see Figures 3.6 and 3.7).

Figure 3.4

Predicted transition probabilities for health asymmetry categories from ELSA Wave 1 to 2 (stratified by age and sex).

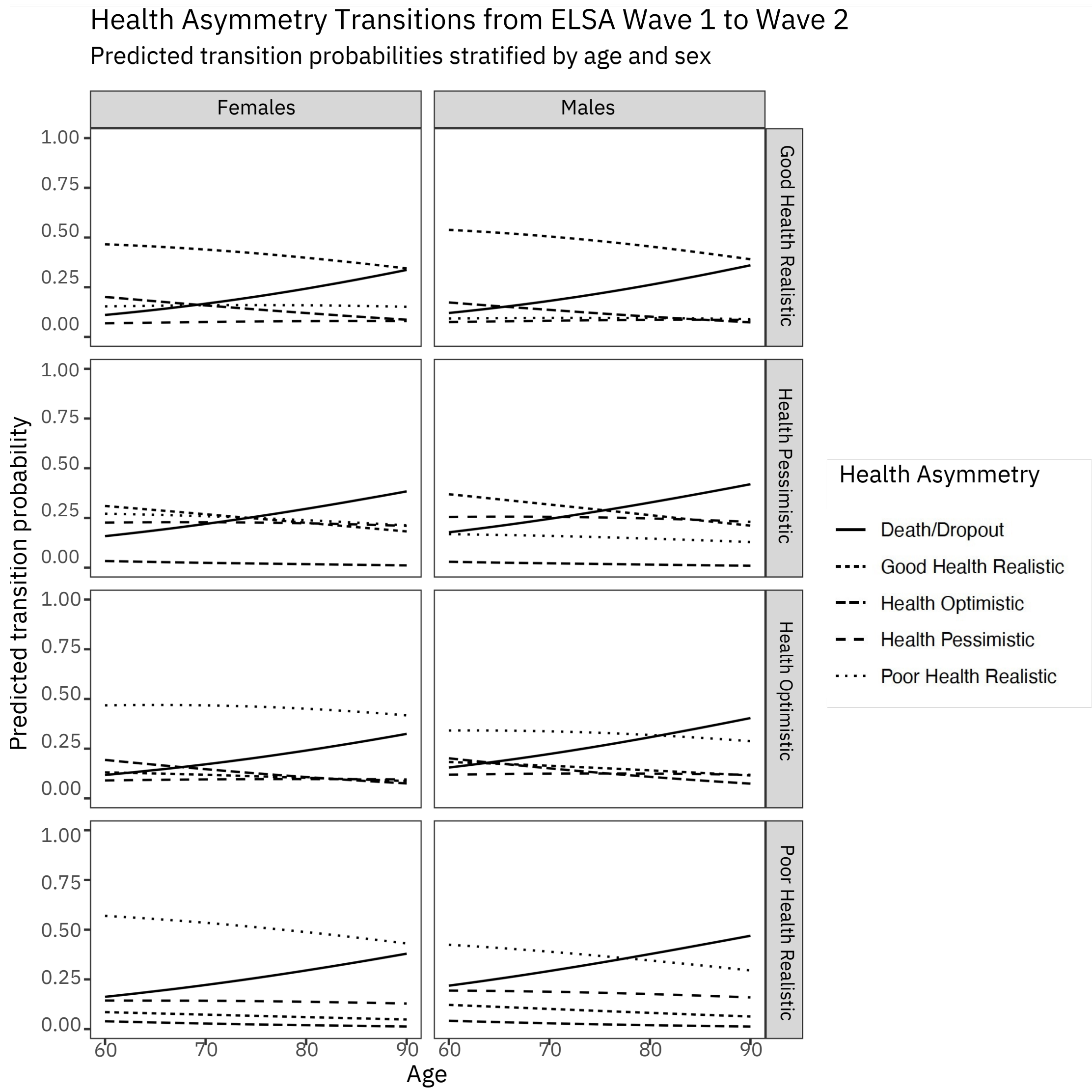


Figure 3.5

Predicted transition probabilities for health asymmetry categories from ELSA Wave 2 to 3 (stratified by age and sex).

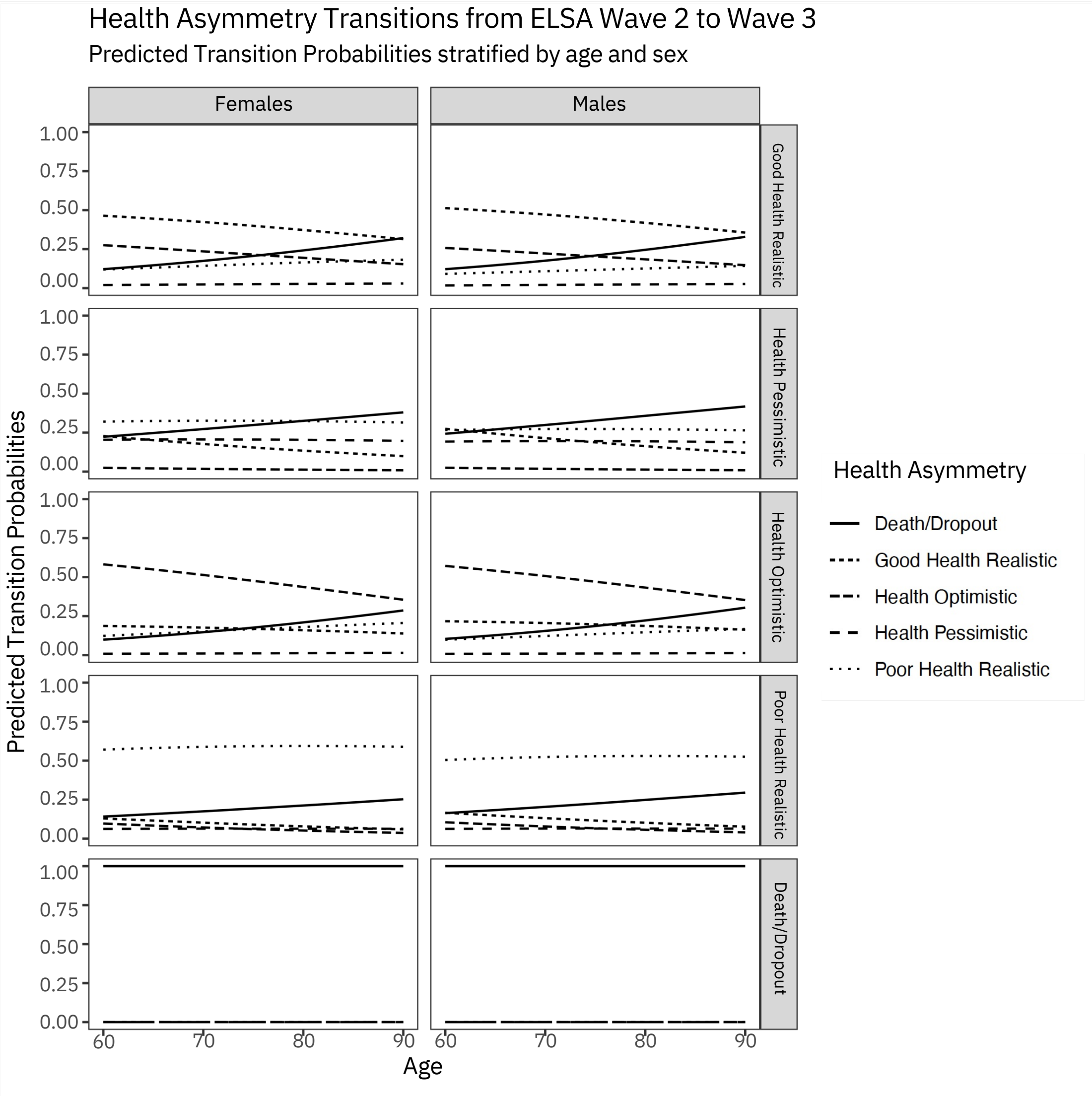


Figure 3.6

Predicted transition probabilities for health asymmetry categories from ELSA Wave 1 to 2 (stratified by sex and depressive symptoms).

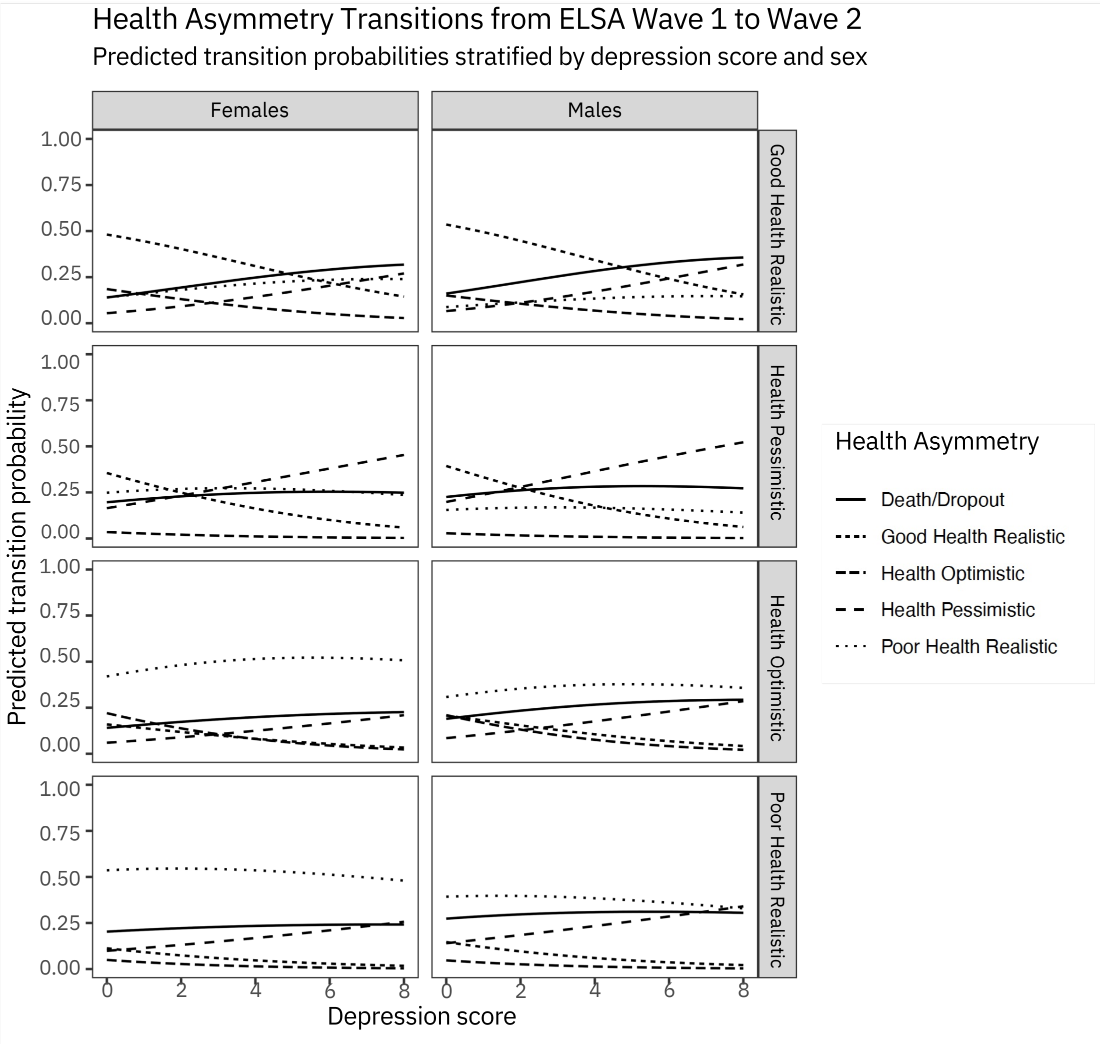
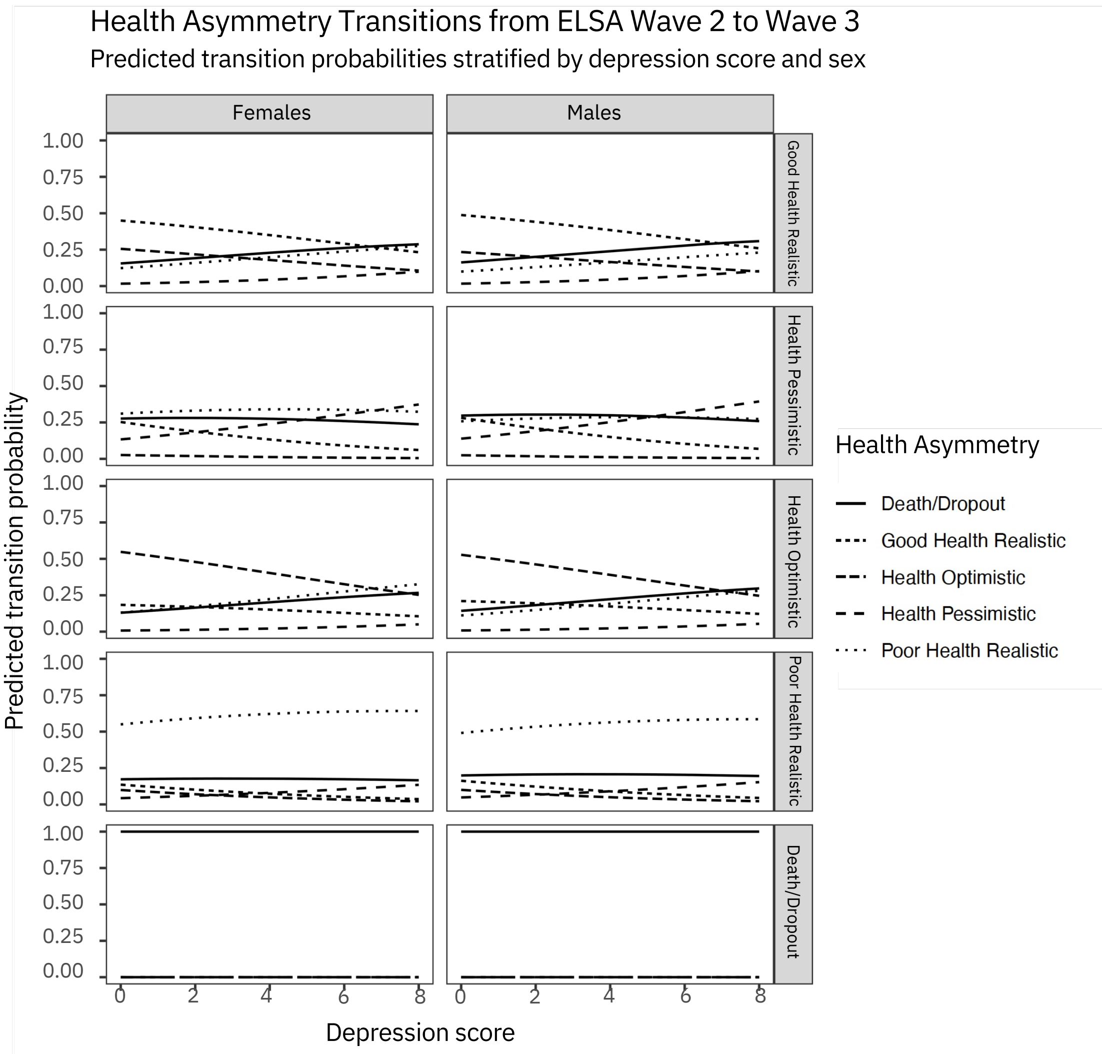


Figure 3.7

Predicted transition probabilities for health asymmetry categories from ELSA Wave 2 to 3 (stratified by sex and depressive symptoms).



Good health realists were most likely to remain good health realists after the first transition (0.47) and the second transition (0.45), in both males and females and across most age groups. However, oldest-old males and female good health realists were almost as likely to die or drop out, rather than retain a good health realistic status. A gradual increase in age resulted in an increased probability of good health realists being lost to attrition (see Figures 3.3 and 3.4).

Good health realists who transitioned to another health asymmetry category were most likely to be lost to death or dropout or to become health optimists. The transition probabilities for becoming health optimistic were higher for the second transition (0.23) than for the first transition (0.15). However, the probability of good health realists becoming health optimists decreased with an increase in age. Additionally, those who were health optimistic in wave one were 3.70 times more likely to remain health optimistic in wave two when compared to those who were good health realists in wave one transitioning to health optimistic in wave two (OR=3.70, $p<.001$), however this decreased significantly after the second transition (OR=1.12, $p<.001$).

Poor health realists had also high probabilities of remaining poor health realistic over time, both after the first transition (0.46) and second transition (0.57). However, transitioning from wave one to two, older males had a higher probability of being lost to death/dropout, a trend which did not appear in females (see Figure 3.4). A small proportion of poor health realists became health pessimists after the first transition (0.16). However, poor health realists were not likely to transition into health optimists (with low probabilities of poor health realists becoming health optimists at wave two (0.03) and at wave three (0.07)).

No consistent transition trends were identified for health pessimists. Health pessimists were most likely to become good health realists after the first transition (0.30). However, in the second wave transition, health pessimists were most likely to become poor health realists (0.30) or to be lost to death or dropout (0.29), particularly for older health pessimists (see Figures 3.4 and 3.5). Despite having similarly good OH levels as good health realists, health pessimists were 1.84 times more likely to be lost to death/dropout at wave 2, when compared to good health realists being lost to death/dropout (OR=1.84, $p<.001$); this likelihood increased to 3.07 times more likely after the second wave transition (OR=3.07, $p<.001$).

A sensitivity analysis revealed that a more objectively measured latent OH score did not considerably affect health asymmetry categories or estimated transition probabilities. In this sensitivity analysis, a latent OH health score for each participant based on 5 health indicators was generated, instead of generating an FI score. There was considerable agreement between our health asymmetry categories in this sensitivity model with the health asymmetry categories included in our final model. Relatively similar estimated transition probabilities were yielded across our main and sensitivity analyses.

3.4 Discussion

This study investigated transition trends in health asymmetry status over time in a sample of older adults resident in England. Notably, health realistic individuals (those categorised as either ‘good health realistic’ or ‘poor health realistic’) had high probabilities of remaining health realistic after each transition (if not lost due to attrition). These findings align with our hypothesis and with previous descriptive accounts of change in health congruence categories (Ruthig et al., 2011). These findings are somewhat consistent with findings from Chapter Two, where the prevalence of 'health realistic' individuals remained relatively consistent with an increase in age group.

The relative stability of health realistic categories over time may be explained by the innate ability of individuals to provide SH estimations which are consistent with OH and which show decent predictive validity (Schnittker & Bacak, 2014). However, an alternative explanation for the stability of health realistic categories may be attributed to a process of cognitive anchoring or temporal comparison that some older adults exhibit (Staudinger et al., 2003). Once older adults establish a health realistic perception, it may become a sort of anchor or reference point. Through repeated observations and lived experiences over time, they may maintain their health realistic perception, as any deviation from the anchoring point becomes noticeable (Gorini & Pravettoni, 2011; Sargent-Cox et al., 2010).

However, transition probabilities from our Markov models were found to be non-stationary, indicating that the overall likelihood of transitioning to and from health asymmetry categories was inconsistent across each wave transition. This resulted in good health realistic individuals having a gradually increasing probability of becoming health optimistic over time. While some good health realists became health optimistic after the first transition, this increased to almost a quarter of good health realists (at wave two) becoming health optimistic at wave three). As a result, there is sufficient evidence to support our hypothesis that a considerable proportion of good health realists transition to being health optimistic, and as such increasing the proportion of health optimists within the sample over time.

A potential explanation for the increasing likelihood of good health realists becoming health optimistic may be that some good health realists ascribe physiological problems to the ageing process, instead of any particular health problem related to themselves. Older adults may gradually normalise, accept and deal with their health problems in an adaptive manner (Idler et al., 1999; Wrosch et al., 2006). As a result, long-term survival against declining health (combined with relatively stable SH) may have resulted in growing discrepancies between SH and OH in some good health realists in our sample (Galenkamp et al., 2012; Wettstein et al., 2016), causing them to transition into health optimists at a later wave.

We also expected a considerable proportion of poor health realists to transition into health optimists, based on previous literature which claimed that SH appraisals may remain stable or even improve over time (Heller et al., 2009; Vogelsang, 2018). However, poor health realists were more likely to remain poor health realistic or to be lost to attrition. Therefore, there is insufficient evidence to support this hypothesis. This is despite the response shift theory postulating that older adults may recalibrate and reconsider SH appraisals after comparing themselves to others who are worse off (Cheng et al., 2007; Henchoz et al., 2008; Wu & Zhang, 2023). This is also in despite of evidence that some older adults experience positive shifts in SH, even after serious health events (Spuling et al., 2017; Wilcox et al., 1996). Positive response shifts in SH are not universal among all older adults. Specifically, it seems that those who are already realistic about their poor health may not exhibit as pronounced improvements in SH as previously thought (Ruthig et al., 2011).

Health pessimism was not a stable trait among our sample, with many health pessimists becoming poor health realistic at a later wave or being lost due to death or dropout. This may be due to declines in OH, where health pessimists noticed somatic experiences or bodily changes that later manifest as poor OH. It is possible that pre-existing states like health pessimism represent prodromal poor OH that older adults are diffusely but not specifically aware of (Idler & Kasl, 1991; Kitzmüller et al., 2013). Relatedly, health pessimists who believe that they are in poor OH just might end up in poor OH, through different psychological and behavioural pathways, since SH affects health and mortality (Idler & Kasl, 1991).

Such findings have pertinent clinical and public health implications. The transitory nature of such short-lived health pessimism may merit the promotion of positive health appraisals among health pessimists (facilitated by healthcare professionals). Future research should explore what factors may shift SH appraisals. For example, implementing cognitive-based interventions that facilitate SH appraisals among continually health pessimistic individuals could be helpful, as health pessimists had high probabilities of being lost due to attrition. It is also possible that interventions designed to increase acceptance of ageing and illness or health literacy could help individuals develop more realistic expectations of their health (Brassington et al., 2016; Sadowski et al. 2011). Identifying and addressing states of health pessimism in older adults is pertinent as health pessimism may perpetuate a cycle of unhealthy lifestyle choices and may undermine efforts to promote healthy ageing and health behaviour change in later life (Boardman, 2004; Graf & Hicks Patrick, 2016).

Additionally, maintaining positive SH appraisals among good health realists may shift such individuals towards health optimism over time. This may be beneficial due to some positive physical and mental health benefits and overall adaptive outcomes associated with health optimism (Calvey et al., 2023; Chipperfield, 1993; Hong et al., 2004; Ruthig et al., 2011). Once again, it may be possible for interventions to encourage positive SH appraisals in good health realists. For example, social cognitive approaches such as downward social comparison, positive reappraisals or through community-based social participation interventions (Ichida et al., 2013; Morling & Evered, 2006), may result in more positive SH scores and subsequently increasing likelihood of survival, despite future declines in OH.

The adaptiveness of health optimism has been well-established in older adults. Health optimistic older adults have more optimal psychological health, engage in exercise more than others and have greater survival outcomes (Calvey et al., 2023; Chipperfield, 1993; Hong et al., 2004; Hong et al., 2005; Ruthig & Chipperfield, 2007). However, there may also be a maladaptive nature to positive SH appraisals in the presence of poor OH. Health optimists have an elevated risk of experiencing an injurious fall (Calvey et al., 2024), as will be described in Chapter Five. Additionally, it is possible that overly health optimistic individuals might not seek medical treatment or engage with healthcare services less than others (Löckenhoff & Carstensen, 2004). As such, having health optimism as a target state should be carefully considered.

We contribute novel findings to the health congruence and health asymmetry literature. Markov models were applied to identify trends regarding how older adults transition to and from health optimistic, pessimistic and realistic perceptions over time, rather than relying solely on descriptive accounts. Additionally, OH was operationalised more broadly than previous health congruence studies, since our OH measure accounted for aspects of physical, functional, cognitive and mental health decline that is typically observed in later life.

However, there are some limitations to our study design. Firstly, our measure of OH is not fully independent of SH, since we relied on self-reported chronic health conditions and functionality in our OH index. This may result in measurement error typically associated with subjective reporting tendencies. While some studies reported decent reliability in the self-reporting of health conditions (Chaudhry et al., 2005; Najafi et al., 2019), others claimed that self-reporting chronic conditions may result in systematic reporting errors, attenuation biases and underestimating the prevalence of such conditions (Baker et al., 2004; Mackenbach et al., 1996). Previous health congruence research also relied on self-reported chronic conditions for measuring OH (e.g. Chipperfield, 1993; Rai et al., 2019). However, objective cognitive tests and other aspects of physiological health were included, which may ensure our OH measure is still distinct enough from participants' SH appraisals. Additionally, our sensitivity analysis indicated that a more objective, latent measure of OH yielded similar health asymmetry categorisations and estimated transition probabilities to our unique FI. Therefore, it can be concluded that the FI was a relatively appropriate and informative proxy of OH among our sample of older adults.

Since personality traits are associated with SH and OH (Kang, 2023; Montoliu et al., 2020), traits such as neuroticism could help explain transitions from one health asymmetry category to another. However, personality traits could not be adjusted for in the analyses, as personality traits were not captured during ELSA waves one to three. Furthermore, a single item of self-rated health was utilised in this study, which is known to captures physical, functional, mental and cognitive aspects of health (Krause & Jay, 1994; Singh-Manoux et al., 2006). The comparison of this single SH item to a more comprehensive, multiple-item index of OH may have contributed to the overall discrepancies between SH and OH at each wave.

Some participants in our sample who were initially in poor health (i.e. poor health realists and health optimists) transitioned to health asymmetry categories associated with good health (good health realists or health pessimists). Further research could untangle what contributes to such unexpected health asymmetry transitions, which possibly reflect unexpected positive shifts in OH. Further investigations could also parse out death and dropout into separate outcomes and subsequently assess how health asymmetry categories transition to death or dropout.

In conclusion, our findings demonstrate how discrepancies between SH and OH scores in older adults change over time. Many older adults consistently maintained a health realistic perspective (whether it was a good or poor health realistic perspective). Good health realists who did change health asymmetry category, however, were likely to become health optimistic. Health pessimism was an unstable trait over time in older adults, with many being lost to attrition. Therefore, future studies should investigate if promoting positive SH appraisals among older adults (whether that be among health pessimists or good or poor health realists) subsequently optimises their physical, functional, mental health and survival outcomes.

CHAPTER 4

Health Asymmetry as a predictor of depressive symptomatology over time among older European adults

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Abstract

Subjective (SH) and objective health (OH) measures are associated with depressive symptomatology in older adults. We explored whether the discrepancy between SH and OH (operationalised as 'health asymmetry' with four categories: 'health optimistic', 'health pessimistic' and 'good health realistic' and 'poor health realistic') may also relate to depressive symptomatology 1) cross-sectionally, and 2) longitudinally, among older European adults. A sample of middle-aged and older adults (n = 26,520), aged 50+, from 11 European countries, were tracked over six waves of data collection (2006–2020) in the SHARE study. A hierarchical multi-level growth curve model explored whether health asymmetry was associated with depressive symptomology at baseline, and with depressive symptom trajectories across time, accounting for country of origin. At baseline, 11.8% of older adults were classified as health pessimistic, with 15.5% being health optimistic, 42.9% being poor health realistic and 29.8% being good health realistic. A positive linear trend in depressive symptomatology was noted across 14 years of SHARE data (β=0.11, p<.001). Health pessimists displayed higher levels of depressive symptoms than both health realistic groups and health optimists. However, health pessimists experienced a less steep increase in depressive symptoms across time (β=0.10, p<.001), relative to good health realists. Health pessimists experience elevated levels of depressive symptoms, but show less growth in depressive symptomatology than expected. Further research is required to understand the underlying causes of the varying depressive symptom trajectories among these groups.

4.1 Introduction

Depressive symptomatology becomes more prevalent with age (Päivärinta et al., 1999) and is repeatedly linked to SH (Benyamini et al., 2000; Bjorner, 1996; Östberg & Nordin, 2022). However, SH may be subject to latent reporting tendencies caused by traits such as optimism and pessimism (Layes et al., 2012) and may be affected by the different interpretations of the measure's phrasing (Krause & Jay, 1994; Sokol et al., 2017). SH may also be affected by an ageing paradox, particularly among those aged 80 and over, where such individuals underestimate their health decline, relative to more objective measures of their health (Abma et al., 2021; Henchoz et al., 2008; Wettstein et al., 2016). Some explanations for this ageing paradox have been proposed: older adults display higher levels of expertise and resilience. These increased capacities account for stability of SH despite declines in OH (Wettstein et al., 2016). Response shift theory postulates that over time, patients reconceptualise and reprioritise internals standards and self-appraisals, which may result in older adults assessing SH to a different standard than younger individuals (Galenkamp et al., 2012; Howard et al., 2011; Sprangers & Schwartz, 1999). Additionally, an age-related positivity effect regarding SH appraisals could explain the relative stability of SH in older age, as these individuals may focus on their still healthy, physically intact body functions, rather than focusing on the decline in health and body functionality (Carstensen & DeLiema, 2018). These explanations may play a significant role in why the oldest old believe they are healthier than what their OH status would indicate.

Depressive symptoms are also repeatedly associated with single indicators of OH, for example, disease prevalence (Gunn et al. 2012; Read et al., 2017), hypertension (Rubio-Guerra et al., 2013) and grip strength (Gu et al., 2021; Marques et al., 2021; McDowell et al., 2018). However, a better alternative to single indicators may be to employ a multidimensional index. One potential measure is the Frailty Index (FI) (Mitnitski et al., 2001) which is designed to capture frailty in ageing adults across a range of health domains. Frailty is defined as older adults' susceptibility to decreased reserve and an increased risk for adverse functional and health outcomes (Hoogendijk et al., 2019; O' Halloran et al., 2014) and has been shown to associate with depressive symptoms in older adults (Chen et al., 2010). The health-related structure of the FI makes it useful as a proxy for OH in older adults (Rockwood et al., 2014; Wuorela et al., 2020) as it measures participants' frailty and relative functional, physical, and cognitive health statuses. However, it must be flagged that the FI is somewhat based on self-reported data, and thus is not fully independent of SH, and is a substitute for OH rather than an actual indication of OH.

The discrepancy between SH and OH may also be relevant with regards to depressive symptomatology. For instance, those who possess a negative perception of their health status, despite good OH, may be prone to depressive symptomatology, while those who face significant OH problems but who are 'health optimistic' may be prone to experiencing fewer depressive feelings (Peterson & Bossio, 1992). Additionally, stressful life events and individual differences highlight why some older adults with good OH provide poor health appraisals (health pessimists) whereas others provide good health appraisals (health realists) (Ruthig et al., 2011).

Certain metrics have been developed to compare OH and SH within individuals. Chipperfield (1993) posits a 'health congruence' framework, wherein the agreement/disagreement between an individual's SH and their OH status results in individuals being categorised as health optimistic, health pessimistic or health realistic. Chipperfield's health congruence framework borrows from earlier typologies of trait optimism and pessimism, which are related to an individual's dispositional life orientation, and not just in the context of health, even though trait optimism and pessimism are predictive of a vast range of health outcomes (Korn et al., 2014; Monzani et al., 2021; Pänkäläinen et al., 2016). Health optimists rate their SH considerably higher than scores they obtain from OH measures, while health pessimists rate their SH to be relatively lower than their OH. Within Chipperfield's health congruence framework, health realists are sub-divided into those realists who have good health ("good health realists") and those with poor health ("poor health realists"). The link between depressive symptomatology and health congruence has been sparsely investigated. Hong and colleagues (Hong et al., 2004) showed that older health pessimists and poor health realists had higher levels of depressive symptoms than health optimists or good health realists. Such associations between health optimism and depression were echoed in recent research (Rai et al., 2019; Ruthig et al., 2011). From our searches, no longitudinal study has yet investigated the relationship between SH/OH discrepancies and depressive symptoms across time.

Since the development of the health congruence framework, a health asymmetry metric was also introduced in Chapters Two and Three, which classifies individuals into similar categories (Calvey et al., 2022). Health asymmetry extends the framework of Chipperfield by offering a clear manner in which health congruence categories can be derived using a multidimensional OH scale, in contrast to previous efforts of operationalising OH using less extensive OH indicators, taken by Chipperfield and other investigators. Health asymmetry classifies older adults into groups (health pessimists, health optimists and health realists), typically based on the incongruence between SH and FI scores, or other multidimensional OH indices (Calvey et al., 2024). The use of a FI within this metric makes it more appropriate for its deployment in older populations, which health congruence metrics were not as suitable for. Health asymmetry has been recently associated with a set of sociodemographic, health behaviour and psychosocial variables, although here, we extend previous health asymmetry research, by sub-dividing health realists, into those who have 'good' or 'poor' health, now deriving four health asymmetry groups instead of three (Calvey et al., 2022), similar to Chapter Three.

In the current study, the clinical importance of health asymmetry is evaluated, specifically, by investigating whether health asymmetry status is a predictor of change in depressive symptomatology in older adults across time. Despite the varying courses of trajectories of depressive symptoms in older adults (de la Torre-Luque et al., 2019), it is expected that, across the 14-year span of data collection in this study, the trajectory of depressive symptoms will see a steady increase. As the prevalence of depressive symptoms in older adults varies considerably across regions within Europe (Horackova et al., 2019), it is also expected that pan-European differences will exist in the proportion of older adults classified as health pessimistic, health optimistic, good health realistic and poor health realistic. Such differences may be reflective of: 1) the disparate efficiency of healthcare systems across Europe, which may hinder adults from accessing healthcare (Cylus & Papanicolas, 2015), and 2) health systems in low-income countries differing from those in high-income countries regarding availability of resources and access to services (Pantoja et al., 2017). Other asymmetry metrics noted cultural differences in their proportion rates too (Power et al., 2019).

Previous research found a protective effect of optimism in health (Borawski et al., 1996; Chipperfield, 1993; Patton et al., 2011) and similar protective effects and general health optimism may shield health optimists from experiencing increasing depressive symptoms across time. Conversely, an underestimation of OH scores (or health pessimism) may act as a risk factor for depressive symptoms, causing growth in symptomatology trajectories across time, in health pessimists. Therefore, based on previous literature (Hong et al., 2004; Rai et al., 2019), it is hypothesised that cross-sectional differences in depressive symptoms will be noted across the four health asymmetry groups, with health pessimists experiencing higher levels of depressive symptoms than health optimists and good/poor health realists. It is also hypothesised that health asymmetry will be a predictor of change in trajectories of depressive symptomatology.

4.2 Methods

Design and participants

Analyses were conducted using a secondary data source, a longitudinal, prospective, observational dataset called the 'Survey of Health, Ageing and Retirement in Europe' (SHARE), which collates social, economic and health data from over 140,000 ageing adults, mainly aged 50+ years. The participants are resident in 28 European nations and Israel. Sampling bias was addressed by sampling of SHARE participants, using probability selection methods. Sample frames, which are primarily from population registers, are selected according to the best available frame resources in the country to achieve full probability sampling, despite minor variations in sampling frames (Aichberger et al., 2010). In terms of sample size estimation, SHARE does not set a minimum size, due to funding and resources varying across participating nations. Instead, nations maximise their sample size with their available budget (Bergmann et al., 2017). Data collection was mainly conducted through computer-assisted personal interviewing in participants' homes. The University of Mannheim's internal review board reviewed the ethical standards of SHARE, though Wave 4 onwards were approved by the Ethics Council of the Max Planck Society (Börsch-Supan et al., 2013).

Six waves of SHARE data were drawn upon, which are spaced 14 years apart: Wave 2 (collected in 2006) up to Wave 8 (collected between 2019 and 2020). This excludes Wave 3 however, since this wave consisted of SHARELIFE, a particular wave of data collection that focused on people's life histories, and therefore, depressive symptoms were not measured. In total, 26,520 independently living and ageing adults were included in analyses. Participants were eligible if: 1) they were resident in a nation which participated in each wave from Wave 2 to Wave 8, as refreshment cohorts were excluded from analyses, 2) were 50+ years old, and 3) were not initially diagnosed with Alzheimer's or Parkinson's Disease at baseline, where cognitive impairment may affect SH ratings and bias self-reporting of depressive symptoms. Of the 29 countries within the SHARE study, participants from 11 countries were included in analyses (as each country participated in each wave of data collection): Austria (n=1146), Belgium (n=3080), Switzerland (n=1438), Czech Republic (n=2610), Germany (n=2516), Denmark (n=2505), Spain (n=2295), France (n=2776), Italy (n=2862), Netherlands (n=2585) and Sweden (n=2707). Of 37,143 participants who initially participated in Wave 2 of SHARE, a total of 10,623 participants were excluded from analyses as they did not meet our exclusion criteria stated above. This resulted in our final sample of n=26,520. Each participant had at least 2 timepoint of EURO-D scores. All participants provided informed consent for secondary archival and subsequent analyses of their data prior to their participation in SHARE.

Measures

Self-rated health

Participants were asked how they would rate their health (SH), on a five-point scale using the following responses: ‘excellent’, ‘very good’, ‘good’, ‘fair’ and ‘poor’. This scale has been used in ageing and health studies, such as the Health and Retirement Study (Juster & Suzman, 1995) and the Irish Longitudinal Study of Ageing (Kenny et al., 2010). It is recommended for inclusion on all health surveys (De Bruin, 1996), due to its usefulness as a health measure in predicting mortality and its association with other domains of health (Idler & Benyamini, 1997). SH measures have shown moderate to good test-rest reliability in previous investigations (Lundberg & Manderbacka, 1996; Zajacova & Dowd, 2011) and have been validated across ethnic groups (Chandola & Jenkinson, 2000).

Objective Health

A unique FI was compiled using health data available in the SHARE dataset, acting as a proxy for OH in the health asymmetry metric. The creation of this FI was carried out following guidelines from Searle and colleagues (Searle et al., 2008). The FI measures a variety of health deficits including disease prevalence, functional, physical and cognitive health. Some examples of health deficits included were, for example, having a previous diagnosis of cancer, or a history of falling. A deficit warrants inclusion in the index if it 1) is associated with health, 2) becomes more prevalent with an increase in age and 3) does not appear in the population too early (e.g. reduced eyesight). A collection of 27 health deficits were included in our FI, most of which are self-reported. Most health deficits were converted into binary variables – either the health deficit was present (=1) or absent (=0). Further details on the dichotomisation of each health deficit is included in Appendix 5. The combined total of present health deficits per individual was divided by the total number of deficits measured, which creates a variable with a discrete proportion. This reveals a FI score from 0 to 1: a higher score within this range implies a more frail individual. The FI differs from other frailty measures, which are more broadly used, such as Rockwood's Clinical Frailty Scale (Rockwood et al., 2005), as the FI can be easily computed from a range of available data in ageing and health datasets. Compiling unique frailty indices yields high inter-rater reliability and a recent meta-analysis has concluded that the FI is a valid instrument for measuring frailty in ageing populations (Drubbel et al., 2014). Appendix 6 illustrates the distribution of our unique FI from SHARE data, across all participants in our sample.

Depressive symptomatology

Depressive symptoms were measured using the EURO–D scale, which was initially developed to compare depressive symptoms across centres in 11 European countries (Prince et al., 1999). Items within the EURO-D scale cover 12 symptom domains including, for example, mood, pessimism, suicidality and irritability. Each item is scored as either 0 (symptom is absent) or 1 (symptom is present). Combining the item scores gives rise to a score from 0 to 12, with the higher scores indicating more depressive symptoms. The EURO-D scale has shown to be reliable and demonstrates high criterion validity while being validated and deployed cross-nationally (Guerra et al., 2015; Larraga et al., 2006; Prajwal et al., 2021). The EURO-D scale at baseline (Wave 2) was measured by Cronbach's alpha ($\alpha = 0.76$), showing moderate internal consistency.

Health asymmetry

Health asymmetry categorises individuals into groups based on the incongruence of an individual's SH and FI scores (Calvey et al., 2022). Similar to other asymmetry metrics (Benke, 2011; Bondi et al., 2008; McHugh Power et al., 2017), health asymmetry creates a categorical variable from continuous data. The same approach to deriving a categorical variable from continuous data as was initially used with social asymmetry was also used here (McHugh Power et al., 2017). The worded SH responses were converted to numeric values ranging from 1 to 5, which created a 5-item ordinal scale (e.g. older adults who rated their SH as "excellent" were attributed a 1, those who rated "poor" received a 5 etc). Then, these SH ratings along with FI scores were both converted to Z scores. SH ratings were then subtracted from FI scores, which derived a discrepancy score for each older adult. One standard deviation of this score determined the cut-off points for the categorical health asymmetry variable. Those whose discrepancy scores were 1 standard deviation below the mean were categorised as health pessimistic (their SH score was considerably lower than their FI score). Those with a discrepancy score within 1 standard deviation of the mean were classified as health realistic (SH and FI scores were relatively consistent). Lastly, those with a discrepancy score 1 standard deviation above the mean were classified as health optimistic (their SH ratings were higher than their FI score). To differentiate between "good" and "poor" health realists, an FI cut-off point of 0.25 was used. This cut-off point differentiates between those who are frail and are not frail (Song et al., 2010). Those with an FI score of 0.25 or higher were considered "poor" health realists, and those with an FI score of lower than 0.25 were classified as "good" health realists.

Covariates

The potential confounding variables age, sex, educational attainment and income were chosen based on a priori knowledge of their associations with depressive symptomatology (Altemus et al., 2014; Bauldry, 2015; Patel et al., 2018; van't Veer-Tazelaar et al., 2008). Educational attainment was categorised using the International Standard Classification of Education (ISCED-97). In order for consistency across all European nations, the following educational attainment categories were implemented: less than primary (0), primary (1), lower secondary (late middle school/early high school) (2), upper secondary (mid-to-late high school) (3) and post-secondary education (4–6), and then combined into 4 overall educational levels for parsimony: no education, primary, secondary and tertiary education. Total household income was categorised into 4 main categories, based on a quartile split: <€12,000, €12,000 – €22,000, €22,000 – €37,000, >€37,000.

Data analysis

All data analyses were carried out in R (R Team, 2013). There were few missing datapoints within the predictor variables in the final dataset, which were missing at random (0.4%). However, multiple imputation was conducted to fill in missing values in predictor variables only, using the R package 'Multiple Imputation by Chained Equations' (MICE) (Van Buuren & Groothuis-Oudshoorn, 2011). Continuous data were imputed using predictive mean matching, while categorical data were imputed using polytomous regression.

To tackle both hypotheses, hierarchical multilevel growth curve modelling was applied. The model aimed to assess: 1) whether cross-sectional associations were found between health asymmetry and depressive symptoms and 2) whether health asymmetry categories were differentially related to trajectories of depressive symptoms across time. Multilevel modelling recognises hierarchies and clusters within longitudinal data. Multilevel modelling is useful when fitting growth curve models, where repeatedly measured data across timepoints can be treated as observations for each wave of data, which are nested within each individual. This allows for the estimation of between-individual differences in within-individual change (Curran et al., 2010). Considering the nature of the SHARE dataset, the data is nested at another higher-order level: country (Level 1) and subsequently at individual level within those countries (Level 2). The hierarchical growth curve model can be generalised as follows:

$$\begin{aligned} Y_{ijtk} \mid p_{ij}, c_j &\sim \mathcal{N}(\mu_{ijtk}, \sigma^2) \\ p_{0ij} &\sim \mathcal{N}(0, \sigma^2_{p_0}) \\ p_{1ij} &\sim \mathcal{N}(0, \sigma^2_{p_1}) \\ c_{0i} &\sim \mathcal{N}(0, \sigma^2_{c_0}) \\ c_{1i} &\sim \mathcal{N}(0, \sigma^2_{c_1}) \end{aligned}$$

where Yijtk is the response variable measured at participant i, from country j, at time t, who was categorised at health asymmetry status k, p0ij and p1ij are the random intercepts and slopes for participant i within country j, and c0j and c1j are the random intercepts and slopes for country j (in order to address potential cross-national differences in levels of depressive symptomatology), all assumed to be normally distributed. Time was included as a fixed effect initially, to ensure that growth appeared in EURO-D scores across time. Then, health asymmetry and its interaction with time were entered into the model, to determine whether health asymmetry acted as a predictor of depressive symptoms and a predictor of change in depressive symptoms across SHARE waves. Covariates were added to the model, along with SH and OH (and an interaction between both) to ensure that the discrepancy between these two health measures were predicting EURO-D scores above and beyond SH and OH alone. Once covariates were added to the model, the final selected linear predictor for the mean parameter was:

$$\mu_{ijtk} = \beta_{0k} + p_{0ij} + c_{0j} + (\beta_{1k} + p_{1ij} + c_{1j})t + \text{Age}_{ij} + \text{Sex}_{ij} + \text{Education}_{ij} + \text{Income}_{ij}$$

The significance of the fixed effects was assessed using F tests with Satterthwaite's correction for the number of denominator degrees of freedom. The significance of the random effects was also assessed using likelihood ratio tests, comparing the full random effect models to models where the random effects were removed from the linear predictor. The modelling was conducted using the 'lme4' (Bates et al., 2005) and 'lmerTest' R packages (Kuznetsova et al., 2017). Full models are presented in Appendix D.

4.3 Results

In total, 26,520 participants were included in the analysis, of whom 45.30% were male (n=12,014). Prevalence rates for the asymmetry categories were obtained: 11.8% of participants were health pessimistic (n=3115), 42.9% of participants were poor health realistic (n=11,381), 29.8% of participants were good health realistic (n=7914) and 15.5% were health optimistic (n=4110). Table 4.1 below presents the baseline descriptive statistics (SHARE Wave 2) compared across the four health asymmetry groups. Partial eta-squared effect sizes are reported for continuous variables and Cramer's V effect sizes are reported for categorical variables, in order to investigate health asymmetry group differences. Additionally, cross-national differences in health asymmetry distributions were assessed: a chi-square goodness of fit test indicated that the proportion of health asymmetry categories significantly differed across European nations (χ^2(30, n=26,520)= 869.96, $p<0.001$). A trend appears in Northern European and Scandanavian nations (e.g Denmark and Sweden), where fewer health pessimists and more health optimists are found. Other European nations such as Czech Republic and Spain have higher numbers of poor health realists and health pessimists, and subsequently lower numbers of health optimists than their European counterparts. These health asymmetry patterns are illustrated in Appendix C.

A multi-level growth curve model tested whether being in a particular health asymmetry group predicted change in the trajectory of depressive symptoms across six timepoints (or 14 years). Table 4.2 presents the final model with the main effect of health asymmetry while controlling for covariates. A random intercept and slope for country was included in the model, so that Simpson's paradox was unlikely to be a concern (Kievit et al., 2013), where differing depression levels across countries would affect the trajectory of depressive symptomatology. The significance of these random effects was assessed using likelihood ratio tests, where the full random effects model was compared to reduced models where the random variances were removed from the linear predictor. Statistically significant differences were noted when likelihood ratio tests compared: 1) the full random effects model to a reduced model where random effects for participants were absent ($p<.001$), and 2) the full random effects model to a reduced model where random effects for country were absent ($p<.001$). As a result, the random slopes and intercepts for both participant and country significantly added to the growth curve model. Trajectories of depressive symptoms across health asymmetry groups are graphed in Figure 4.1 (along with their respective standard error bounds in grey).

Changes in depressive symptomatology were modelled by a significant positive linear trend ($\beta=0.11$, $p<.001$). A significant interaction between SH and OH was obtained ($\beta=2.09$, $p<.001$), which indicates that it was important to correct for a response surface in terms of OH and SH. In this model, relative to good health realists, the health pessimistic category was associated with depressive symptoms at baseline ($\beta = 0.72$, $p < .001$), with poor health realists ($\beta=0.14$, $p<.001$) and health optimists ($\beta=0.47$, $p<.001$) showing significant associations with EURO-D scores at baseline too. Notably, statistically significant interaction effects between time and health pessimism ($\beta=0.10$, $p<.001$), where health pessimists experience a less steep growth in depressive symptoms than relative to good health realists. However, no significant interaction between health optimism and time, or poor health realism and time was found on depressive symptoms as an outcome, indicating that being health optimistic or poor health realistic is not predictive of change in depressive symptomatology across six timepoints of SHARE data.

Table 4.1

Baseline characteristics (mean and standard deviation or percentage and frequency) of our study sample of SHARE participants, stratified by health asymmetry category

	Full Sample	Health Pessimist	Poor Health Realist	Good Health Realist	Health Optimist	Effect Sizes
Age	65.36 ± 9.9	66.07 ± 9.22	66.40 ± 9.80	62.98 ± 9.05	66.50 ± 11.02	0.02 (p<.001)
Sex						
Male	45.30% (n=12,014)	39.36% (n=1,226)	48.03% (n=5,466)	41.74% (n=3,303)	49.12% (n=2,019)	0.29 (p<.001)
Female	54.70% (n=14,506)	60.64% (n=1,889)	51.97% (n=5,915)	58.26% (n=4,611)	50.88% (n=2,091)	
Education						
None	4.13% (n=1,094)	5.84% (n=182)	4.69% (n=534)	2.27% (n=180)	4.82% (n=198)	0.38 (p<.001)
Primary	23.81% (n=6,315)	28.35% (n=883)	26.96% (n=3,068)	17.82% (n=1,410)	23.21% (n=954)	
Secondary	49.55% (n=13,140)	49.82% (n=1,552)	49.26% (n=5,606)	52.39% (n=4,146)	44.67% (n=1,836)	
Tertiary	22.51% (n=5,971)	15.99% (n=498)	19.09% (n=2,173)	27.52% (n=2,178)	27.30% (n = 1,122)	
Income						
<€12,000	25.82% (n=6,847)	31.59% (n=984)	27.88% (n=3,173)	21.94% (n=1,736)	23.21% (n=954)	0.05 (p<.001)
€12,000–€22,000	27.60% (n=7,318)	30.21% (n=941)	29.35% (n=3,340)	25.06% (n=1,983)	25.64% (n=1,054)	
€22,000–€37,000	25.00% (n=6,631)	23.82% (n=742)	24.12% (n=2,745)	26.46% (n=2,094)	25.55% (n=1,050)	
>€37,000	21.58% (n=5,724)	14.38% (n=448)	18.65% (n=2,123)	26.54% (n=2,101)	25.60% (n=1,052)	

Note Chi-square and one-way ANOVA tests were conducted to investigate potential significant baseline group differences among health asymmetry categories. P values are reported along with Cramer's V effect or partial eta-squared effect sizes (where relevant).

Figure 4.1

Average trajectories of Depressive Symptomatology stratified by Health Asymmetry categories, spanning 6 waves (14 years) of SHARE data.

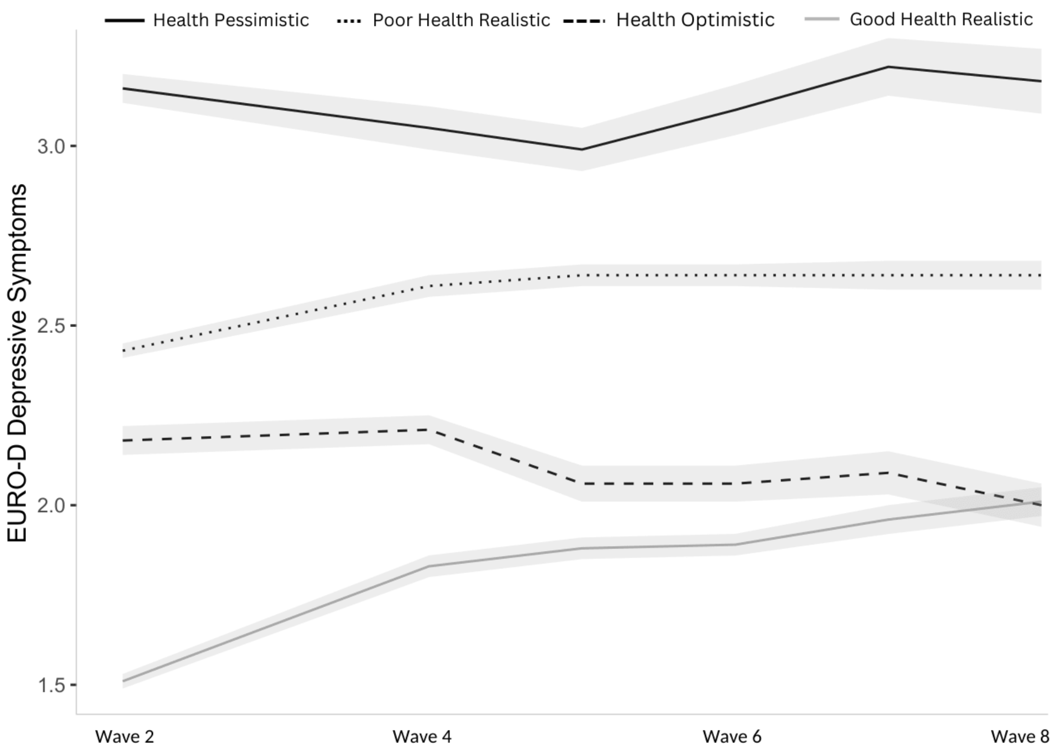


Table 4.2

Multilevel growth curve model for depressive symptoms as a multilevel outcome, with time-varying, time-fixed and covariates, across SHARE waves 2 to 8 (full models in Appendix 4.4).

	Estimate	**95% CI**
Fixed Effects		
Intercept	1.77***	. (1.41, 2.12)
Age	0.004***	(0.002, 0.006)
Sex (Male)	-0.74***	(-0.77, -0.70)
Education: Primary	-0.38***	(-0.49, -0.27)
Education: Secondary	-0.50***	(-0.62, -0.39)
Education: Tertiary	-0.49***	(-0.61, -0.37)
Income: €12,000 - €22,000	-0.16***	(-0.22 / -0.10)
Income: €22,000 - €37,000	-0.13***	(-0.19 / -0.07)
Income: > €37,000	-0.2***	(-0.27 / -0.13)
Subjective Health (SH)	0.02	(-0.05, 0.1)
Objective Health (OH)	-4.1**	(-5.30, -2.90)
SH*OH	2.09***	(1.82, 2.36)
Health Optimistic	0.47***	(0.36, 0.57)
Poor Health Realistic	0.14**	(0.07, 0.21)
Health Pessimistic	0.72***	(0.61, 0.83)
Time*Health Optimistic	-0.01	(-0.03, 0.01)
Time*Poor Health Realistic	-0.01	(-0.02, 0.01)
Time*Health Pessimistic	-0.1***	(-0.12, -0.06)
Variance Components	σ^2	
Participant		
Random Intercept ($\sigma^2 p0$)	1.24	
Random Slope ($\sigma^2 p1$)	.04	
Country		
Random Intercept ($\sigma^2 c0$)	.05	
Random Slope ($\sigma^2 c1$)	.001	
Residuals	2.29	

*Note: *significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$; Sex: Female (Ref); Education: None (Ref); Income: <€12,000 (Ref); Health Asymmetry: Good Health Realistic (Ref). 95% CI = 95% confidence interval. Marginal* R^2 : 17.6%.*Conditional*$\mathbb{R}^2$: 53.4%.

4.4 Discussion

This study investigated the influence which health asymmetry (the discrepancy between SH and OH) has on depressive symptoms. Our analyses found a considerably lower proportion of health pessimists than a previous use of health asymmetry (Calvey et al., 2022). In our study, 11.8% of the sample were health pessimistic, in contrast to 16% previously. The proportion of health optimists in our study, however, was relatively consistent with previous research (Calvey et al., 2022). Interestingly, there was a considerably higher proportion of poor health realists than good health realists, which is contrast to previous studies, where higher proportions of good health realists than poor health realists were found (Ruthig et al., 2011), and another study where relatively even proportions of good and poor health realists were found. These variance in health asymmetry proportions across different European countries in this study, and compared to previous studies may be reflective of cultural and lexical differences, along with differences in health care systems and costs of care (Cylus & Papanicolas, 2015; Pantoja et al., 2017; Power et al., 2019).

Our use of the health asymmetry metric revealed subtle group differences in depressive symptoms. Health pessimists displayed higher levels of depressive symptoms than optimists, good and poor health realists. This finding is consistent with previous health congruence research, where health optimism has been associated with decreased depression scores and conversely, health pessimism associated with increased depressive symptoms (Hong et al., 2004; Ruthig et al., 2011). Significant cross-sectional associations between the health asymmetry groups and baseline EURO-D scores were obtained in our growth curve model, and thus supports our first hypothesis.

However, counterintuitive findings were obtained regarding the prospective influence of health asymmetry on depressive symptomatology. The implementation of a multilevel growth curve model of depressive symptoms revealed that some health asymmetry categories were differentially related to trajectories of depressive symptoms across time. Relative to being good health realistic, health pessimists saw a less steep incline in depressive symptoms: it was hypothesised that health pessimists would see considerable growth in symptoms. Average EURO-D scores among health pessimists seem to remain stable (as Figure 4.1 indicates), when compared to other groups who show more consistent change in symptoms. This may be due to health pessimists already having elevated levels of depressive symptoms at baseline, likely caused by regression to the mean. Health pessimists still display the highest levels of depressive symptoms consistently across time, however. Being poor health realistic or health optimistic did not result in any significant change in depressive symptoms across time when compared to good health realists. Although no statistically significant change was observed in health optimists, this group did display a steady decrease of symptom levels over time, which may allude to the supposed protective effect of health optimism (Chipperfield, 1993; Borawski, Kinney & Kahana, 1996; Patton et al., 2011). However, our findings raise questions about the suitability of these health asymmetry labels in the context of depression. Specifically, the label 'health optimist' — which is typically associated with better psychological health outcomes — does not perfectly correspond with the observed data, as health optimists displayed a steady decrease in depressive symptoms over time, yet had elevated levels compared to good health realists. This discrepancy suggests that the labels used to categorise health asymmetry may not fully capture the nuanced relationship between health perceptions and depressive symptom trajectories.

There is some evidence at least to suggest that health asymmetry categories are somewhat clinically relevant. Previously, it was noted that the metric may be helpful in the context of identifying different mental health profiles (Calvey et al., 2022). Our findings suggest that the difference between SH and OH is clinically meaningful: group differences in depressive symptoms and some longitudinal changes in EURO-D trajectories were found.

We have introduced a novel metric into an already ill-defined field (regarding the operalisation of OH). However, health asymmetry is a helpful addition as it offers an alternative and arguably more holistic and well-rounded measure of OH scores (measured by the FI) when identifying health congruence categories. Previous attempts have focused on physicians' health ratings, or self-reported number of diagnosed chronic illnesses as measures of OH for example (Hong et al., 2004; Ruthig & Chipperfield, 2007). Health is multidimensional and complex, which the FI mirrors, as the index accounts for cognitive, functional and physical health measures along with illness diagnoses. However, future studies should investigate the agreement between health asymmetry and other health congruence metrics in categorising older adults into their related categories.

There are some limitations to the present paper and its design. Firstly, our study could not include Wave 3 (SHARELIFE) as depressive symptoms were not measured during this wave. Consequently, our growth curve model had a slightly uneven distribution of timepoints, which may compromise some statistical power when compared to a balanced design (Liu, 2003). Also, as noted previously, the derivation of a categorical variable using continuous data is not error-free, and statistical power is reduced (Calvey et al., 2022; McHugh Power et al., 2017). However, there is great benefit to identifying individuals who have incongruent SH and OH scores, in a clinical setting. Future studies should incorporate more biomarkers/objective health deficits into the FI, which would make the FI less dependent on self-report and perhaps more apt as an OH proxy. Finally, our creation of an FI partially accounts for the presence or absence of health conditions but does not account for the severity of such diagnosed conditions. Future FIs could incorporate illness management and severity into their ratings.

Health incongruence has been shown to affect survival rates and mortality (Chipperfield, 1993). This was indirectly captured in Chapter 3, however it would be beneficial to confirm this, where death/dropout are parsed out into separate outcomes. This would offer more reliable insights into the relevance of health optimism in terms of selective optimisation and compensation in older adults, confirming if optimistic appraisals of health affect mortality in some capacity (Baltes & Baltes, 1990). Further research is also warranted to expand on our findings above and to determine a cause for the negative trend in depressive symptoms in health pessimists over time.

Our findings significantly contribute to the health congruence literature, particularly focusing on older populations, by illustrating that the incongruence between SH and OH results in groups differences in depressive symptoms and results in some varying trajectories of depressive symptomatology. Consequently, the above findings show the relevance of health asymmetry as a clinical metric. From a public health perspective, it is worthwhile that those whose SH perception varies considerably to their OH status are identified. It is also important to acknowledge the groups of individuals who have the most to gain from health interventions. It is possible from our current findings that interventions will be of the highest impact in clinical outcomes for older adults who are more pessimistic about their health than OH measures would indicate.

CHAPTER 5

Do discrepancies between subjective and objective health predict the risk of injurious falls? A study of community-dwelling Swedish older adults

Bill Calvey, Joanna McHugh Power, Rebecca Maguire, Anna-Karin Welmer, Amaia Calderón-Larrañaga

Abstract

Previous studies demonstrated that discrepancies between subjective and objective health measures are associated with physical and mental health-related outcomes in older adults. We investigate whether such discrepancies are also associated with risk of injurious falls in community-dwelling Swedish older adults. Through a prospective, observational cohort study. Using data from the Swedish National Study on Aging and Care in Kungsholmen, 2,222 community-dwelling older adults aged >60 years at baseline, were followed across a ten-year period of data collection (2001 – 2011). A 'health asymmetry' metric classified older adults into four categories, based on the level of agreement between their subjective and objective health scores ("health pessimist", "health optimist", "poor health realist" and "good health realist"). Time-varying Cox proportional hazard and Laplace regressions were employed to investigate if these categories were associated with the risk of injurious falls. Over a ten-year follow-up, 23.5% of the sample experienced an injurious fall. Health optimists had the greatest risk of experiencing an injurious fall [hazard ratio (HR): 2.16, 95% CI: 1.66, 2.80], compared to good health realists. Poor health realists (HR: 1.77, 95% CI: 1.50, 2.11) and health pessimists (HR: 1.66, 95% CI: 1.21, 2.29) also had an increased risk of experiencing injurious falls, compared to good health realists. Being a health pessimist was only associated with the risk of injurious falls within the younger-old cohort (HR=2.43, 95% CI=1.63, 3.64), and among males (HR=1.95, 95% CI=1.14, 3.33). Older adults with similar objective health levels may differ in terms of their injurious fall risk, depending on their subjective health. Interpreting subjective health alongside objective health is clinically pertinent when assessing injurious fall risk.

5.1 Introduction

An injurious fall, defined as a fall that requires medical attention, is the leading cause of injury-related death and hospitalisation among older adults (Baker & Harvey, 1985; Bergen et al., 2016). More than one third of community-dwelling older adults aged 65+ years fall each year, of which 10% require medical care (Tinetti & Kumar, 2010). Injurious falls often lead to cognitive decline, higher anxiety, increased risk of mortality and functional decline (Gill et al., 2013; Hallford et al., 2017; Trevisan et al., 2019; Trevisan et al., 2021). Injurious falls also precipitate admissions to nursing homes and, consequently, increase healthcare expenditure (Dellinger & Stevens, 2006; Thapa et al., 1996), costing an estimated €500 million per year in Sweden (Hellner et al., 2007). Evidently, injurious falls are not only a concern for the faller, but also for burdened healthcare systems.

The identification of fall risk factors in older adults is therefore paramount. Identifying such risk factors allows for the effective utilisation of (often scarce) resources in order to prevent injurious falls. Research has primarily focused on identifying and intervening on traditional risk factors such as environmental hazards and muscle depletion (Gillespie et al., 2012). However, risk factors for injurious falls are multifactorial, including sociodemographic (e.g. age, sex, living situation), medical (e.g. previous falls, chronic diseases, cognitive impairment), mobility-related (e.g. balance and gait impairments) and psychological (self-rated health, concerns about falling) (Deandra et al., 2010; Montero-Odasso et al., 2022; Welmer at al., 2023) factors.

An individual's health status is a well-established predictor of injurious falls. This holds true when examining both objective health (i.e. an individual's medically determined health status) and subjective health (i.e. an individual's perception of her/his own health). Both objective (OH) and subjective health (SH) scores have been associated with the risk of injurious falls

(Clemson et al., 2015; Ek et al., 2021; Gill et al., 2008), with better OH scores and better self-appraisals of health leading to a decreased risk of injurious falls. While SH appraisals are valuable predictors of clinical outcomes in older adults (Idler & Benyamini, 1997; Mulstant et al., 1997; Santoni et al., 2020), they do not always align with objective measures of health. Clear declines in OH are noted with increasing age, yet SH scores tend to remain more stable. Some explanations for this may be an age-related positivity effect in older adults or acquired capabilities to down-regulate negative psychological responses to health decline (Wettstein et al., 2016). Ultimately, this leads to a 'health congruence' paradox, where older adults tend to provide overestimations of their own health status (Chipperfield, 1993; Hong et al., 2004).

To address this, a 'health asymmetry' framework was proposed in Chapters 2 through 4 (Calvey et al., 2022; Calvey et al., 2023), where older adults are classified into four different groups ("health optimist", "health pessimist", "good health realist" and "poor health realist") based on the level of agreement between their SH and OH scores. These categories have been associated adverse clinical outcomes, such as mortality, functionality and healthcare usage (Borawski et al., 1996; Ruthig & Chipperfield, 2007; Ruthig et al., 2011). Notably, a link between health discrepancies and functional status exists (Hong et al., 2004). Those who rate their OH better than their SH ("health optimists") display higher levels of functional independence and are more mobile, while those who rate their OH worse than their SH ("health pessimists") display sub-optimal levels of functionality and mobility.

The link between such discrepancies and functionality may indicate that being more health optimist or health pessimist may also be associated with injurious falls. It may be that the gap between the perception of, and the reality of one's physical function and general health leads to a mismatch between older people's functional ability and their actual risk of falling.

However, this relationship has remained unexplored. The present study addresses this gap in the literature. We explore if being health optimist, pessimist or realist is associated with the risk of an injurious fall in an urban sample of Swedish older adults, across a ten-year follow-up period.

5.2 Method

Study Population

Data from a longitudinal, prospective, population-based cohort study called the Swedish National Study on Aging and Care in Kungsholmen (SNAC-K) were utilised. SNAC-K samples older adults (aged 60+ years) living in the Kungsholmen neighbourhood of Stockholm, Sweden. After the baseline assessment (2001-2004) of 3,363 individuals, follow-up assessments occurred either every six years (for those aged 60-72 at baseline) or every three years (for those aged 78+). Ethical approval for SNAC-K was obtained from the Swedish Ethical Review authority, with participants (or their next of kin) providing written and informed consent to participate.

Four waves of SNAC-K data were analysed (from 2001 – 2011). From the initial 3,363 baseline participants, those who did not provide consent to accessing their hospital register data were excluded (n = 62). Additionally those who were living in a nursing home at baseline were also excluded (n = 189), as we wanted to evaluate the risk of injurious falls in noninstitutional community-dwellers. Those who presented with a formal diagnosis of dementia at baseline (n = 102) were excluded, as cognitive impairment may bias the reliability of self-rated health appraisals. Finally, those who did not have a health asymmetry score at baseline were excluded (n = 788). Ultimately, we arrived at a final sample size of n = 2,222 individuals. SNAC-K participants who were excluded based on the above exclusion criteria (n = 1,141) significantly varied from those included in our study (n = 2,222).

Those excluded from our study were significantly older, had more previous injurious falls, lower education levels, worse global cognition (assessed though the Mini Mental State Examination, MMSE), worse objective health (assessed through the Health Assessment Tool, HAT), lower self-rated health and were more likely to be living with others.

Measures

Incident Injurious Falls

An injurious fall was defined as any fall that required medical attention (evaluation and/or hospitalisation). Data on injurious falls were obtained from diagnoses made at hospital discharge, which were identified through codes W00 to W19 of the International Classification of Diseases, 10th edition (ICD-10). Subsequently, incident of injurious falls was identified in the National Patient Register (which includes information from inpatient care and specialised outpatient care) and in the Local Outpatient Register (which includes information from primary care). Data from the National and Local Patient Registers were linked to each SNAC-K participant using their Swedish personal identification number (Ludvigsson et al., 2009).

Subjective Health

Self-rated health was used as a measure of subjective health, where participants provide holistic self-appraisals of their general health status (Kaplan & Baron-Epel, 2003). In SNAC-K, participants were asked how they would rate their health, on a five-point Likert scale, selecting one of the following responses: “excellent”, “very good”, “good”, “fair” and “poor”. Self-rated health has shown moderate to good test-rest reliability in previous investigations (Lundberg & Manderbacka, 1996; Zajacova & Dowd, 2011).

Objective Health

The Health Assessment Tool (HAT) was used in the present study as a measure of OH. HAT was developed in SNAC-K as a tool that summarises clinical and functional health in older populations (Santoni et al., 2017), by integrating five objectively assessed health indicators into one continuous scale, using nominal response models: 1) gait speed (as a measure of physical function), 2) the Mini-Mental State Examination (as a measure of cognitive function), 3) the count of chronic diseases (measuring morbidity burden), 4) the number of instrumental activities of daily living an older adult could not perform independently (measuring mild disability) and 5) the number of personal activities of daily living an older adult could not perform independently (measuring severe disability). HAT scores range from 0 (poor health) to 10 (good health). HAT has demonstrated good predictive accuracy for death and hospitalisation (Santoni et al., 2017).

Health Asymmetry

Using a similar framework to previous asymmetry metrics (Bondi et al., 2008; McHugh Power et al., 2017), health asymmetry derives a categorical variable from continuous data. Self-rated health responses along with HAT scores were standardised and converted into Z scores. Although self-rated health and HAT scores are ordinal (but treated here as interval), converting them into Z scores does not carry the assumption of normality associated with Z scores, but merely scales these scores. This should still make it suitable for comparison purposes, as done in previous studies (Andres et al., 1988; Capitani & Laiacona, 2017). HAT scores were subtracted from self-rated health scores, deriving a discrepancy score for each participant. For this study, 1.5 standard deviations (SD) of this discrepancy score were used as the cut-off point for categorisation of the health asymmetry metric.

An older adult whose discrepancy score was 1.5 standard deviations above the mean was considered “health optimists”, as their self-rated health was better than their HAT score. Conversely, older adults whose discrepancy scores were 1.5 SDs below the mean were considered “health pessimists”, as their self-rated health was worse than their HAT score. Those whose discrepancy score was within ±1.5 standard deviations from the mean were considered “health realists”. However, the health realist category was further dichotomised, since health realists have different health profiles (Calvey et al., 2023). Health realists with a HAT score equal to the population median or higher were considered “good health realists”, while health realists whose HAT scores were below the population median were categorised as “poor health realists”. As a sensitivity analysis, health asymmetry groups were calculated using a one standard deviation cut off, given that previous studies have also used this cut-off (Calvey et al., 2022; Calvey et al., 2023). Self-rated health and HAT scores from waves two, three and four were converted into Z scores based on the means and standard deviations from baseline, to ensure that the health asymmetry categories assigned to participants in subsequent waves were relative to their baseline status.

Statistical Analysis

Baseline characteristics were derived for the sample and were stratified by health asymmetry status. To study group differences between health asymmetry categories, ANOVA and chi-square tests were conducted. To determine whether health asymmetry was associated with the risk of an injurious fall within the ten-year follow-up, a set of time-varying multivariable Cox proportional hazards regressions were conducted. Participants were censored at the date of their first injurious fall, death or at the end of the ten-year follow-up period, whichever occurred first. All models included the following covariates based on established associations with the exposure and outcome: age, sex, education (elementary, high school or university), living arrangement (living alone or not), MMSE score, and history of previous falls within three years prior to SNAC-K baseline (Ganz et al., 2007; Welmer et al., 2017; Ek et al., 2019).

The first Cox regression (Model 1) tested the association between baseline self-rated health and the risk of injurious falls. Self-rated health scores were dichotomised into 'poor' ('poor' and 'fair') and 'good' ('good', 'very good' and 'excellent'). Model 2 tested the association between baseline HAT scores and the risk of an injurious fall. HAT scores were dichotomised into 'good' and 'poor' objective health based on a population median cutoff point. Our final model (Model 3) included the main exposure of interest, health asymmetry, using a 1.5 standard deviation cutoff point. In our final model, health asymmetry status was time-varying (as long as the SNAC-K assessment was carried out before the fall occurred). The remaining covariates in this model were fixed at baseline. The association between a self-rated health and HAT interaction and the risk of an injurious fall was tested (see Appendix 5.1). The sensitivity analyses operationalising health asymmetry using a one standard deviation cutoff can also be found in Appendix 5.1. Since discrepancies between subjective and objective health scores change with increasing age and by sex (Calvey et al., 2022), age (<78 vs >78 years) and sex stratified analyses were conducted (see Appendix 5.2a & 5.2b). Laplace regressions were also run for the same models mentioned above, to study the impact of exposures on the difference in the median number of years until the first injurious fall. A sensitivity Cox and Laplace regression analysis was conducted, excluding those with a previous history of falling before baseline, to ensure that previous fallers were not biasing our estimates (see Appendix 5.3). All statistical analyses were carried out in R (R Studio, 2015). Cox regressions models were run using the 'survival' package (Therneau, 2015) and Laplace regressions were conducted using the 'ctqr' package (Frumento, 2021).

5.3 Results

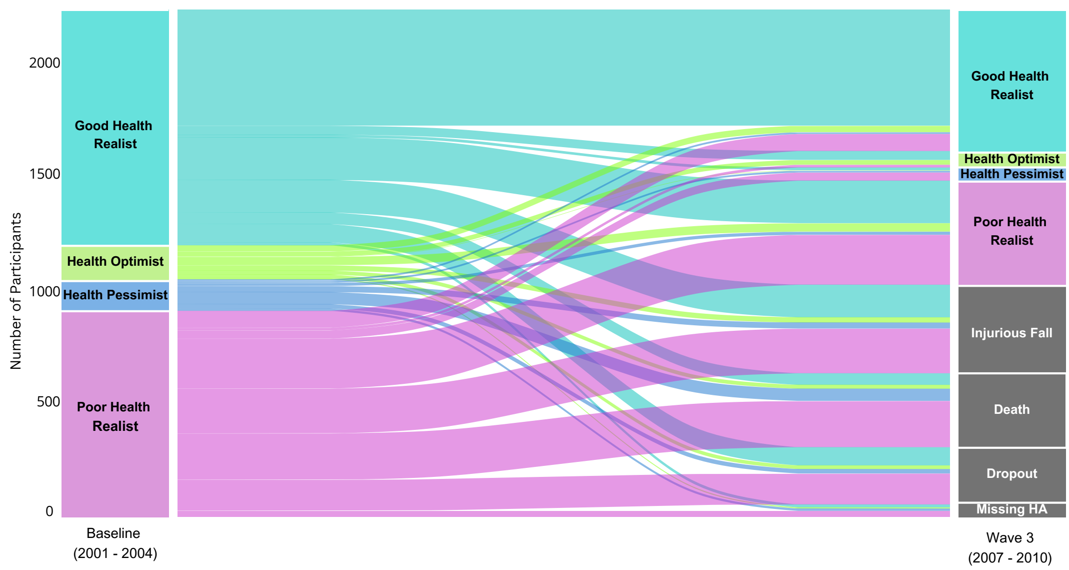
In a sample of 2,222 older Swedish adults aged 60 years or older, 523 (23.5%) had experienced at least one injurious fall over the ten-year period. The mean age of the sample was 72.09 years (± 9.75), with 61.75% of the sample being female (Table 5.1). At baseline, 46.5% of the sample was categorised as “good health realists”, 40.6% as “poor health realists”, 6.2% as “health optimist” and 6.7% as “health pessimist”. A significantly greater proportion of female participants were found in the health pessimist and health optimist categories, while health pessimists and good health realists were significantly younger than the other groups. Figure 5.1 illustrates how participants transitioned from one health asymmetry group to another between baseline and wave three (ie, six-year follow-up).

The incidence rate (IR) for injurious falls was highest for health optimists (IR=69.91, per 1,000) and lowest for good health realists (IR=151 per 1,000) (Table 5.2). A poor self-rated health appraisal was significantly associated with an increased risk of an injurious fall in model 1 [hazard ratio (HR) = 1.18, 95% CI = 1.06, 1.31]. Similarly, a poor HAT score was associated with an increased risk of an injurious fall in model 2 (HR = 1.75, 95% CI = 1.56, 1.96). There was no statistically significant interaction between self-rated health and HAT scores. Relative to good health realists (who had the lowest risk of injurious falls), being health optimist (HR = 2.16, 95% CI = 1.66, 2.80), poor health realist (HR = 1.77, 95% CI = 1.50, 2.11), as well as health pessimist (HR = 1.66, 95% CI = 1.21, 2.29) were all significantly associated with an increased risk of an injurious fall. The sensitivity analysis using a one standard deviation cut-off for health asymmetry did not result in a statistically significant association for health pessimists. Full models (including sensitivity analyses) are presented in Appendices 5.1 through 5.3. Laplace regressions showed that, relative to good health realists, being a health optimist reduced the time to an injurious fall by 2.8 years and being poor health realist by 1.14 years.

Similar trends were observed in stratified regressions. However, being a health pessimist was only associated with the risk of an injurious fall within the younger-old cohort (HR = 2.43, 95% CI = 1.63, 3.64), and among males (HR= 1.95, 95% CI = 1.14, 3.33) (see Appendix 5.2a & 5.2b). A sensitivity analysis removing those with a history of falls from the analyses showed similar results across health asymmetry groups (see Appendix 5.3).

Figure 5.1

River diagram illustrating the transitions among health asymmetry categories from SNAC-K baseline to wave three (ie, six-year follow-up).



Note: "Missing HA Data" means that either HAT or self-rated health scores were missing so health asymmetry status could not be derived.

Table 5.1

Baseline descriptives (mean and standard deviation or percentage and frequency) for the study sample and stratified by health asymmetry category.

	Full Sample (n=2,222)	**Health Pessimist (n=149, 6.70%)**	**Poor Health Realist (n=903, 40.64%)**	**Good Health Realist (n=1032, 46.44%)**	**Health Optimist (n=138, 6.20%)**	**p**
Age	72.09 ± 9.75	66.84 ± 6.78	77.13 ± 9.06	67.04 ± 6.99	82.58 ± 9.03	p<.001
Sex						
Male	38.25% (n=850)	42.95% (n=64)	34.88% (n=315)	41.57% (n=429)	30.43% (n=42)	p<.001
Female	61.75% (n=1372)	57.05% (n=85)	65.12% (n=588)	58.43% (n=603)	69.57% (n=96)	
Living Arrangement						
Living Alone	51.50% (n=1,145)	49.66% (n=74)	62.02% (n=560)	40.31% (n=416)	68.84% (n=95)	p<.001
Not Alone	48.50% (n=1,077)	50.43% (n=75)	37.98% (n=343)	59.69% (n=616)	31.16% (n=43)	
Education						
Elementary	22.19% (n=493)	18.79% (n=28)	31.56% (n=285)	13.28% (n=137)	31.56% (n=43)	p<.001
High School	43.56% (n=968)	32.21% (n=48)	47.40% (n=428)	42.05% (n=434)	47.40% (n=58)	
University	34.20% (n=761)	48.99% (n=73)	21.04% (n=190)	44.67% (n=461)	21.04% (n=37)	
Previous Falls						
Yes	6.75% (n=150)	2.68% (n=4)	9.30% (n=84)	3.20% (n=33)	21.01% (n=29)	p<.001
No	93.25% (n=2072)	97.32% (n=145)	90.70% (n=819)	96.80% (n=999)	78.99% (n=109)	
MMSE	28.96 ± 1.33	29.39 ± 1.04	28.44 ± 1.55	29.45 ± 0.75	28.12 ± 1.80	p <.001
HAT	7.83 ± 1.63	8.80 ± 0.39	6.80 ± 1.21	8.98 ± 0.43	4.84 ± 2.22	p <.001
Self-rated Health	3.18 ± 1.04	1.89 ± 0.31	2.58 ± 0.80	3.84 ± 0.74	3.51 ± 1.25	p <.001

Note Chi-square and one-way ANOVA tests were conducted to investigate potential significant baseline group differences among health asymmetry categories. P values are reported along with Cramer's V effect or partial eta-squared effect sizes (where relevant).

Table 5.2

Cox proportional hazards and Laplace regression models for risk of injurious falls across a 10-year follow-up period.

	Incidence Rates per 1,000 (95% CI)	Hazard Ratio	95% CI	Median Years to Injurious Fall†	95% CI
Model 1					
Self-rated Health: Poor Health		1.18**	(1.06, 1.31)	-0.32	(-1.18, 0.54)
Model 2					
HAT: Poor Health		1.75***	(1.56, 1.96)	-2.27***	(-3.59, -0.95)
Model 3					
Good Health Realist (Reference)	18.20 (15.33, 21.60)				
Health Optimist	69.91 (53.87, 90.72)	2.16***	(1.66, 2.80)	-2.80***	(-4.39, -1.21)
Health Pessimist	53.78 (39.06, 74.04)	1.66**	(1.21, 2.29)	-0.74	(-3.44, 1.96)
Poor Health Realist	57.54 (48.67, 68.32)	1.77***	(1.50, 2.11)	-1.14*	(-2.27, -0.01)

*Note: *significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$. All models adjusted for age, sex, education, living alone, history of falls as time-fixed covariates. Self-rated Health was dichotomised into 'good' (good, very good and excellent) and 'poor' health (poor and fair). HAT was dichotomised into 'good' (median or higher) and 'poor' (lower than median) health. † Difference in Median Number of Years to Injurious Fall*

5.4 Discussion

The potential association between health asymmetry and injurious falls over a comprehensive ten-year follow-up was assessed. Our analyses of data from a population-based cohort study of Swedish older adults showed that health optimists (i.e. those who rate their SH better than their OH) are at a greater risk of experiencing injurious falls, when compared to good health realists. Poor health realists (i.e. those who provide poor SH appraisals while also having poor OH) were also at an increased risk of experiencing an injurious fall. The results for health pessimists (i.e. those who rate their SH worse than their OH), however, depend on the cut-off point used to define health asymmetry categories, and its negative effect was more evident in the younger-old cohort and in males.

Health pessimists experienced a greater injurious fall risk than good health realists, despite both of these health asymmetry groups having similarly good OH. However, health pessimists only had an increased risk among those who were younger and male. This finding could be explained by the literature on concerns about falling (Welmer et al., 2023). Welmer et al (2023) concluded that concerns about falling may increase injurious fall risk primarily among younger-old people, given the maladaptive nature of the fear response, manifesting as mental distress and needless mobility restrictions (Trevisan et al., 2020; Yardley et al., 2002). Such restrictions may cause younger health pessimists to incur a significantly higher injurious fall risk than good health realists.

However, health optimists had the highest IR of injurious falls. Delbaere et al (2010) found that discrepancies between perceived and physiological fall risk were primarily associated with psychological factors (depressive symptoms, executive functioning and neuroticism), which strongly influenced the probability of falling. Similarly, it is possible that health optimists also experienced elevated injurious fall risk due to psychological factors, as health asymmetry categories are differentially associated with psychosocial variables such as anxiety and loneliness, while also predicting depressive symptoms over time (Calvey et al., 2022; Calvey et al., 2023). In particular, it may be a sort of optimistic bias which leads health optimists to believe that they are at a decreased fall risk. Those who experience an optimist bias also believe they are at a decreased risk of developing health conditions, are less motivated to take health precautions, and engage less in behavioural changes (Fragkaki et al., 2021; Park et al., 2014; Park et al., 2021; Wendt, 2005). Also, health optimists may pay less attention to physical and cognitive deficits, making themselves less risk averse and thus increasing their injurious fall risk. While there was no direct comparison between health optimists and poor health realists in our models, health optimists had the highest injurious fall risk when compared to good health realists and had a higher IR of injurious falls than poor health realists (despite both groups having similar objective health profiles). Further research could directly investigate if subjective health appraisals are responsible for potential differences in injurious fall risk, between these two groups.

Another noteworthy explanation for the increased injurious fall risk in both health optimists and poor health realists is their poor OH. As injurious fall risk is intrinsically linked to OH indicators like reduced balance and muscle depletion (Gillespie et al., 2012), OH seems to remain the primary driver of injurious fall risk across health asymmetry groups. However, our findings suggest that there is also clinical pertinence to interpreting SH appraisals alongside objective health. Previous research noted that self-rated health may affect an older adult's confidence regarding their abilities and may moderate decisions about the social and physical activities which they engage in (Cwickel et al., 1990).

Essentially, the risk of injurious falls is somewhat expressed by SH appraisals and should be interpreted alongside OH in clinical settings.

Our findings emphasise the usefulness of a health asymmetry metric. Identifying health asymmetry status when assessing injurious fall risk may be particularly useful in primary care or public health settings, in order to identify those who could benefit from further assessment and preventive interventions. However, this metric may be less useful in hospital settings since hospitals represent a special setting in terms of falls risk and all hospitalised older adults should be considered at risk and be offered comprehensive assessment followed by multidomain interventions (Montero-Odasso et al., 2022). Additionally, the derivation of this metric enables the prognostication of health outcomes by examining the synergistic predictive effects of SH and OH. Discrepancies between subjective and OH have clinical pertinence not only for injurious falls but for other health outcomes too. Health asymmetry categories have been differentially associated with psychosocial and health behaviours such as anxiety, loneliness and smoking, while also predicting trajectories of depressive symptomatology over time (Calvey et al., 2022; Calvey et al., 2023). Other conceptualisations of subjective and objective health discrepancies have also shown to predict long-term survival, hospitalisations and functional health among older adults (Chipperfield 1993; Hong et al., 2004; Ruthig & Chipperfield, 2007).

A strength of our study is that data from a large community-based sample were utilised, with our objective outcome measure of injurious falls being obtained from high-quality register data (Bergström et al., 2010). Recent health asymmetry research operationalised objective health using a frailty index as a proxy (Calvey et al., 2022; Calvey et al., 2023) which is still somewhat reliant on self-reported data, and is therefore not fully independent of subjective health. We rectified this by introducing a fully objective HAT score as a measure of objective health.

On the other hand, we relied on self-reported measures for education and living arrangement, which is common within falls research (Deandrea et al., 2010), but this should not have posed any major measurement error problems. Another limitation of this study is that only injurious falls that resulted in medical attention were identified. This may have excluded non-injurious falls which were not registered, or injurious falls for which older adults did not seek medical care. This likely led to an underestimation of the true prevalence of falls in the general population. The potential underlying psychosocial mechanisms that cause health optimists to be at a greater risk of experiencing injurious falls were not investigated – future research could address this. The relatively healthy and well-educated sample of older adults in Kungsholmen, Stockholm, may limit the generalisability of our results. Finally, there may be other factors that affect the risk of injurious falls that are not accounted for in the HAT tool. However, gait speed is included in the HAT score and the World Guideline for Falls Prevention and Management for Older Adults recommend assessing gait speed to detect risk of falls (Montero-Odasso et al., 2022) so our measure of objective health is strengthened in this regard.

Our findings highlight that the discrepancy between an older adult's OH and SH status can significantly increase the risk of an injurious fall, with important clinical and practical implications in daily life. Special attention may need to be paid to those older subjects who rate their SH better than their OH. Ultimately, our study reinforces the need to assess both OH and SH in both clinical practice and research, with SH having a potential moderating effect on injurious fall risk.

CHAPTER 6

Subjective and objective health as predictors of health anxiety: An Ecological Momentary Assessment study of middle-aged and older adults

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Abstract

Health anxiety is likely to fluctuate over short timeframes, but consensus on how it should be measured is lacking. This study aimed to: 1) validate a measure appropriate for assessing fluctuations in health anxiety over short timeframes, 2) yield distinct trajectories of health anxiety fluctuations in adults aged 50 and over and 3) assess the causal role of subjective and objective health appraisals in predicting health anxiety. An intensively longitudinal, observational smartphone-based Ecological Momentary Assessment design was employed. Health anxiety was repeatedly measured in a non-clinical sample of older adults (n=47), resident in Ireland. An exploratory factor analysis investigated the construct and concurrent validity of a single-item measure of health anxiety, compared with scores from the established Whiteley Index-6 (WI-6). Growth mixture models were leveraged to identify distinct trajectory groups of health anxiety over six days. Single-item health anxiety scores strongly loaded onto a single factor and correlated strongly with WI-6 scores ($r=0.75$, $p<.001$). Health anxiety followed a polynomial growth trend over the study period ($\beta=-0.01$, $p<.001$). Two trajectories of health anxiety in older adults were identified: "low-stable" (74.7%) and "volatile" (25.3%). Objective health scores predicted health anxiety scores over time ($\beta=1.61$, $p=0.048$), but subjective health appraisals did not. A single-item measure of health anxiety is sufficient to measure fluctuations in health anxiety, with objective health being an important predictor of such anxiety. The heterogeneity in health anxiety trajectories provides evidence for the potential benefit of personalised and tailored therapeutic approaches to resolving health anxiety. .

6.1 Introduction

Health anxiety refers to a broad spectrum of worries that an individual can have about health or illness (Salkovskis & Warwick, 1986; Salkovskis & Warwick, 2001). Some individuals experience transient health concerns triggered by temporary somatic symptoms, while others suffer from long-term, debilitating fears of illness (Ferguson, 2009; Taylor & Asmundson, 2004). Approximately 3% of the general population experience clinically significant health anxiety (Sunderland et al., 2013), increasing to 10% of all primary care users and up to 20% of medical clinic out-patients (Escobar et al., 1998; Seivewright et al., 2004; Tyrer et al., 2011).

Health anxiety can be distinguished from general anxiety by the cognitive-emotional belief that one's health is in danger and, as such, is synonymous with an individual's health belief model (El-Gabalawy et al., 2021; Shayganfard et al., 2021). Theoretical models of health anxiety acknowledge both cognitive and behavioural components of the construct. Core cognitive features of health anxiety, such as disease conviction, illness preoccupation, worry and dysfunctional beliefs, can drive maladaptive coping behaviours, such as reassurance-seeking and avoidance (El-Gabalawy et al., 2021). Although such behaviours may offer temporary relief (Haenen et al., 2000), health anxiety is nonetheless linked to catastrophic interpretations of symptoms and results in increased ratings of disability (Hadjistavropoulos et al., 2000; Looper & Kirmayer, 2001; Marcus, 1999; Marcus & Church, 2003; Rief et al., 1998;).

Approximately 8% of community-dwelling older adults experience elevated health anxiety levels (Boston & Merrick, 2010). Older adults may be at an increased risk of health anxiety, not due to age per se (Boston & Merrick, 2010; Bourgault-Fagnou & Hadjistavropoulos, 2009), but due to declines in objective health which can happen in this life stage, such as increased multimorbidity, cognitive impairment, frailty and injurious falls (Calvey et al., 2024; Götze et al., 2019; Verity et al., 2018; Vetrano et al., 2019;). Conversely, the Socioemotional Selectivity Theory and Selective Optimisation with Compensation Theory (Baltes, 1997; Carstensen, 1993) suggest that emotional health improves with age, a prediction already validated with respect to anxiety (Lee et al., 2015), which would seem to suggest that older adults as a group have lower levels of health anxiety than their younger counterparts. Given that there is a noted under-representation of older adults in the existing health anxiety literature (Bourgault-Fagnou & Hadjistavropoulos, 2013), further consideration of health anxiety in middle-aged and older adults is warranted.

As with broader discussions of anxiety, which differentiate between state and trait types, health anxiety may also be conceptualised with respect to temporality. Some traits are stable over time and can be reliably assessed using cross-sectional instruments (Ozer & Benet-Martinez, 2006). However, anxiety is a dynamic construct (Schoevers et al., 2021) with symptoms showing considerable variability over time (Ben-Zeev & Young, 2010; Moore et al., 2016; Thompson et al, 2012; Walz et al., 2014). Relatedly, feelings of health anxiety are likely to fluctuate on a daily basis too. Fluctuations in health anxiety may be related to factors included in cognitive-behavioural models of health anxiety, for example, somatic symptoms, cognitive and attentional patterns or engagement with healthcare (Warwick, 1989; Warwick & Salkovskis, 1990). However, only a handful of intensive, longitudinal investigations tracked health anxiety over shorter periods of time (Gautreau et al., 2015; Kerstner et al., 2015), with none of these focusing on older populations. These studies focused on symptom attributions and the catastrophising of bodily sensations in health anxiety, but not necessarily examining change in health anxiety itself.

Studies of daily mental health fluctuations require appropriate methodologies. Intensive longitudinal designs, such as ambulatory assessments or Ecological Momentary Assessments (EMA) are useful, naturalistic study designs which involve regular measurement of constructs that likely fluctuate over time (such as health anxiety) (Smyth & Stone, 2003). However, because of the frequency of data collection involved, EMA designs are not very compatible with the use of long-form scales, such as those typically used in health anxiety research, which range from 6 to 64 items (Pilowsky et al., 1967; Salkovskis et al., 2002). Capturing health anxiety multiple times a day using such long-form scales would threaten attrition rates, increase participant load and threaten the validity of participant responses (Barta et al., 2012; Gabriel et al., 2019). As such, a challenge exists for researchers who wish to measure health anxiety in intensive study designs.

Single-item measures are a commonly explored solution for such challenges and can be useful for assessing psychological and affective constructs, to reduce burden on respondents and researchers, particularly in an EMA context (Allen et al., 2022; Song et al., 2023). While single items may mischaracterise multidimensional constructs, can increase item response bias and are likely to be biased by some random error (Borsboom, 2006; Spector, 1992), single items of stress and cyberchondria (i.e. excessive online searching for medical information) have been successfully validated against more extensive psychological scales (Eastin & Guinsler, 2006; Elo et al., 2003). On this basis, a validated single item of health anxiety that has little interference in participants' daily routines may be feasible.

Another open question with respect to health anxiety concerns its fluctuation over time, an issue which was previously identified as a priority (Wright et al., 2016). Yet, to date, little evidence exists regarding how health anxiety changes over time and whether individuals cluster into specific trajectories of such changes. General anxiety and depressive symptomatology indeed show distinct clusters of older participants: one remaining low and stable, and one with elevated levels (Holmes et al., 2017).

Identifying different trajectories of health anxiety may allow clinicians to tailor interventions based on specific needs of each individual. For example, tailored approaches to identifying and treating anxiety disorders have been shown to be effective (Carlbring et al., 2017; Sinnema et al., 2011). Similarly, if different trajectories of health anxiety are yielded in older adults over time, then personalised and tailored approaches to resolving health may be viable. If some older adults experience consistently elevated levels of health anxiety, then they may benefit from more intensive therapies, compared to those who may just have occasional spikes in health anxiety, and as a result, might need less intensive intervention or perhaps alternative therapeutic approaches.

Additionally, while milder levels of health anxiety may lead to adaptive outcomes in older adults (such as adherence to medical prescriptions or seeking appropriate care) (El-Sayed et al., 2023), the early detection of mild to moderate health anxiety among older adults may reduce the likelihood that such health anxiety progresses into more severe presentations (El-Gabalawy et al., 2011). However, evidence is needed to confirm whether older adults' health anxiety evolves along different trajectories over time.

Identifying risk factors or causes of health anxiety is also crucial. An individual's health status may be, at times, a driver of health anxiety in older adults. This may be the case for both an individual's objective health (OH) and an individual's subjective appraisal of their own health status (SH). Older adults have on average 3.5 physical health conditions (Blazer, 1998), with mental health issues (including health anxiety) being particularly prevalent in chronically ill older adults (Kim et al., 2001; Lebel et al., 2020). A dose-response relationship may explain this association between physical symptoms and mental health issues in older adults: greater numbers of somatic symptoms have been associated with an increased risk of anxiety (Gurian & Minor, 1991; van Balkom et al., 2000; Wolitzky-Taylor et al., 2010). It may be that older adults with poorer OH levels experience elevated health anxiety levels, as they may not have the physical and psychological resources to cope with their poor health (Kastenbaum, 1994).

Additionally, poorer SH is associated with higher levels of health anxiety (Lodin et al., 2019), while individuals who report having poor SH are 4.1 times more likely to receive a clinical diagnosis of health anxiety (Mewton & Andrews, 2013). SH status emerges as a significant factor influencing the development of health anxiety (Hedman-Lagerlöf et al., 2017), however, there may also be a shared factor influencing both SH and health anxiety (e.g. a tendency to endorse negative symptoms). A bidirectional relationship may exist, where health anxiety causes individuals to report poorer SH ratings (Hedman-Lagerlöf et al., 2017). Ultimately, SH/OH levels may provide valuable insights into understanding health anxiety (Asmundson et al., 2010; Csibi et al., 2023), but these associations need to be teased out further.

A growing body of research investigates the influence that discrepancies between SH and OH have on physical, functional and mental health outcomes in older adults. Discrepancies between SH and OH predict physical and mental health related outcomes in older adults, including depressive symptomatology, functionality and mortality (Calvey et al., 2023; Chipperfield, 1993; Hong et al., 2004). In Chapter Two, a health asymmetry metric was developed, where older adults were classified into groups, based on the level of agreement between their SH and OH scores (Calvey et al., 2023; Calvey et al., 2024). This health asymmetry metric identifies health optimists, health pessimists, good health realists and poor health realists. In Chapter Two, it was reported that increased anxiety levels were associated with being classified as a health pessimist and reasoned that health asymmetry metric may be a useful tool in predicting clinical and pre-clinical levels of health anxiety. There is reason to believe that a considerable overlap between health pessimistic and health anxious individuals. It may be that not only SH and OH, but the discrepancy between the two measures, are related to health anxiety.

To address gaps in the health anxiety literature, the following aims were identified: 1) develop a single-item measure of health anxiety and investigate its construct and concurrent validity by comparing its performance to that of a multiple-item instrument of health anxiety, 2) identify distinct latent trajectories of momentary fluctuations in health anxiety over time in middle-aged and older adults and 3) determine whether OH, SH and health asymmetry scores are associated with longitudinal health anxiety scores in middle-aged and older adults.

6.2 Methods

Study Design

A six-day Ecological Momentary Assessment (EMA) study was employed to track health anxiety intensively in older adults. EMA designs are feasible in older populations, even in those who experience cognitive difficulties and mental health-related decline (Burke & Naylor, 2022; Liu & Lou, 2019; Ramsey et al., 2016). The study was limited to a duration to six days in order to avoid overburdening participants and to maximise data quality. The study design and procedures were approved by Maynooth University Social Research Ethics Committee (HRE18-224).

Sample and Recruitment

A non-clinical sample of older adults resident in Ireland were recruited using a combination of online and snowball sampling from October 2023 to February 2024. Participants were required to be at least 50 years old, living in Ireland, speaking sufficient English to participate, and to confirm no prior receipt from a medical doctor of a formal diagnosis of Alzheimer's or Parkinson's Disease. Individuals with Alzheimer's or Parkinson's Disease were excluded to limit any potential self-reporting bias that may result from cognitive impairment. (Shulman et al., 2006; Slavin et al., 2010). Online recruitment involved posting advertisements on social media and in online support groups for older adults. Once participants had completed the study, they were encouraged to send the study details onto other suitable candidates. Participants were not compensated for their participation.

The ema.powercurve function from the R package ‘EMAtools’ to estimate the sample size given two entries per day across six days (Kleiman, 2017). To detect a medium effect size with a mean data completion rate of 75%, 25 participants were required assuming 80% power. However, to detect a small effect size, a sample size of n=140 would be required. Although larger samples are desirable for mixture modelling (which is implemented in this study), samples as small as n=25 can produce meaningful latent profiles given adequate signal strength (Lubke & Neale, 2006). In total, n=53 older adults were recruited, whom all completed a baseline assessment. However, similar to previous longitudinal analyses (Difrancesco et al., 2021; Frank et al., 2021; West et al., 2015), participants with a completion rate of less than 50% were removed, which resulted in a sample size of n = 47.

Procedures

Data were collected via participants’ personal smartphones using the mpath platform (https://m-path.io/landing/), which was designed for researchers and clinicians to monitor momentary observation and intervention data. The mpath app can be installed with Android and iOS devices. After expressing interest in the study, and prior to participation, potential candidates received a study instruction manual by email, which detailed the study’s procedures, how to self-register for the study and frequently asked questions on EMA studies. After familiarising themselves with the nature of the study, then, participants were invited to electronically record their informed consent. Once consent was provided, participants self-registered for the study using their smartphone. Participants were required to: 1) download the mpath application on their smartphone, 2) create an account with a unique username that would self-anonymise their data and 3) enter the study code provided in the instruction manual.

Ecological momentary assessment protocol

Once participants had registered for the study, they conducted a baseline assessment on day one of their participation. This baseline assessment gathered sociodemographic data, health histories, health behaviours and health anxiety levels (see Measures below). The baseline assessment also measured our outcome of interest, a single item measure of health anxiety. From day two onwards, participants received two EMA prompts each day to their smartphones, for the remainder of the study period (days two to six). These remaining bidaily prompts assessed health anxiety using the single-item measure. EMA prompts were sent to participants each morning (from 8am to 12pm) and each evening (from 6pm to 10pm), with the precise time of the prompt pseudo-randomised by the mpath app (i.e. participants were informed that they would receive a prompt between 8am to 12pm and 6pm to 10pm, but were not sure exactly when a prompt would be sent during those timeframes). If participants responded within one hour of receiving the prompt, data were recorded; otherwise, the notification disappeared and the datapoint was recorded as "missing".

Measures

Baseline: Health Anxiety (The Whiteley Index 6)

At baseline, participants completed a six-item version of the Whiteley Index (WI-6) (Fergus et al., 2019; Pilowsky, 1967). WI-6 measures two dimensions of health anxiety: 'somatic preoccupation' and 'health worry'. Participants responded to each item with one of the following options: "not at all", “to some extent”, “moderately”, “to a considerable extent” or “to a great extent”. Scores from each item were transformed into values from 0 to 4 and summed to a total WI-6 score, ranging from 0 to 24; a higher score indicating greater levels of health anxiety. WI-6 is considered to be more factorally stable than the original 18-item version of the index (Asmundson et al., 2008; Welch et al., 2009). WI-6 has shown satisfactory psychometric properties (Veddegjærde et al., 2014) and showed good internal consistency within our sample (Cronbach’s alpha: α=0.85).

Baseline: Subjective Health

Self-rated health was used as a measure of SH. This self-rated health single item asked participants "how would you rate your health generally, ranging from ‘poor’ to ‘excellent’?”. This single item is an independent predictor of mortality (Idler & Benyamini, 1997; Jylhä, 2009) and is associated with health anxiety (Fink et al., 2010).

Baseline: Objective Health

An electronic Frailty Index (eFI) was determined to be the most suitable method of receiving an approximation of older adults’ OH status remotely. An eFI is a fully remote, electronic version of a Frailty Index (FI), which typically shows decent convergent validity with more objective, non-remote FIs (Brundle et al., 2019). An eFI was compiled using guidelines set out by Searle et al (2008) and included formal diagnoses of acute and chronic conditions, independent activities of daily living, mobility, memory, psychological wellbeing and functional health. For the eFI, 33 health deficits were measured. Inclusion of a health deficit is recommended if it is associated with age and does not appear or saturate too early in general populations (for example eyesight).

All deficits were given a score of 0 to indicate absence in each participant, and a score of 1 indicated full expression of the health deficit. Scores between 0 and 1 indicated partial expression or presence of the health deficit. The number of present deficits was divided by the number of deficits considered, giving rise to an eFI score ranging between 0 and 1. A score of 0.25 or lower indicates the absence of frailty, while higher scores indicate frailty (Rockwood & Mitnitski, 2007). FIs are comparable across studies, even when different numbers (at least 30 deficits) or types of deficits are included, as shown by previous research (Kulminski et al., 2007; Mitnitski et al., 2001; Mitnitski et al., 2005). Due to its global health-related structure, an FI can be interpreted as a health indicator or measure in older populations (Calvey et al., 2022; Rockwood et al., 2014; Wuorela et al., 2020), as it forms a holistic indication of a participant's relative functional, physical and cognitive health status. However, an eFI is limited in its use as a proxy for OH, as it is still reliant on self-reporting, and therefore is not fully independent of SH. Despite this, the use of eFIs is well-documented in previous health research and is a useful tool to obtain approximations of OH status (Clegg et al., 2016).

Baseline: Health Asymmetry

A 'health asymmetry' framework was utilised to categorise our sample of older adults into groups, based on discrepancies between their SH and OH scores (as measured by an eFI). Health asymmetry status was treated as a categorical, exposure variable within this study. In order to determine each participants' health asymmetry status, both SH and OH scores were standardised, by converting them both into Z scores. SH scores were subtracted from OH scores to reveal a discrepancy score for each participant in our EMA study. One standard deviation was used as a cut-off point for the identification of health asymmetry categories. Those whose discrepancy score was at least one standard deviation above the mean were considered 'health optimistic' as their SH score was higher than their OH score.

Conversely, those whose discrepancy score was at least one standard below the mean were labelled 'health pessimistic' as they rated their SH worse than their OH. Those with discrepancy scores within one standard deviation of the mean were identified as 'health realists'. We identified only three health asymmetry categories, similar to Calvey et al (2022) due to a lower sample size in our EMA study. Previous studies used Frailty indices (FI) and Health Assessment Tools to demonstrate how health asymmetry categories are significantly associated with different levels of depressive symptomatology and varying injurious fall risk (see Chapters 4 and 5).

Baseline and Longitudinal: Single-item measure of health anxiety

A single item of health anxiety was used both at baseline and at each subsequent EMA timepoint, amounting to a total of 11 timepoints throughout the study period. The single item measure asked respondents "On a scale from 1 to 7, how anxious do you feel about your health right now?" with responses ranging from 1 (not anxious at all) to 7 (very anxious). Since no other single-item measures of health anxiety were available, the design of this single-item measure was based on other self-report single-item measures of self-esteem (Robins et al., 2001) and for emotional exhaustion and depersonalisation (West et al., 2009).

Data Analysis

To respond to our first objective of assessing the construct and concurrent validity of a single item in measuring health anxiety, an exploratory factor analysis was conducted to examine the underlying structure of our measures, and Pearson's correlations between single item and WI-6 scores to hint at the concurrent validity of our measure. In the factor analysis, both the single item and all WI-6 items were included, allowing us to explore whether they load onto the same factor or different factors, similar to previous investigations which validated single items (Elo et al., 2003). If scores from a single item and scores from WI-6 items load onto the same factor, it suggests construct validity, indicating that they are measuring similar constructs. Conversely, if they load onto different factors, it may indicate differences in the constructs being measured. The maximum likelihood method and varimax rotation were applied.

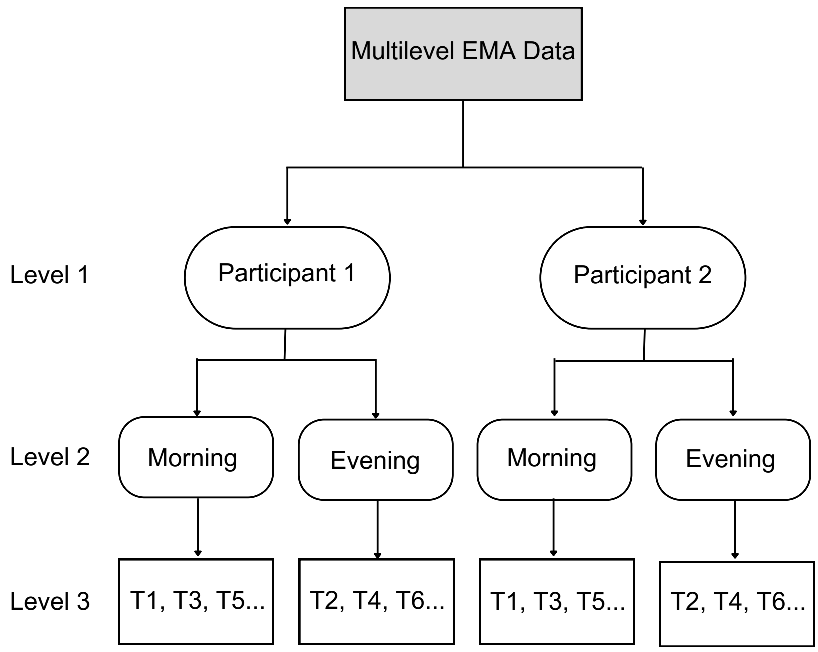
To respond to our second and third objective, growth mixture modelling (GMM) was applied to identify different trajectories of health anxiety within our sample. GMMs recognise the hierarchical data structures within clustered longitudinal EMA data, since multiple datapoints are nested within each individual. The multilevel structure of our EMA data was visualised (see Figure 6.1). GMMs allow different classes of individuals to vary around different intercepts and slopes (Muthén & Shedden, 1999). The classes are introduced by a latent categorical variable where the classes represent the unobserved heterogeneity of the data.

To determine the overall growth function for our GMMs, a set of unconditional single class GMMs was conducted: an intercept only model, an intercept and linear slope model, an intercept and quadratic slope model and finally an intercept and polynomial slope model. To select the best fitting model for health anxiety growth over time, multiple fit statistics were used including: Akaike Information Criteria (AIC), Bayesian Information Likelihood Criteria (BIC), Sample Size Adjusted BIC (SABIC), Log likelihood and Lo-Mendel-Rubin Likelihood Ratio Test (LMR-LRT). Smaller AIC, BIC and SABIC values indicate better model fit (Kim, 2014; Nylund et al., 2007). LMR-LRT compared two adjacent models, and significant p values ($<.05$) indicated that the k model fit better than the k-1 model (Lo et al., 2001). The growth function with the best fit was chosen as our basis for all proceeding GMMs in determining the optimal number of classes.

Once a suitable growth function was identified for the overall sample, a set of conditioned GMMs were ran with K latent classes (K=1, 2, 3 and 4), which were controlled for covariates, to determine the optimal number of latent health anxiety trajectories within our sample. In addition to our predictor variables of interest (i.e. SH, OH and health asymmetry), age and gender were adjusted for, based on their established association with health anxiety (MacSwain et al., 2009; Norbye et al., 2022). Along with previously mentioned fit indices, normalised entropy values were also calculated to evaluate the quality of class separation, and it was ensured that no class had a mixture proportion of lower than 5% (Ram & Grimm, 2009). Normalised entropy values ranged from 0 to 1, with values closer to 1 indicating a more accurate classification and values above at least 0.6 being desirable (Celeux & Soromenho, 1996). GMM analyses were conducted in R studio (R Core Team, 2024), using the 'lcmm' package (Proust-Lima et al., 2015).

Figure 6.1

A visual diagram illustrating the three levels within the hierarchical multi-level structure of our EMA data.



Note: T1... T6 denotes the timepoints, within which there were a maximum of 11 throughout the study period.

6.3 Results

Data was collected from a sample of n=53 older adults. In terms of the full sample, the mean age of the sample was 62.75 years (± 5.61), with 58.49% (n = 31) being female and 52.83% (n = 28) being currently retired. Compliance with EMA reports were high: 83.8% of scheduled EMA reports were completed, excluding the baseline assessment, which is relatively high, considering previous smartphone-based EMA studies yielded response rates ranging from 43% to 95% (Jung et al., 2024). Response rates during the morning were higher (85.7%) than response rates during the evening (81.9%).

Objective 1: Exploring the validity of a single item measure of health anxiety

An exploratory factor analysis was conducted to investigate if a single item of health anxiety had satisfactory construct validity in capturing health anxiety in older adults. One factor was extracted in the factor analysis of all seven items concerning health anxiety, including a single item of health anxiety and WI-6 items. This factor had an eigenvalue of 3.69, explaining 53% of overall variance. The first item of the WI-6 (0.87) and the single item of health anxiety (0.82) had the highest loadings on the general health anxiety factor. The communality (h^2) of the single item was 0.66 which indicated satisfactory reliability of this variable. Pearson's correlation tests indicated that there were moderate to strong positive correlations between our single item and all individual WI-6 items (r = 0.40 − 0.70), and with the overall WI0-6 score ($r(51) = 0.75$, $p < .001$), in our sample of older adults (see Table 6.1).

Table 6.1

Factor loadings and correlations for the health anxiety item and the Whiteley Index-6 (n = 53).

Variable	Factor 1	h^2	r
Health anxiety single item	0.82	0.66	/
Whiteley Index-6			
Item 1: Something wrong with body	0.87	0.76	0.73***
Item 2: Worry about health	0.80	0.63	0.68***
Item 3: Trust in doctor	0.67	0.44	0.40**
Item 4: Worry about possible illness	0.59	0.34	0.50***
Item 5: Worry about new illnesses	0.75	0.57	0.58***
Item 6: Bothered by symptoms	0.53	0.28	0.48***
Eigenvalue	3.69	0.66	
Total variance explained		53%	

*Note: *significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$; r = Pearson's Correlation Coefficient; (h^2)* = communality score.

Table 6.2

Fit indices from unconditioned, single-class growth mixture models to determine optimal growth function.

	Intercept only	*Linear growth*	*Quadratic growth*	*Polynomial growth*
AIC	1325.74	1291.32	1272.42	1265.47
BIC	1246.83	1302.42	1285.37	1280.27
ssaBIC	1248.49	1210.72	1197.01	1182.47
Log likelihood	-659.87	-639.66	-629.21	-624.73
LMR-LRT	/	<.001	<.001	<.001

Table 6.3

Fit indices from conditioned growth mixture models of trajectories with 1 to 4 latent classes (n = 47), controlling for covariates. A two-class model was selected.

	1-class model	*2-class model*	*3-class model*	*4-class model*
AIC	599.32	557.22	551.02	551.45
BIC	638.18	605.33	603.26	601.10
ssaBIC	572.58	531.38	527.64	526.91
Log Likelihood	-278.66	-252.61	-249.20	-248.73
LMR-LRT	/	<.001	0.02	0.05
Entropy	/	0.98	0.95	0.90
Mixture proportion (%)	100	74.47	70.21	70.21
		25.53	25.53	19.15
			4.26	8.51
				2.13

Table 6.4

Estimates, intercept and slope values for a two-class model of health anxiety (n = 47), stratified by latent class.

	B	*SE*	*p*
Age	-.003	.01	.69
Gender: Female	-.06	.10	.52
Objective Health	1.61	.86	.048
Subjective Health	0.01	.04	.72
Health Asymmetry: Health Optimistic	-0.06	.13	.65
Health Asymmetry: Health Pessimistic	-0.02	.12	.83
Low-stable (n = 35)			
Intercept	2.59	.58	<.001
Linear Slope	-.62	.17	.01
Quadratic Slope	.08	.03	.01
Polynomial Slope	-.004	.001	.02
Volatile (n = 12)			
Intercept	4.29	.70	<.001
Linear Slope	-1.28	.29	.09
Quadratic Slope	.22	.05	<.001
Polynomial Slope	-.01	.002	<.001

Note: SE = standard error, B = standardised beta estimate.

Objective 2: Identifying trajectories of health anxiety in older adults

GMMs were applied to identify distinct trajectories of health anxiety in older adults. N = 6 participants were removed from GMM analyses since they had at least 50% missingness in their EMA responses, resulting in a sample of n=47. Firstly, to characterise the longitudinal growth pattern of health anxiety over time, fit indices including AIC, BIC, ssaBIC, LMR-LRT and Log-likelihood indicated that a polynomial growth function (β=-0.01, $p<.001$) best characterised health anxiety change in older adults (see Table 6.2).

Then, a set of conditional GMMs were conducted, to determine the optimal number of latent class trajectory groups. Based on fit indices, it was determined that a two-class model fit the data best. The LMR-LRT was significant when α=5% and the entropy was 0.98, indicating satisfactory distinction between classes. A three and four-class model had similar results from some fit indices to a two-class model, with a three-class model having a significant LMR-LRT vs a two-class model. However, three and four-class models were rejected as they both had a class with a proportion of <5% (see Table 6.3).

Figure 6.2 visualises the average trajectories of health anxiety over a 6-day period, stratified by the two distinct trajectory classes. The intercept and slopes for both classes are shown in Table 6.4. The first class, accounting for 74.47% of the sample had a slightly elevated intercept (I=2.59, $p<.001$; PS=-0.004, p=.02). However, health anxiety levels in this class decreased and remained low and stable for the remainder of the study period. As a result, this class was termed "low-stable". The second class, accounting for 25.53% of older adults, had particularly elevated health anxiety at the beginning of the study period which sharply decreased, though showed considerable volatility throughout the rest of the study period. This group demonstrated rapid increases and decreases in health anxiety, compared to the “low-stable” group, and therefore, this class was termed as “volatile” (I=4.29, p<.001; PS=-0.01, p=<.001).

Objective 3: The role of subjective and objective health

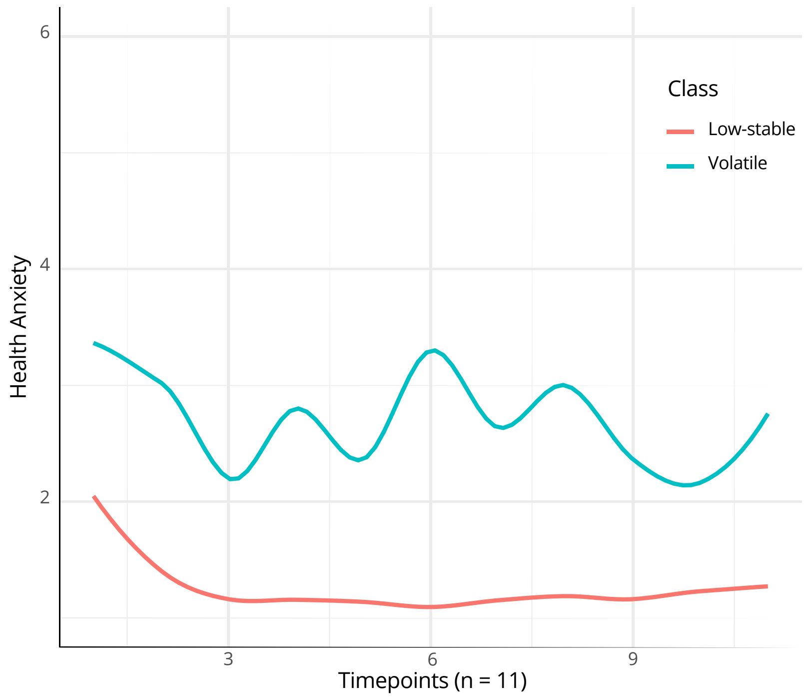
The final selected GMM model indicated that OH scores were significantly associated with health anxiety: poorer OH significantly predicted higher health anxiety scores (β=1.61, p=0.048). Subjective health appraisals and health asymmetry categories did not significantly predict health anxiety scores in older adults (see Table 6.4).

6.4 Discussion

Responding to established multiple-item measures of health anxiety on a regular basis could increase participant burden, affect study attrition rates and threaten the validity of participant responses (Barta et al., 2012; Gabriel et al., 2019). Our study investigated whether a single item measure could offer a feasible solution to capturing momentary changes in health anxiety repeatedly over time. An exploratory factor analysis provided evidence for strong construct validity of a single item of health anxiety. The single item loaded significantly onto one single factor, along with scores from the WI-6, a reliable and well-validated measure of health anxiety in both clinical and non-clinical populations (Asmundson et al., 2008; Veddegjærde et al., 2014; Welch et al., 2009). Additionally, there were moderate to strong positive correlations between the single item and WI-6 items, providing some preliminary evidence for satisfactory concurrent validity for our single item, which seems to capture a similar construct to the WI-6.

Figure 6.2

Average trajectories of health anxiety in older adults over a six-day study period, stratified by distinct latent trajectories.



Note: T1. . . T6 denotes the timepoints, within which there were a maximum of 11 throughout the study period.

The feasibility and validity of a single item measure of health anxiety has practical implications for healthcare providers, policymakers and researchers. A single item of health anxiety is a promising and efficient tool for briefly assessing health anxiety in longitudinal designs and clinical settings (wherever repeated, intensive measurement of health anxiety is required). Regular monitoring of this measure could identify those at risk of heightened health anxiety, allowing for timely intervention and support, similar to previously validated single items of anxiety and depression (Skoogh et a., 2010; Turon et al., 2019).

Our study also offered insights into the temporal dynamics of health anxiety, yielding two distinct trajectories in our sample of older adults. Most participants exhibited a "low-stable" trajectory, suggesting that older adults typically experience lower levels of health anxiety, with minimal fluctuations over short periods of time. This may be reflective of a capacity in many older adults to exhibit adaptive coping mechanisms and stable health perceptions (Bourgault-Fagnou & Hadjistavropoulos, 2009), and as such, these individuals would require less frequent monitoring and intervention than other groups.

A "volatile" group was found, who demonstrated significantly elevated and fluctuating levels of health anxiety. This suggests that a substantial minority of our sample of adults aged 50 and over experienced pronounced and sharp increases and decreases throughout the study period. The identification of these individuals is helpful as they may be more vulnerable to daily stressors that trigger their health anxiety. However, our findings raise questions about what these potential triggers are, which result in episodic increases among the "volatile" group. These triggers may be internal (e.g. safety-seeking behaviours or attentional or memory recall biases) or external factors (e.g. medical appointments or changes in health status) (Asmundson et al., 2010; Görgen et al., 2014; Guthrie et al., 2024). For example, volatile individuals may have a lower threshold for stress tolerance, with physiological and psychological pathways frequently being in a state of arousal (Larrazabal et al., 2022; Sauer et al., 2020). It may also be that volatile changes in health anxiety are triggered by dysfunctional coping and emotional regulation strategies in older adults, which makes them more susceptible to the negative impacts of daily stressors (Cisler et al., 2010; Görgen et al., 2014). Therefore, these individuals should be a priority in terms of targeted interventions and psychological support (Bouman, 2014).

Both trajectory groups experienced a sharp decrease in health anxiety levels immediately after the baseline assessment, likely due to an initial elevation bias in subjective reporting (Shrout et al., 2018). Such biases relate to the reporting of greater severity of a target state than what is actually experienced, with the severity of the target state weakening after baseline assessments.

It may be that our sample of older adults reported gradually lower levels of health anxiety after baseline due to measurement reactivity, or after repeated exposure to the same measurements, which is common within intensive studies (Barta et al, 2012; French & Sutton, 2010). Previous research acknowledged that initial elevation biases in reporting of negative mental states and physical symptoms is higher than for positive states (Anvari et al., 2023).

Frailty scores were captured remotely using an eFI (Clegg et al., 2016) to obtain approximations of OH in our sample. Higher eFI scores imply a frailer older adult with poorer OH. OH scores were significantly associated with health anxiety levels across our study period. Frailer individuals, in poorer OH, were found to have higher health anxiety scores using our single item, providing empirical evidence that a potential dose-response relationship explains the association between physical OH symptoms and mental health issues in older adults (Gurian & Minor, 1991; van Balkom et al., 2000; Wolitzky-Taylor et al., 2010). Older adults with poorer OH may experience heightened health anxiety due to a lack of physical and psychological resources to cope (Kastenbaum, 1994), waning functional independence (Looper & Kirmayer, 2001; Sunderland et al., 2013; Warwick & Salkovskis, 1990), somatic symptom burden (Lee et al., 2015) and increased interactions with healthcare services (Norbye et al., 2022). Naturally, this leads us to believe that therapeutic interventions should focus more on individuals who are frailer and in poorer OH, as they experience higher levels of health anxiety, on a day-to-day basis.

However, SH appraisals were not significantly associated with health anxiety in our sample, despite the potential for a shared factor between SH and health anxiety (Hedman-Lagerlöf et al., 2017) and despite empirical evidence supporting a significant relationship between the two constructs (Asmundson et al., 2010; Csibi et al., 2023; Lodin et al., 2019; Mewton & Andrews, 2013). None of these studies focused particularly on older populations however, so it may be that the association between SH and health anxiety weakens with increasing age – further research should investigate this.

It is also plausible that we yielded no significant association between SH and health anxiety since we were focusing on momentary assessments of health anxiety (using a single item measure), rather than scores from WI-6 or SHAI, which previous studies implemented. This lack of association between SH and health anxiety might, in turn, explain why health asymmetry categories were also not significantly associated with health anxiety over time, despite it being hypothesised that health asymmetry would be a potential proxy for health anxiety (Calvey et al., 2022). Future research should determine whether health asymmetry predicts general health anxiety over longer study periods, and perhaps not momentary assessments of the construct.

A particular strength of our study is the high response rates of ecologically valid data obtained throughout the study period. Our response rates were comparable to recent EMA studies measuring affective constructs in older populations, which also had high response rates (De Vries et al., 2021; Maher et al., 2018). Other smartphone-based EMA studies yielded response rates ranging from 43% to 95% (Jung et al., 2024). Our health anxiety data were captured in real time and unlikely to be affected by recall or retrospective bias. The study is also the first to our knowledge which captures health anxiety levels in adults aged 50 and older, using an intensive, longitudinal study design.

While our study provides valuable insights into the temporal dynamics of health anxiety in middle-aged and older adults, there are some noteworthy limitations to our study. Firstly, our sample size, though sufficient for detecting medium effect sizes and identifying latent classes through growth mixture modelling, may preclude the generalisability of our findings. An issue with general epidemiological surveys of health anxiety, including ours, is that they often sample healthier, more well-resourced, community-dwelling older adults (Boston & Merrick, 2010).

Our sample consisted of older adults who were largely in good OH. Relatedly, this study relied on self-reported measures, namely SH and OH. Despite eFIs being decent approximations of OH status, it must acknowledged that our OH is reliant on the reporting of subjective health information, as this study conducted a fully remote EMA assessment. Our self-reported measures likely introduced some reporting biases (Lauderdale et al., 2008; Mackenbach et al., 1996). While subjective measures are informative and can sometimes be even more informative than objective measures themselves (Hyland & Shevlin, 2024), future studies could incorporate more objective measurements, for example, accessing health records for official diagnoses of chronic conditions and conducting clinical health assessments of OH to complement self-reported data.

Finally, the six-day duration of our study, while adequate for capturing short-term fluctuations, may not have fully captured longer-term trends and influences on health anxiety. Extending the EMA period to several weeks could provide a more comprehensive understanding of the stability and change in health anxiety over time, particularly in relation to chronic health conditions and life events.

To conclude, a novel single item measure was introduced which appears to adequately capture daily health anxiety levels in a sample of middle-aged and older adults resident in Ireland. The implementation of this single item measure in future research and clinical practice is feasible, where health anxiety levels need to be intensively monitored. Additionally, the distinct trajectories identified in our study suggest that personalised approaches to managing health anxiety may be useful, particularly for those in poor OH. Tailored interventions to the specific needs of each trajectory group could enhance the effectiveness of health anxiety management strategies. Future research should investigate what underlying internal and external factors drive episodic fluctuations in health anxiety, in older populations. Such knowledge could better support the physical and mental well-being of older adults in an ageing population.

CHAPTER 7

Feeling Healthy versus being healthy: A critical discussion

7.1 Health asymmetry: Summary of thesis objectives

The present thesis addressed three objectives: 1a) to develop a 'health asymmetry' metric which quantifies discrepancies between SH and OH scores in older adults and subsequently categorising them into four distinct groups, 1b) to investigate the stability of these health asymmetry categories over time and 2) to conduct a set of observational, longitudinal studies to determine whether this health asymmetry metric is a clinically useful tool in predicting various health sequelae. This chapter will recap the findings of the three objectives, before discussing them in the context of existing literature and theory, their methodological strengths and limitations, and the broader implications of the research described in this thesis.

7.1.1 Objective 1a: Developing a distance-based health asymmetry metric

SH is considered to be a reliable proxy for OH status in most populations and has been shown to independently predict mortality (Bath, 2003; Idler, 2003; Falk et al., 2017). However, SH and OH scores do not always agree, particularly in later life. While existing OH measures quantify tangible aspects of physical and functional health, SH reflects an individual's personal perception and experience of their health, viewing health in a broader context than OH. Idler and her colleagues (Idler & Benyamini, 1997; Idler, et al., 1999) speculated that SH may tap into a more holistic view of health and acts as a sort of summation tool of such health-related experiences, such as risky health behaviours, emotional constructs, severity of illness and prodromal poor health. Consequently, SH may be a broad index of health, which explains why SH scores do not always align with more narrowly defined OH measures that were used in previous health congruence literature. Despite the theoretical explanations for why SH and OH scores do not always align in later life, there are few ways of systematically identifying older adults whose SH and OH scores are at odds with each other.

Previous health congruence studies identified discrepancies between SH and OH scores in older adults using a 2x2 indicator variable (Abma et al., 2021; Chipperfield, 1993; Hong et al., 2004). Here, SH and OH scores are dichotomised into 'good' and 'poor' health, and cross-classified, resulting in four subgroups: 1) good health realists (good SH and good OH), 2) health optimists (good SH but poor OH), 3) health pessimists (poor SH but good OH) and 4) poor health realists (poor SH and poor OH). However, this 2x2 indicator variable requires researchers to identify somewhat arbitrary cut offs between good and poor SH and OH. The first objective of this thesis was to offer a more flexible alternative to previous health congruence metrics, in the form of a distance-based metric. Health asymmetry is referred to as a distance-based metric since the discrepancy or 'distance' between standardised SH and OH scores were quantified and as a result, created a raw discrepancy score for each participant. The goal was to derive such a discrepancy score which could be used on its own, or which could classify older adults into potentially clinically meaningful categories.

In Chapter Two, we borrowed from other asymmetry metrics and outlined a framework for such an alternative distance-based metric. To compare SH and OH among older adults, both scores were standardised, by converting them into Z scores (Caldwell et al., 2019). One set of standardised scores were subtracted from the other to derive a continuous discrepancy score for each participant. A one standard deviation score was used as a cut-off in within this discrepancy score to identify 'health optimists', 'health pessimists' and 'health realists'. The derivation of this discrepancy score allowed us to sensitively capture variations in SH and OH more effectively than a dichotomised 2x2 indicator approach. In addition to this, there is flexibility to change the standard deviation cut-off to the desired cut-off point (for example, a larger standard deviation cut-off will identify very health optimistic and very health pessimistic individuals). However, a limitation of Chapter Two was that the health realistic category contained older adults with considerably varying degrees of OH (both poor and good OH). With this in mind, in Chapter Three, the health realistic category was further dichotomised into 'good health realists' and 'poor health realists' based on the valence of their OH and SH scores, to reflect the varying levels of OH among these older adults.

The creation of an ordinal health asymmetry variable enables the prognostication of health outcomes, by examining the synergistic predictive effects of SH and OH (Calvey et al., 2024), instead of examining of the predictive effects of SH, while holding OH effects constant (Ruthig et al., 2011). Health asymmetry also allows us to distinguish between health optimists and good health realists (who have similarly good OH levels), and between health pessimists and poor health realists (who have similarly poor OH levels), yet different SH appraisals. In an alternative approach (where one would control for OH in response to SH) assumes that a static relationship exists, where OH operates as a covariate that 'subtracts' its variance from SH. Health asymmetry, by contrast, treats the relationship between SH and OH to be dynamic and context-dependent, allowing for a more nuanced exploration of discrepancies and their implications over time. This approach reflects the complexity of SH and OH scores, where discrepancies between these scores often signify underlying psychosocial, cultural or behavioural factors (Chipperfield, 1993; Layes et al., 2012; Miilunpalo et al., 1997).

A key advantage of our distance-based approach is that health perceptions are not necessarily binary, in that older adults exist on a continuum of health optimism or health pessimism. A distance-based approach allows for more granularity in detecting variations between SH and OH and allowing for the differentiation of those whose health perceptions fall anywhere along the health asymmetry spectrum. For example, health asymmetry can distinguish between older adults who might be moderately health optimistic or health pessimistic and those who might be slightly health optimistic or health pessimistic, providing the ability to create more nuanced categories if necessary, rather than simply classifying individuals as 'congruent' or 'incongruent', as done in previous health congruence research. Additionally, the discrepancy score which health asymmetry derives can be utilised as a continuous variable in models, or similar to the studies presented in this thesis, specific health asymmetry categories can be subsequently identified to determine their association with clinical outcomes. Health congruence studies force binary classifications on the valence of 'good' or 'bad' SH and OH, which may overlook subtler, clinically meaningful differences in health perceptions and may potentially result in inadequate granularity.

This granularity is crucial, as even small variations in self-rated health have been shown to predict important outcomes like mortality (Idler & Benyamini, 1997). Standardising both SH and OH scores into Z scores makes them comparable on the same scale, enhancing sensitivity (Caldwell et al., 2019). As a result, our approach is better suited to identifying both health optimists and pessimists at the extremes, offering more refined insights into health discrepancies than the health congruence framework. Furthermore, the need for more sensitive and standardised health metrics has been widely acknowledged (Collins & Varmus, 2015; Mathers et al., 2003; Murray & Frenk, 2008; Pinquart, 2001; Rosenthal & Shannon, 1997), reinforcing the value of this method in capturing health discrepancies more precisely. While the present thesis develops a health asymmetry metric that can result in 2x2 categories, similar to previous health congruence research, the present metric is more flexible. Health asymmetry acknowledges that discrepancies can be slight or substantial and that both ends of the spectrum deserve attention.

7.1.2 Objective 1b: The stability of health asymmetry categories over time

Incongruence in the form of health optimism has been touted to be protective (Chipperfield, 1993; Ruthig & Chipperfield, 2007), while incongruence in the form of health pessimism seems to inhibit good OH (Ruthig & Chipperfield, 2007). However, a prevailing gap in the literature exists regarding how stable states of health optimism and health pessimism are, ultimately determining if it is possible to invoke health optimism and its protective effect and to avoid the maladaptive nature of health pessimism. A previous study descriptively investigated the stability of these health congruence states over a 5-year period, finding that health realism is stable, and that health optimists and pessimists eventually shift to states of health realism over time. However, no model-based investigation into the stability of these states has been conducted since. Objective 1b of the present thesis aimed to rectify this.

In Chapter Three, first-order Markov transition models and generalised probit models were applied to investigate whether English older adults transitioned to and from health asymmetry categories over three waves of the English Longitudinal Study of Ageing (ELSA) (2002-2007). The health asymmetry status of a large sample of older adults aged 60+ years was determined, at three separate waves of ELSA, by quantifying the discrepancy between their SH and OH scores (as measured by a Frailty Index). Findings indicated that good and poor health realists were likely to remain stable, suggesting that older adults with aligned SH and OH retain a balanced view of their health over time. However, the study also revealed that a considerable proportion of a good health realists transitioned to health optimism over time, potentially due to adaptation and coping mechanisms in response to adverse health challenges.

Conversely, health pessimism was less stable and was relatively short-lived in this study. Health pessimistic individuals were more likely to be lost to death or dropout than the other health asymmetry categories were, despite having relatively good OH. It was reasoned that this was due to potential declines in OH, where health pessimists noticed somatic experiences or bodily changes that later manifested as poor OH. It is possible that health pessimism represents prodromal poor OH that older adults are diffusely but not specifically aware of (Idler and Kasl, 1991; Kitzmüller et al., 2013), and as a result just might end up in poor OH, through different psychological and behavioural pathways. Therefore, the transient nature of health pessimism makes it a viable target for therapeutic interventions. Healthcare professionals could leverage this by promoting positive health appraisals among individuals who exhibit health pessimistic tendencies. Ultimately, this chapter successfully investigated the stability of the health asymmetry categories and subsequently identified intervention points for older adults with discrepant health perceptions.

An interesting point to consider is that the proportions of the health asymmetry categories varied from study to study. Table 7.1 below illustrates how the prevalences of these categories changed from study to study.

7.1.2 Objective 2: Health asymmetry as a predictor of health sequelae

Existing research shows that the agreement or disagreement between an older adult's SH appraisal and their OH score is associated with psychological, functional and physical health outcomes (Hong et al., 2005; Ruthig & Chipperfield, 2007), including survival (Chipperfield, 1993). However, such literature mostly relies on cross-sectional analyses, where causality cannot be inferred. As a result, a major component of the thesis was the second objective, where the clinical utility of this metric was evaluated, by investigating whether health asymmetry categories could predict health sequelae over time. To achieve this, a set of longitudinal, observational cohort studies were conducted. It was investigated whether health asymmetry categories were predictive of a variety of critical geriatric outcomes such as mortality, depressive symptoms, incidences of injurious falls and health anxiety.

Health asymmetry is likely to be associated with mortality as an outcome. Chapter Three previously described how older English adults transitioned to and from health asymmetry categories over time. While death and drop out were not separated into two different outcomes, health pessimists did have a continuously elevated likelihood of being lost to death or dropout across both wave transitions. Health pessimists were even more likely than poor health realists to be lost to death or dropout by wave three, despite health pessimists having objectively better health than poor health realists. These findings align with previous literature, where it was also found that health pessimists had an increased likelihood of mortality (Chipperfield, 1993; Vuorisalmi et al., 2012). Conversely, health optimists were less likely to be lost to death or drop out, despite their objectively poor health, which is also consistent with previous literature (Borawski et al., 1996; Chipperfield, 1993).

Our findings also suggest that health optimism may be protective against mortality, when compared to other health asymmetry groups. However, conclusive statements cannot be made regarding the association between health asymmetry categories and mortality, until future studies ensure that death and drop out are treated as separate outcomes. Additionally, while health pessimists had a continuously elevated likelihood of being lost to death or dropout across wave transitions, the effect sizes for predicting mortality were larger for health optimists and poor health realists than health pessimists. One possible explanation for this discrepancy is that the predictive strength of health pessimism on mortality might be influenced by other factors not accounted for, such as health behaviours or executive functioning (Kimura et al., 2024; Ruthig et al., 2011). Further research could explore these relationships in more detail to better understand the role of health perceptions in predicting mortality.

To our knowledge, there are no longitudinal studies thus far that investigated whether discrepancies between SH and OH scores predict depressive symptomatology over time in older adults. In Chapter Four, we harmonised data from 11 European countries and tracked participants' depressive symptoms over a 14-year study period. A multi-level growth curve model was conducted to determine whether baseline health asymmetry status predicted trajectories and change in trajectories of depressive symptomatology over time. Results indicated that health pessimists had higher levels of depressive symptoms at baseline, consistent with previous cross-sectional studies (Hong et al., 2004). Interestingly however, health pessimists exhibited a less steep increase in depressive symptoms over time compared to good health realists, potentially due to regression to the mean. Meanwhile, while health optimists did have slightly elevated depressive symptoms at baseline (compared to good health realists), health optimists did in fact display a relatively consistent decline in depressive symptoms, whilst other categories were subject to stable or increasing symptom levels, emphasising that there may be a long-term protective or psychological benefit of having a health optimistic perception. This chapter highlighted the clinical utility of the health asymmetry metric as a predictor of depressive symptoms trajectories and supported the metric's relevance for understanding long-term mental health outcomes in older adults.

In Chapter Five, health asymmetry status was a significant predictor of the risk of an injurious fall in Swedish older adults. Incidences of injurious falls were identified within a sample of community-dwelling older adults over a 10-year follow-up. Using time-varying Cox proportional hazard and Laplace regressions, time-varying health asymmetry status significantly predicted injurious fall risk. Analyses revealed that health optimists had the highest risk of experiencing injurious falls. This may have been due to optimistic and cognitive biases that health optimists experience regarding their physical abilities. Poor health realists and health pessimists also exhibited an elevated fall risk, when compared to good health realists. Poor OH seemed to be a considerable driver of elevated injurious fall risk (see health optimists and poor health realists), however, SH appraisals added additional context to the risk stratification. Despite having similar OH levels, health optimists and health pessimists had considerably varied injurious fall risks (due to their varying SH levels). Similarly, health pessimists had an elevated risk of falling when compared to good health realists (both groups had similarly good OH levels). The findings underscored the complex interplay between SH, OH and injurious fall risk, ultimately highlighting that health optimism might pose functional health risks, despite its psychological benefits.

Finally, in Chapters Two and Six, the relationship between health asymmetry and other aspects of psychological health was explored. In Chapter Two, being health pessimistic was associated with increased anxiety and loneliness levels and associated with decreased social connectedness, further highlighting an intrinsic link between health asymmetry and psychological health. In Chapter Six, it was determined whether health asymmetry status was a significant predictor of health anxiety in middle-aged and older adults over a six-day study period, using a six-day EMA study design, and whether distinct trajectories of health anxiety emerged. Two distinct trajectories of health anxiety were yielded in middle-aged and older adults: a "low-stable" group and a "volatile" group. The study found that OH scores were a significant predictor of health anxiety, while SH appraisals and health asymmetry categories in general did not significantly predict health anxiety levels. Ultimately, it was concluded that health asymmetry may be a more useful predictive tool over longer study periods and on larger, more representative samples (as noted in Chapters Three and Four) and may be less useful as a predictive, clinical tool in smaller samples and over shorter timeframes.

7.2 Critical evaluation of the health asymmetry metric

7.2.1 Multidimensional indices of objective health and measurement error

Previous health congruence studies often operationalised OH using comorbidity indices or physician's ratings of patients' health, and as such, adopted a strictly biomedical, reductive view of health. This directly contradicts the recommendations made by theorists (Cacioppo & Berntson, 2011; Currie & Madran, 1999; Guinn, 2001; Leonardi, 2018; Shaw & Mackinnon, 2004). Health asymmetry addresses these concerns by introducing more comprehensive measures of OH (such as FIs and HATs) which reflect the multidimensionality of health decline that is typically observed in later life, while also mirroring the multidimensional nature of SH appraisals (Idler & Benyamini, 1997; Idler et al., 1999).

In Chapters Two, Three and Four, it was demonstrated that a FI suitably captured the multidimensionality of OH in later life. Unique FIs were compiled by summing together various physical, functional, mental and cognitive health deficits (such as falls, chronic pain, disease diagnoses and MMSE scores) into an overall FI score for each participant. The discrepancy between FI scores and participants' SH appraisals was calculated. The FI was an apt approximation of overall OH scores as it accounted for the functional, psychosocial and cognitive health decline which is typically observed in later life (Colón-Emeric et al., 2013; Diehr et al., 2013; Lin et al., 2013; Pronk et al., 2014), and did not rely on disease count alone (Tkatch et al., 2017).

In Chapter Six, it was demonstrated that multidimensional measures of OH are useful, even when captured remotely. Here, an approximated OH score for each participant was captured using an electronic version of the Frailty index (eFI), which was self-reported through smartphone devices. Despite eFIs being easily implemented in research, eFIs rely heavily on SH, as the data have to be self-reported by the participant. However, in Chapter Five, a fully objective, HAT measure was utilised. This tool calculated an overall OH score for each participant based on five objectively measured indicators of OH, including aspects of disease burden, functionality and cognition. Any concerns regarding the subjectivity associated with self-reported health data in FIs was not a concern in Chapter Five, as a robust, objective HAT score was utilised instead. Ultimately, the health asymmetry metric is flexible in using a variety of different multidimensional OH approaches.

However, a limitation of using secondary data to construct these multidimensional indices is the reliance on self-reported data, as previously mentioned, which may introduce measurement and recall error. Stolz et al. (2024) found that while FIs are internally consistent and can reliably differentiate between community-dwelling older adults, a FI can be prone to measurement error. For example, error associated with OH indices may stem from the retrospective, self-reporting of functional limitations or chronic conditions, which are particularly vulnerable to recall bias (Baker et al., 2004; Mackenbach et al., 1996).

Additionally, self-reports may be compromised in a select few older adults with cognitive impairment, where the presence of cognitive impairment may further diminish the accuracy of self-reported health information (Hale et al., 2019). In an attempt to minimise bias from self-reported data in our studies, all participants who presented at baseline with a health condition associated with considerable cognitive impairment were excluded, such as Alzheimer's Disease and Parkinson's Disease. Despite this however, the reliance on self-reported data within our some of our multidimensional OH indices may undermine their true "objective" nature.

The retrospective construction of OH indices using secondary data sources is also limited in other ways. FIs or eFIs that are constructed post-hoc may not always accurately capture all facets of an individual's OH status. For example, in Chapter Two, the TILDA dataset included few cognitive health deficits that could be incorporated into our FI. While MMSE scores were calculated and noted the presence of subjective cognitive complaints as a compromise, the resulting FI scores were disproportionately weighted towards functional health (which was measured by 11 IADLs) and disease prevalence (where we accounted for seven chronic conditions). Other clinical geriatric measures (such as gait speed or grip strength) may not be captured at each wave of large-scale health and ageing studies, and as such, the comparison of OH scores from wave to wave may be limited. Furthermore, secondary data sources may be prone to incomplete or missing information (Lu & Shelly, 2023), and outdated variables which can undermine the reliability of the resulting indices. Therefore, caution is needed when retrospectively constructing OH indices within a health asymmetry framework.

Finally, comparing a single SH indicator to more multidimensional indices of OH (through comprehensive FIs or HATs) may have introduced more measurement error, that could potentially contribute to the discrepancy between SH and OH. The reliance on a single SH item may fail to capture the full complexity of an individual's health perceptions, leading to discrepancies that may not accurately reflect the individual's true dissonance between their SH and OH scores (Jylhä, 2009). This simplification could result in misclassification or bias in the health asymmetry metric, as previously discussed. Future research could consider incorporating multiple SH items, such as measures of health-related quality of life measures like SF-12 (Ware, 1993), to offer a more robust and nuanced health asymmetry score. Such an approach could allow for a more accurate reflection of personal health perceptions, that reduces measurement error.

7.2.2 Misclassification and loss of statistical power

The creation of a health asymmetry metric, which categorises individuals based on continuous data, introduces some considerable statistical challenges. One drawback is the reduction in statistical power (Altman & Royston, 2006). Grouping a wide range of continuous data points into fewer, broader categories diminishes the variance that can be analysed within statistical models. For instance, dichotomising a variable at the population median not only results in a loss of information but also reduces statistical power by the same amount as discarding approximately one-third of the data (Cohen, 1983; MacCallum et al., 2002). Although creating multiple categories to generate an ordinal health asymmetry variable is generally preferable to dichotomising, this approach also involves complexities in analysis and may still result in a loss of information (Austin & Brunner, 2004).

Consequently, this weakening of statistical power may limit the clinical utility of the metric (Cohen, 1983). Clinical decision-making relies on detecting subtle differences in health outcomes and being able to predict or identify individuals at risk for certain health events or conditions (Lange & Lippe, 2017). If a health asymmetry metric is based on three or four broad categories which reduce the variance in the data, the metric may become less sensitive to these nuanced differences. Deriving categories from continuous data increases the risk of false positives and can mask variations within groups, as individuals near the cut-off points are treated as distinctly different, despite their similarities (Royston et al., 2006). This loss of sensitivity could lead to less accurate assessments of an individual's risk profile, making it harder to identify who may benefit the most from early intervention or targeted treatment.

Furthermore, the health asymmetry categories may have concealed any non-linear relationships that exist between SH and OH scores in older adults. Given that the SH does not decline with the same rate of change as is typically observed in age-related OH decline (Ferraro, 1980; Henchoz et al., 2008), it is expected that non-linear patterns between SH and OH exist in later life. In particular, SH tends to remain more stable, perhaps until a critical threshold of OH deterioration is reached. Other non-linearities may come in the form of a curvilinear relationship where SH could be higher at both excellent and poor levels of OH, for instance, individuals with poor

OH might exhibit health optimism as a coping strategy. Future analyses could control for any interaction effects between SH and OH when investigating the predictive ability of health asymmetry, similar to our model in Chapter Four. Here, a significant interaction effect between SH and OH was found with regards to depressive symptoms, meaning that the effect of SH on depressive symptoms depends on the level of the OH, and vice versa. However, it would be worthwhile visually or analytically confirming that non-linear relationships between SH and OH exist, outside of the context of depressive symptoms.

A trade-off between statistical integrity and clinical utility exists, however we argue that a health asymmetry metric is a helpful addition in clinical settings. Diagnostic and risk categories, where individuals are labelled as having a particular attribute or not, play a crucial role because they provide a framework for identifying individuals at risk of adverse health outcomes, enabling targeted interventions and facilitating decision-making. For example, hypertension thresholds are well-established diagnostic categories that inform clinical decisions and interventions within their respective fields (James et al., 2014). Similarly, while risk stratification methods, such as Framingham risk scores for cardiovascular disease, are not flawless or free of error, they can help to prioritise patients for preventive measures based on their differential risk profiles (Schnabel et al., 2009; Wilson et al., 1998). Therefore, there is clinical merit to creating an ordinal health asymmetry metric, which identifies health optimists, pessimists and realists, beyond the quantifiable distance between their SH and OH scores. These health asymmetry categories should be viewed as analogous to the previously mentioned diagnostic practices, as our health asymmetry categories have been shown to predict be various clinically relevant functional and mental health outcomes.

7.2.3 Response biases in subjective health appraisals

SH responses may vary based on cultural, psychological and contextual factors, as discussed in Chapters One and Two. For example, macro-level cultural values can shape how individuals perceive and report their health, resulting in discrepancies in how SH is understood across countries. These cultural differences may introduce potential biases when SH scores are converted into numerical values for use in a health asymmetry metric. Research has illustrated considerable variation in SH, social life and living conditions across European countries (Bobak et al., 2000; Jürges et al., 2008). The contributors of SH also vary internationally, with some countries exhibiting higher standards of health than other countries (Bardage et al., 2005; Olsen & Dah, 2007). This cultural variability in the interpretation and measurement of SH may lead to inconsistencies when comparing SH responses across populations. In Chapter Four, significantly different proportions of health asymmetry categories were found across 11 European countries, even though some of these countries included in our analyses had similarly structured healthcare systems, life expectancies and meanings of health more generally (Leon, 2011). As a result, health asymmetry metrics applied in a cross-national context might be slightly skewed.

While Jylhä et al. (1998) concluded that SH is somewhat comparable across cultures, they cautioned that these comparisons should be interpreted carefully. Additional studies explicated the complexity of interpreting SH within and across countries. For example, American individuals reported higher SH due to a greater influence of positive reappraisal, even when controlling for OH indicators, compared to Japanese respondents (Choi & Miyamoto, 2022). Similarly, Kobayashi et al. (2008) identified significant ethnocultural disparities in SH scores across Canadian-born and first-generation immigrant populations. These health disparities converged after controlling for sociodemographic, SES and lifestyle factors. Given the evidence of variance in SH and health asymmetry categorisations across different cultural contexts, it is possible that response bias was introduced, particularly when categorising older adults within the health asymmetry framework. Our studies attempted to mitigate such biases by adjusting for educational attainment as a proxy for SES in Chapters Two to Five and income level in Chapter Four. Despite such efforts, future health asymmetry work should address these potential biases by incorporating more robust measures of cultural and SES factors to increase the reliability of health asymmetry metrics.

7.3 Implications of the findings: Theory, policy and clinical implementation

7.3.1 Implications for theories of subjective health and ageing

The findings of the present thesis have substantive implications for understanding the paradox between SH and OH in later life. A considerable proportion of our findings align with theoretical frameworks, while some of our findings remain contradictory to what is known this far.

For example, the age-related positivity effect has been proposed as a key explanation for why older adults tend to report more positive SH despite declining OH. This effect is characterised by a relative preference for positive over negative information during cognitive processing, which becomes more pronounced with age (Charles et al., 2003; Reed & Carstensen, 2012). In Chapter Two, our analysis revealed that the prevalence of health optimism – where individuals perceive their health more positively than their OH scores would suggest – was significantly higher among older adults compared to younger age groups. Furthermore, in Chapter Three, it was observed that the prevalence of health optimism increased over a 4-year period, reinforcing the notion that this positivity effect intensifies with age. These findings align with and extend the theory of age-related positivity effects by confirming that as individuals age, they increasingly focus on positive aspects of their health, which may possibly be as a coping mechanism or as a result of a shift in cognitive priorities. This increased health optimism in older adults may serve to enhance well-being and life satisfaction, even in the face of declining OH, thereby contributing to the paradoxical relationship between SH and OH observed in later life. Overall, our results provide empirical support for the age-related positivity effect and highlight its relevance in understanding how older adults perceive their health.

Response shift theory is frequently invoked in the literature to explain why SH evaluations often remain stable or even improve in very late life, despite a decline in OH. As discussed in Chapter One, response shift theory purports that older adults reconceptualise and reprioritise internal standards and self-appraisals over time, by reconsidering their health standards and priorities as they grow older as a result of comparing themselves with similarly-aged peers or an acceptance of the ageing process (Kurpas et al., 2013; Robinson- Whelen & Kiecolt-Glaser, 1997; Spini et al., 2007). In Chapter Three, good health realists had a gradually increasing probability of becoming health optimistic over time. While some good health realists transitioned to health optimism at wave two, by the third wave, nearly a quarter had made this shift. This suggests that their SH appraisals remained stable or even improved, despite stable or age-related OH decline, supporting the presence of a positive response shift. These findings imply that older adults may engage in self-protective adaptation, adjusting their internal health standards response to irreversible declines in OH (Sprangers & Schwartz, 1999). The observed growth in health optimism over time may also reflect a recalibration of SH appraisals to lower standards and expectations (Galenkamp et al., 2012), perhaps driven by an acceptance of the ageing process, illness acceptance and a desire to maintain a positive quality of life (Kurpas et al., 2013; Robinson-Whelen & Kiecolt-Glaser, 1997; Sharpe & Curran, 2006; Spini et al., 2007; Ubel et al., 2005).

However, our findings also challenge aspects of the response shift theory. It was anticipated that a considerable proportion of poor health realists would transition into health optimists, suggesting that SH appraisals might remain stable or even improve over time, despite poor OH, as suggested by previous studies (Heller et al., 2009; Volgelsang, 2018). Contrary to our expectations, poor health realists were less likely to become health optimists and were more likely to remain poor health realists or to be lost to death or dropout. This indicates that there is insufficient evidence to support the hypothesis that poor health realists experience a significant response shift. The theory postulates that older adults recalibrate and reconsider SH appraisals after comparing themselves to others who are worse off (Cheng et al., 2007; Henchoz et al., 2008; Wu & Zhang, 2023). However, our results suggest that the response shifts may not be as pronounced among those who are already realistic about their poor OH, which aligns with the notion that response shifts in SH are not homogeneous across all groups of older adults (Spuling et al., 2017). Specifically, SH may not remain stable or improve as much in poor health realists as previously thought (Ruthig et al., 2011).

However, it must be acknowledged that the prevalence of health optimism or health pessimism - as defined by health asymmetry - may be confounded by the manner in which these categories are derived. Typically, a one standard deviation score was used to derive the categories, but the standard deviation is dependent on the sample size and the number of participants in each tail, by definition. Therefore, caution of the strict interpretation of the prevalence of health optimism and pessimism within a health asymmetry metric should be cautioned, as they may be under or overestimations of the true prevalence rates.

It has also been suggested that selective survivorship helps explain the strong association between age and health optimism (Idler, 1993). The oldest-old seem to adapt to declines in health and down-regulate negative psychological responses to OH decline (Wettstein et al., 2016), which creates a disconnect between SH and OH in later life. This notion that long-term survival against declining health and functionality is an adaptive response is logical. However, the resulting outcome of survival (i.e. health optimism) may not be entirely adaptive. While health optimists have greater survival outcomes, more optimal psychological health (as noted in Chapter Four) and engage in more exercise than others (Chipperfield, 1993; Hong et al., 2004; Hong et al., 2005; Ruthig & Chipperfield, 2007), health optimists are also at an increased likelihood of experiencing injurious falls, as found in Chapter Five. Health optimists may also refrain from seeking medical treatment or engaging in healthcare services less than others (Löckenhoff & Carstensen, 2004). As a result, while those who survive may naturally be healthier and more health optimistic than others, health optimism as a state may not be entirely adaptive.

Our findings add to quite a contradictory literature regarding the supposed adaptive or maladaptive nature of health optimism. For instance, in previous research, health pessimists reported more difficulties with functional limitations, greater number of hospitalizations and were less socially engaged than good health realists (Ruthig & Allery, 2008). The findings suggest the adaptive value of optimism over realism for individuals in poor health in all aspects of functioning, and supply further evidence of the detrimental impact of pessimism on individuals, such that their level of functioning is considerably reduced compared to individuals with similar levels of OH.

7.3.2 Implications for policy: a healthy dose of realism

Considering that health optimism may be both adaptive and maladaptive, depending on the health content, it is difficult to recommend promoting health optimism as a universal therapeutic or policy goal. While dispositional optimism (i.e. the general expectation that good things will happen) is generally linked to positive health outcomes like healthier ageing, better post-surgery recovery, and improved health-related quality of life (Liu et al., 2021; Scheier & Carver, 2018; Steptoe et al., 2006), health-specific optimism is less clear. Health-specific optimism, in which individuals "overestimate" their SH scores relative to their OH status, may lead to unintended negative consequences. Therefore, a balanced view of health expectations — neither overly optimistic nor pessimistic — seems to result in positive health outcomes, depending on the individual's level of OH, however. Intervening on states such as health optimism and pessimism could be possible, since they are not necessarily intrinsic, stable traits. They are states that are liable to fluctuate, as noted in Chapter Three. Previous studies found that self-rated health scores in older adults can be intervened on and improved, using social participation and health promotion interventions (Ichida et al., 2013; Rana et al., 2010). As a result, a manipulation of health optimism, pessimism or realism (as defined by health asymmetry) may be possible by the promoting of positive or realistic health appraisals.

Strictly in the context of psychological health, health optimism may be a better therapeutic target or a policy goal. Our results hint there may be a sort of protective psychological effect to health optimism in terms of depressive symptomatology, as health optimists displayed a steady decline in depressive symptoms over a 14-year follow-up (see Chapter Four). However, health optimism may not be a suitable target regarding the functional health of older populations. Health optimists had considerably elevated risks of experiencing injurious falls. As a result, further research is required to determine whether health optimism has adaptive or maladaptive health outcomes across a more varied range of health sequelae.

A prudent approach may then be to promote a healthy dose of realism. Our findings suggest that good health realists generally have the most optimal health outcomes across a variety of health outcomes, such as having lower levels of depressive symptoms (see Chapters Three and Four) and the lowest incidence of injurious falls over a 10-year follow-up (see Chapter Five). Chipperfield et al (2019) supports this notion, arguing that when health begins to decline, encouraging a realistic view of one's condition can lead to better outcomes. In fact, Chipperfield et al (2019) found that there was a 313% higher mortality risk for those with unrealistic health optimistic perceptions.

These benefits of health realism likely stem from from its ability to promote adaptive health behaviours. It may be that generally realistic expectations allow individuals to recognise early warning signs and seek medical intervention before their condition worsens. In this context, health realism may enable adaptive health behaviours that can mitigate the adverse effects of declining health while fostering resilience and long-term health maintenance (Bortolotti & Antrobus, 2015; Chipperfield et al., 2019). Conversely, unrealistic health optimism, while potentially beneficial for psychological well-being in the short term, can lead to delayed health-seeking behaviors, non-adherence to medical advice and inadequate preparation for health challenges (Coetzee & Kagee, 2020; Shepperd et al., 2015; Shepperd et al., 2017). A reasonable sense of realism may even be somewhat beneficial for those who are in poor OH. By acknowledging their limitations without catastrophising, poor health realistic individuals may be able to focus on achievable goals, adopt healthier lifestyles, and engage in coping strategies that improve quality of life (Petrie & Weinman, 2012). Thus, promoting health realism (even in those with poor OH) may represent a balanced approach, however further research is warranted in order to support such recommendations for policy.

7.3.3 Clinical utility: Implementing a health asymmetry metric into practice

It has been demonstrated that health asymmetry categories are associated with clinically relevant health outcomes, suggesting its potential as a valuable tool across various clinical settings. The integration of a health asymmetry metric in primary care could be useful and already aligns with recommendations from authoritative bodies such as National Institute for Health and Care Excellence in the United Kingdom. These bodies have emphasised the need for holistic discussions on patients' overall well-being rather than solely relying on symptom checklists (NICE, 2021). Since clinicians are already encouraged to consider both mental and physical health for early detection of problems, consideration of a health asymmetry metric could naturally fit into such broader screening processes, especially considering the metric's potential to for risk stratification in various health outcomes, such as depressive symptomatology and injurious falls.

Furthermore, GPs in primary care settings often have access to comprehensive clinical data, which makes the integration of a health asymmetry metric somewhat feasible within busy clinical workflows. The European Commission has actively promoted the integration of electronic health records (EHRs) into healthcare systems across Europe, particularly in primary care, where most patients have routine encounters within the healthcare system (Currie & Seddon, 2014; Piha, 2014; WHO, 2008). The growing implementation of eHealth, including electronic prescribing and EHRs (Brennan et al., 2015) demonstrates that the infrastructure is already in place (or at least it should be) to support and integrate metrics like health asymmetry, which could utilise pre-existing, stored electronic data obtained in primary care.

For instance, health asymmetry is linked to anxiety, loneliness and is also predictive of depressive symptomatology over time. Considering that primary care and GPs are often the first point of contact for older adults with mental health concerns (Haugh et al., 2019; Kraxner, 2023), a health asymmetry metric could be useful in such settings to identify those who may be health pessimistic. Given that health pessimists are more prone to elevated depressive symptoms (as noted in Chapter Four) and are likely to have elevated anxiety and loneliness (see Chapter Two), the early identification of these individuals could prompt timely mental health screenings, allowing for earlier intervention, therapy, or referral to mental health services.

Health asymmetry is also particularly useful in assessing injurious fall risk, as demonstrated in Chapter Five. By integrating the metric into primary care or community healthcare settings, clinicians could identify older adults at varying levels of injurious fall risk based on the disconnect between their SH and OH scores, and as such, could identify those who could benefit from further assessment and preventive interventions. For instance, it was noted that health optimists are at an increased risk of experiencing an injurious fall, which may be due health optimists exercising more than others (Hong et al., 2005; Ruthig & Allery, 2008), and as such, putting themselves in riskier situations. Health optimists may also experience an optimistic bias, where they believe they are at a decreased risk of falling, and as such, these individuals could benefit from targeted preventive interventions and further assessment.

However, health asymmetry as a risk stratification tool for injurious fall risk may be limited in hospital settings, since hospitals represent a special setting in terms of falls risk. All hospitalised older adults should be treated as high-risk and subjected to comprehensive fall assessment, followed by multidomain interventions (Montero-Odasso et al., 2022). In these cases, individualised assessments based on health asymmetry may be redundant. Similarly, the metric may not hold value in clinical settings where SH is less influential, such as emergency or intensive care. Here, clinical decisions must be based on immediate, objective data due to time constraints and critical care needs.

Health asymmetry could also be directly integrated into mental health services. Understanding how a patient's SH appraisal compares with clinical observations could provide additional insight into their mental health status. For instance, individuals with major depressive disorder exhibit cognitive distortions and abnormal self-referential processing (Liu et al., 2019) that may lead them to perceive their health more negatively (Beck et al., 2024). This is reinforced by a growing body of evidence which suggests that health pessimists experience elevated levels of depressive symptoms, compared to others (Calvey et al., 2023; Hong et al., 2004). Identifying those with discrepancies between SH and OH can inform more tailored psychotherapeutic interventions, such as cognitive-behavioural therapy, that could help health pessimistic older adults who may be at an increased risk of elevated depressive symptoms, anxiety or loneliness.

There may also be drawbacks to the clinical implementation of a health asymmetry metric. In general, health is likely precipitous (Guralnik & Ferrucci, 2003), and as such, it is possible for an individual's score on certain health instruments to change abruptly. If health does change precipitously, the metric might not be equipped to accurately capture the full temporal and dynamic range of shifts between SH and OH, and as such, could undermine the validity of the health asymmetry metric. For example, assuming that a good health realist experiences a temporary abrupt decline in OH but still reports solid SH, the metric might classify them as a health pessimist (even though they typically would not belong in the health pessimistic category). In an ideal world, more frequent data collection could address this limitation by providing a more granular view of how health changes over time. However, the health asymmetry metric was developed retrospectively using secondary archived data, which inherently restricts the frequency and granularity of health measurements. As a result, the current metric may not be fully equipped to capture the rapid transitions in the health of older adults, limiting its ability to reflect abrupt health changes accurately.

Despite this, the health asymmetry metric still holds promise as a clinically relevant tool for holistic and primary care environments. However, its application should be carefully considered in fast-paced, highly objective care settings where immediate clinical needs take precedence. Additionally, careful consideration regarding the metric's ability to capture temporal and granular changes in health status must be considered. To fully realise its potential, further validation and exploration of the metric across various clinical contexts are essential, which will enhance its relevance in both research and practice.

7.4 So what now? Future directions for health asymmetry

The present thesis highlights several avenues for future health asymmetry research. In Chapter Two, health asymmetry categories were associated with psychosocial constructs such as generalised anxiety, loneliness, and social connectedness. However, prevailing gaps in the literature remain, particularly regarding the predictive power of health asymmetry categories on these constructs over time. Since we only examined whether health asymmetry categories predicted depressive symptomatology and health anxiety levels in older adults, future research should explore whether these health asymmetry categories also predict other psychological outcomes, such as psychological distress and generalised anxiety. Additionally, longitudinal research could investigate how shifts in health asymmetry categories influence changes in these psychosocial outcomes over time, identifying whether individuals become more vulnerable or resilient as their SH and OH diverge. It would also be valuable to examine potential moderating factors, such as coping styles, social support, and cognitive functioning, which might influence the relationship between health asymmetry and psychological outcomes. By addressing these gaps, future health asymmetry research could offer deeper insights into how SH and OH discrepancies influence psychological wellbeing, given that there is clear evidence for a link already.

It would also be of clinical importance to investigate whether health asymmetry categories are associated with a broader range of functional health outcomes in older adults. Our findings revealed that health optimists had the highest risk of experiencing an injurious fall over a 10-year follow-up. This contrasts with previous health congruence research, which found that health optimists performed better on functional status tests compared to other health congruence categories (Hong et al., 2004; Ruthig & Allery, 2008). These discrepancies might stem from the different ways in which health congruence and health asymmetry metrics categorise older adults or from variations in how OH is measured. To clarify these relationships, further research could explore the complex dynamics between SH and OH discrepancies and their influence on functional health. Such research could illuminate which health asymmetry categories are more conducive to better functional health outcomes and which lead to healthier behaviours, ultimately fostering greater emotional resilience and proactive management of the functional challenges that often arise in later life.

The clinical usefulness of a general health asymmetry metric may be somewhat limited by its broad scope, contrasting overall SH and OH. There is potential to enhance its clinical relevance by developing more specific health asymmetry metrics, that are tailored to particular domains of geriatric health in later life. For example, it would be valuable to investigate health asymmetry in areas such as sleep, vision, and hearing among older adults, so to create a 'sleep health asymmetry' metric or a 'hearing health asymmetry' metric. Research has demonstrated that objective hearing tests often fail to capture the complexities of subjective, everyday listening experiences (Ramakers et al., 2017), highlighting substantial gaps between subjective and objective hearing assessments. These discrepancies could be associated with distinct psychological and functional health outcomes, suggesting the need for a targeted hearing health asymmetry metric.

Similarly, expanding this framework to other critical domains of health, such as vision and sleep, could yield important findings too. Despite their impact on daily functioning, discrepancies between subjective and objective measures of vision have been understudied, leaving questions about their potential health implications for older adults. Additionally, discrepancies between subjective and objective measures of sleep are often observed, with studies frequently reporting mismatches between perceived and objectively measured sleep quality (Hughes et al., 2018; Landry et al., 2015). However, few studies have examined the long-term consequences of such discrepancies, particularly in terms of psychological distress and other health sequelae. Developing domain-specific health asymmetry metrics, such as sleep health asymmetry, could offer clinicians a more nuanced understanding of the ever-evolving health of older populations and could guide interventions that target both the subjective experience and objective reality of health issues in later life.

7.5 Mind the gap: A conclusion

To this end, this thesis highlights a crucial dimension of health measurement in older populations, where discrepancies between SH and OH scores may appear in older populations. While previous literature established cross-sectional associations between such discrepancies and physical health, mental health and mortality outcomes, these studies often relied on limited single indicators of OH or comorbidity indices, which failed to capture the multidimensional nature of OH in later life. Furthermore, prior health congruence metrics derived 2x2 indicator variables, which constrained their ability to fully explore the complexities of the relationship between SH and OH. As a result, this thesis presented a novel health asymmetry metric which quantifies the discrepancy between SH and OH scores and consequently can categorise older adults into 4 clinically pertinent groups if needed ('health optimistic', 'health pessimistic', 'good health realistic' and poor health realistic'). Our health asymmetry framework experiments with various multidimensional indices as proxies of OH, such as a Frailty Index, electronic Frailty Indices and Health Assessment Tools, instead of relying on single indicators of OH or comorbidity indices.

This thesis also validated the clinical utility of a health asymmetry metric determining whether the metric significantly predicted various clinical geriatric outcomes. This was achieved by utilising archived, nationally-representative, secondary European datasets in order to conduct a series of prospective, observational cohort studies. Discrepancies between SH and OH were longitudinally associated with adverse health outcomes, such as varying levels of depressive symptomatology and an increased risk of injurious falls over time. Future research should aim to expand on these findings by exploring the predictive ability of health asymmetry in relation to other clinical health outcomes. Additionally, studies could develop more targeted health asymmetry metrics that compare SH and OH within specific, clinically relevant domains of geriatric health, such as sleep, hearing and vision.

From a public health perspective, it may be helpful to identify those whose SH appraisal is at variance with their OH status, as this subgroup of the population may stand to benefit the most from tailored health and functioning interventions aimed at older adults. The integration of a health asymmetry into clinical practice may be feasible with the increasing adoption of electronic health records. Ultimately, addressing the disconnect between 'feeling healthy' and 'being healthy' in later life may offer a pathway to contribute to advancing geriatric care and the promotion of healthier ageing for older populations.

CHAPTER 8

References

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CHAPTER 9

Appendices

Appendix 2.1

Health deficits included in the frailty index (FI) from the Irish Longitudinal Study on Ageing (TILDA), which formed our objective (OH) measure.

Number	**Health Deficit**
	Functional independence and mobility
1	Difficulty dressing, including putting on shoes and socks
2	Difficulty walking across a room
3	Difficulty bathing or showering
4	Difficulty eating, such as cutting up your food
5	Difficulty getting in or out of bed
6	Difficulty using the toilet, including getting up or down
7	Difficulty preparing a hot meal
8	Difficulty doing household chores
9	Difficulty shopping for groceries
10	Difficulty taking telephone calls
11	Difficulty taking medications
	Health conditions diagnosed by health professionals
12	Cancer
13	Hypertension
14	Heart Attack
15	Diabetes
16	Arthritis
17	Chronic Lung Disease
18	Chronic Heart Failure
	Physical health
19	Polypharmacy
20	Supplement Intake
21	Illness-related Weight Loss
22	Pain
24	Joint Replacements
25	Healthcare Utilisation
	Cognitive function and mental health
25	Mini-mental State Examination
26	Subjective memory complaints

Note: All binary variables are recoded, using the convention that '0' indicates absence and '1' presence of a deficit. Deficit points are summed for each individual, and divided by the total number of deficits, to produce a frailty index score with a range from 0 to 1. Some health deficits are not binary coded (e.g. MMSE, which is coded with 5 scores: 0, 0.25, 0.5, 0.75, 1).

Appendix 3.1 *Comparing baseline characteristics between study participants (n=6,803) and those excluded based on exclusion criteria (n=657).*

	Included (n=6803)	**Excluded (n=514)**	**p**	**Effect Sizes**
Age (years)	70.85 ± 7.44	73.47 ± 8.32	p <.001	0.35
Sex				
Male	45.4% (n = 3089)	43.97% (n = 226)	p = .84	0.002
Female	54.6% (n = 3714)	56.03% (n = 288)		
Education				
None	50.29% (n = 3421)	62.84% (n = 323)	p <.001	0.06
Foreign/other	9.20% (n = 626)	7.78% (n = 40)		
GSCE/O	18.05% (n = 1228)	11.87% (n = 61)		
A-level	4.34% (n = 295)	2.33% (n = 12)		
Higher	18.12% (n = 1233)	15.18% (n = 78)		
CESD-D	1.62 ± 1.96	1.76 ± 1.99	p <.001	0.13
Objective Health	0.2 ± 0.13	0.25 ± 0.17	p <.001	0.33
Subjective Health	2.89 ± 1.12	3.09 ± 1.21	p <.001	0.48

CES-D scores (Centre for Epidemiological Studies – Depression) range from 0 to 8, with higher scores implying higher levels of depressive symptoms. Objective health scores (measured using a frailty Index) range from 0 to 1, with higher scores implying poorer health. Subjective health scores range from 1 (excellent) to 5 (poor), with higher scores indicating poorer self-rated health. P values were reported for t-tests (with Cohen's d effect sizes) and chi-square tests (with Cramer's v), for continuous and categorical variables respectively.

Appendix 3.2

Comparing baseline characteristics between study participants who were present at all three measurement occasions (n=4252) and those were lost to attrition during the study period (n=2551).

	Present (n=4252)	Lost to Attrition (n=2551)	p	Effect Sizes
Age (years)	69.96 ± 6.97	72.35 ± 7.93	p <.001	0.33
Sex				
Male	43.91% (n = 1867)	47.90% (n = 1222)	p = .002	0.04
Female	56.09% (n = 2385)	52.10% (n = 1329)		
Education				
None	45.0% (n = 1916)	59.00% (n = 1505)	p <.001	0.14
Foreign/other	9.60% (n = 408))	8.55% (n = 218)		
GSCE/O	19.28% (n = 820)	15.99% (n = 408)		
A-level	4.73% (n = 201)	3.68% (n = 94)		
Higher	21.33% (n = 907)	12.78% (n = 326)		
CESD-D	1.49 ± 1.87	1.84 ± 2.07	p <.001	0.18
Objective Health	0.19 ± 0.12	0.23 ± 0.14	p <.001	0.31
Subjective Health	2.76 ± 1.12	3.13 ± 1.21	p <.001	0.34

CES-D scores (Centre for Epidemiological Studies – Depression) range from 0 to 8, with higher scores implying higher levels of depressive symptoms. Objective health scores (measured using a frailty Index) range from 0 to 1, with higher scores implying poorer health. Subjective health scores range from 1 (excellent) to 5 (poor), with higher scores indicating poorer self-rated health. P values were reported for t-tests (with Cohen's d effect sizes) and chi-square tests (with Cramer's v), for continuous and categorical variables respectively.

Appendix 3.3

Health deficits included in the frailty index (FI) from the English Longitudinal Survey of Ageing (ELSA), which formed our objective (OH) measure.

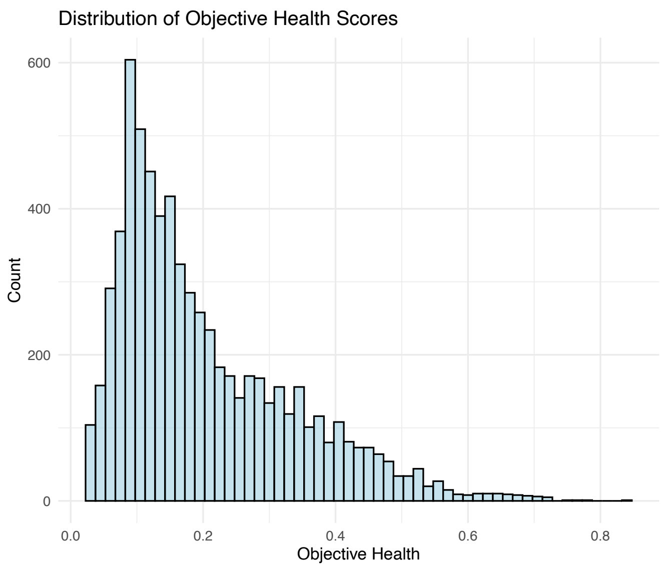
Number	**Health Deficit**
	Mobility
1	Difficulty walking 100 yards
2	Difficulty sitting for 2 hours
3	Difficulty getting up from chair after sitting long periods
4	Difficulty climbing several flights stairs without resting
5	Difficulty climbing one flight stairs without resting
6	Difficulty stooping, kneeling, or crouching
7	Difficulty reaching or extending arms above shoulder level
8	Difficulty pulling or pushing large objects
9	Difficulty lifting or carrying weights over 10 pounds
10	Difficulty picking up 5p coin from the table
	Health conditions diagnosed by health professionals
11	High blood pressure or hypertension
12	High cholesterol
13	Blood disorder
14	Angina
15	Heart attack
16	Congestive heart failure
17	Heart murmur
18	Abnormal heart rhythm
19	Diabetes/high blood sugar
20	Stroke
21	Chronic Lung Diseases (eg chronic bronchitis or emphysema)
22	Asthma
23	Arthritis (including osteoarthritis or rheumatism)
24	Osteoporosis
25	Cancer or a malignant tumour (excluding minor skin cancers)
26	Parkinson diseases
27	Any psychiatric condition
28	Alzheimer diseases
29	Dementia or organic brain syndrome
	Physical health
28	Fallen down
29	Fractured hip
30	Had joint replacement
31	Smoking status
32	Chronic pain
33	Balance

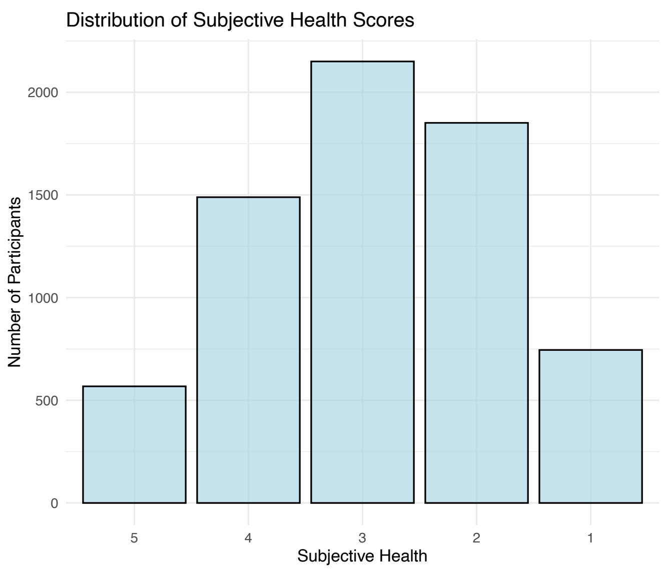
	Cognitive function and mental health
34	Depressive mood
35	Executive (non-numeric) Function
36	Memory Function (not including prospective memory)

Note: All binary variables are recoded, using the convention that '0' indicates absence and '1' presence of a deficit. Deficit points are summed for each individual, and divided by the total number of deficits, to produce a frailty index score with a range from 0 to 1. Some health deficits are not binary coded (e.g., MMSE, which is coded with 5 scores: 0, 0.25, 0.5, 0.75, 1).

Appendix 3.4

The distribution of baseline OH (as measured by a frailty index) and SH scores among ELSA participants at baseline





Appendix 3.5

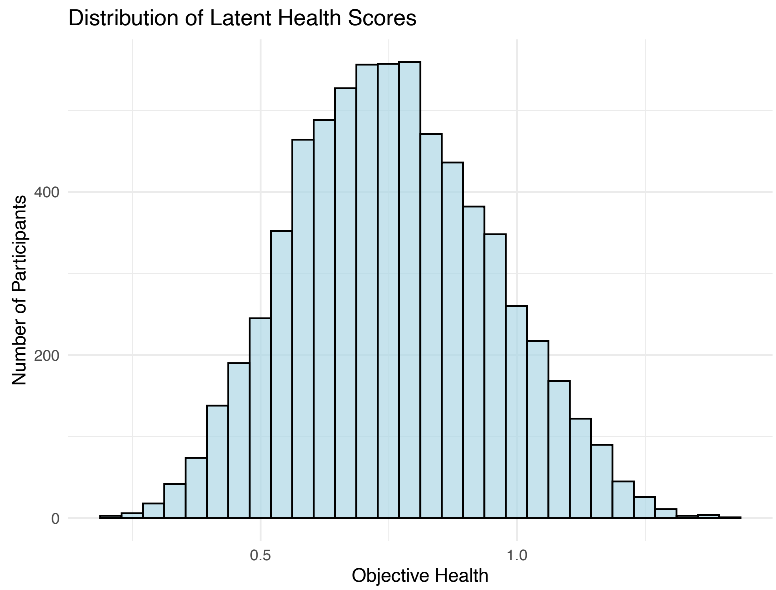
Correlations between subjective and objective health scores across ELSA waves 1 to 3

	SH (ELSA Wave 1)	SH (ELSA Wave 2)	SH (ELSA Wave 3)
OH (ELSA Wave 1)	0.61***	0.55***	0.53***
OH (ELSA Wave 2)	0.58***	0.52***	0.54***
OH (ELSA Wave 3)	0.55***	0.55***	0.45***
Autocorrelations within objective health scores across ELSA waves 1 to 3			
	OH (ELSA Wave 2)		
OH (ELSA Wave 1)	0.82***		
OH (ELSA Wave 3)	0.76***		
Autocorrelations within subjective health scores across ELSA waves 1 to 3			
	SH (ELSA Wave 2)		
SH (ELSA Wave 1)	0.64***		
SH (ELSA Wave 3)	0.54***		
Correlations between changes in subjective and objective health scores			
	$\Delta SH(Wave2to3)$		$\Delta OH(Wave2to3)$
$\Delta SH(Wave1to2)$	-0.47***	$\Delta OH(Wave1to2)$	0.13***

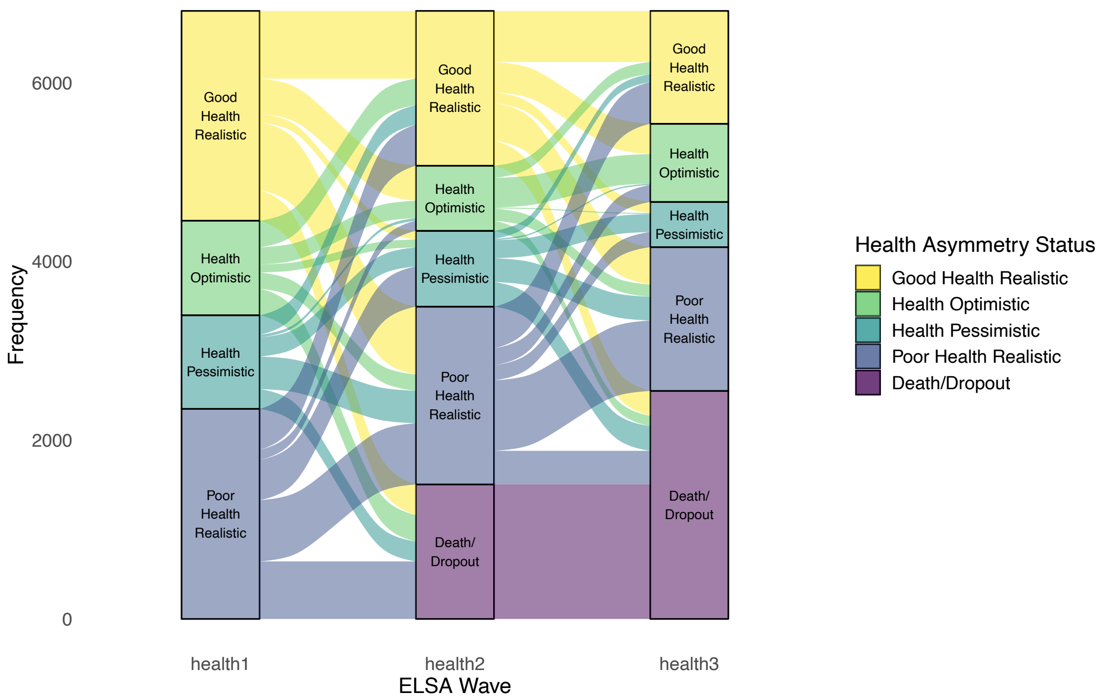
Appendix 3.6

A sensitivity analysis was conducted where health asymmetry categories were derived using latent OH scores, obtained from more objectively measured indicators than the OH measure (frailty index) included in the main text. We entered 5 health indicators into a confirmatory factor analysis model, extracting a latent health score for each participant. We included: 1) smoking status, 2) executive functioning, 3) memory function, 4) CES-D scores (as a measure of depressive symptoms) and 5) confirmed diagnoses of chronic health conditions. Our latent OH scores at each wave ranged from 0 (poor health) to 1.5 (good health). A histogram below visualises the distribution of baseline OH scores using this latent OH approach. A river diagram below also illustrates how participants transitioned from one health asymmetry category to another, when derived with a latent OH score. Finally, we tabulated the estimated transition probabilities from a first-order Markov model.

Distribution of latent objective health scores among ELSA participants at wave one.



A river diagram showing the observed frequencies of transitioning to and from health asymmetry categories at ELSA waves one, two and three (in the sensitivity analysis). Health asymmetry categories were derived here using SH scores and latent OH scores obtained through latent modelling of 5 health indicators.

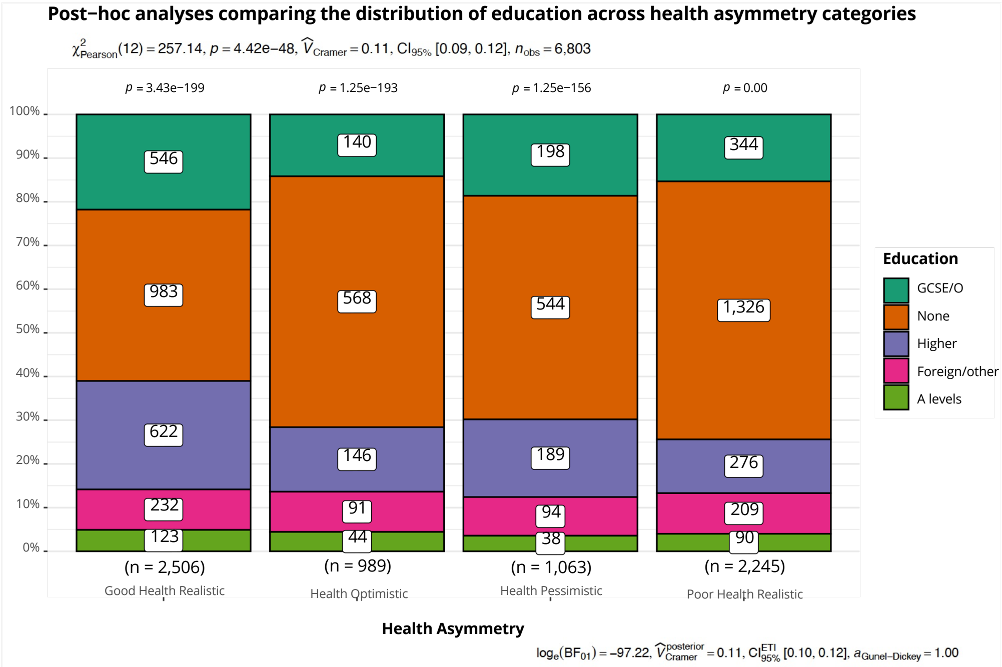


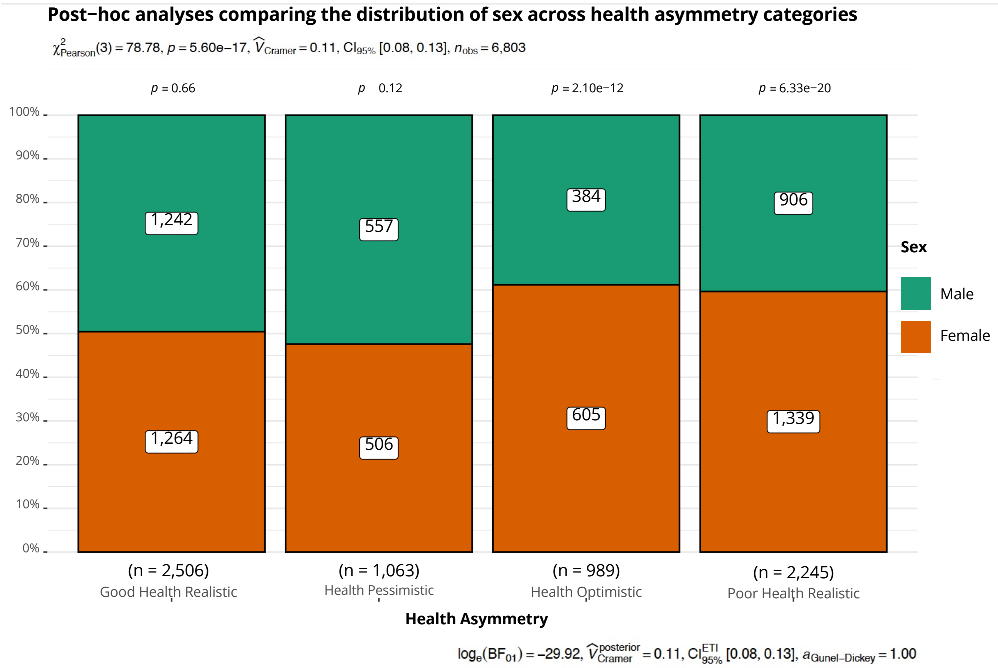
Frequencies (and transition probabilities) of health asymmetry transitions from ELSA waves 1 to 3, where health asymmetry categories were derived using a latent OH score, obtained from confirmatory factor analyses (Sensitivity analysis).

	Health	**Asymmetry**	**Wave 2**		
Health Asymmetry (Wave 1)	Good Health Realist	Health Pessimist	Health Optimist	Poor Health Realist	Death/Dropout
Good Health Realist	758 (0.32)	96 (0.04)	392 (0.17)	759 (0.32)	342 (0.15)
Health Pessimist	218 (0.21)	213 (0.20)	31 (0.03)	364 (0.35)	222 (0.21)
Health Optimist	298 (0.28)	89 (0.08)	193 (0.18)	181 (0.17)	297 (0.28)
Poor Health Realist	458 (0.19)	450 (0.20)	113 (0.05)	685 (0.29)	644 (0.27)
	Health	**Asymmetry**	**Wave 3**		
Health Asymmetry (Wave 2)	Good Health Realist	Health Pessimist	Health Optimist	Poor Health Realist	Death/Dropout
Good Health Realist	572 (0.33)	122 (0.07)	339 (0.19)	419 (0.12)	280 (0.16)
Health Pessimist	89 (0.10)	202 (0.24)	15 (0.02)	266 (0.31)	276 (0.33)
Health Optimist	136 (0.19)	12 (0.02)	331 (0.45)	136 (0.18)	114 (0.16)
Poor Health Realist	466 (0.23)	169 (0.08)	190 (0.10)	788 (0.40)	376 (0.19)
Death/Dropout	0 (0)	0 (0)	0 (0)	0 (0)	1505 (1)

Appendix 3.7

Post-hoc analyses comparing the proportion of health asymmetry categories across different levels of sex and education





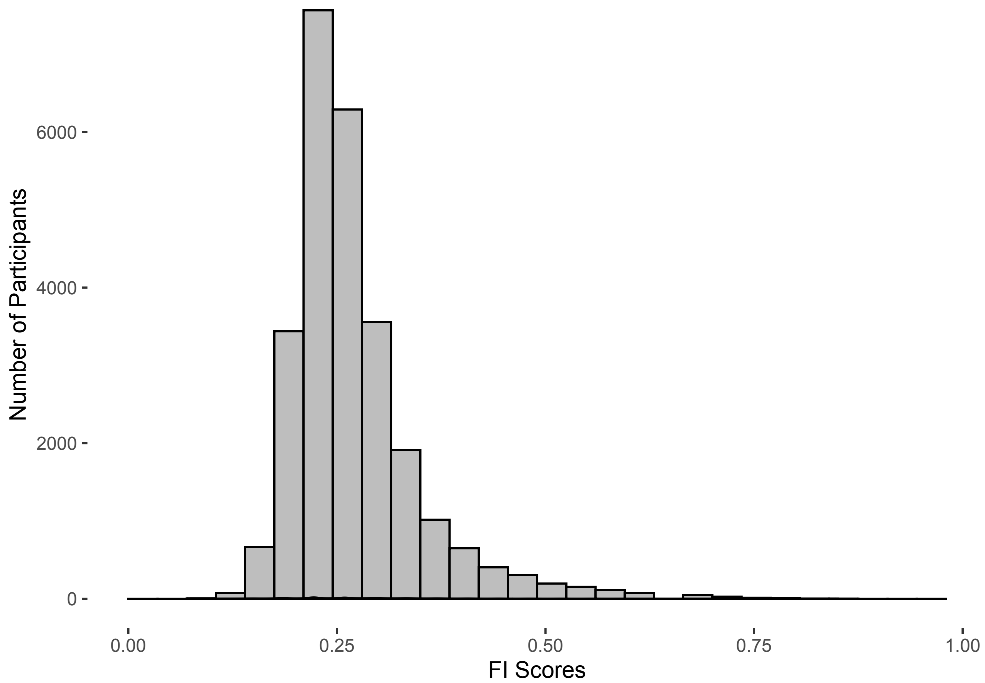
Appendix 4.1

Health deficits included in the frailty index (FI) from the Survey of Healthy Ageing and Retirement (SHARE), which formed our objective health measure.

SHARE code	**Health Deficit**
Functional limitations and mobility	
ph049d3	Difficulty bathing or showering
ph049d1	Difficulty dressing, including shoes and socks
ph048d3	Difficulty getting up from chair
ph049d2	Difficulty walking across a room
ph049d4	Difficulty eating, cutting up food
ph048d7	Difficulty reaching or extending arms
ph049d6	Difficulty using the toilet
ph048d5	Difficulty climbing flight of stairs
ph048d9	Difficulty lifting or carrying weights over 5 kilos
ph048d1	Difficulty walking 100 metres
ph049d5	Difficulty getting in or out of bed
Health conditions diagnosed by health professional	
ph006d10	Cancer
ph006d2	High blood pressure or hypertension
ph006d1	Heart attack
ph006d5	Diabetes or high blood sugar
ph006d8	Arthritis
ph006d6	Chronic lung disease
Physical health	
hc029	Stayed in a nursing home overnight during the last twelve months
hc012	Stayed overnight in hospital during the last twelve months
ph010d7	Prone to falling down
ph084	Troubled with pain
bmi	Body mass index (Kg/m2) deficit
maxgrip	Grip strength (Kg) deficit
ph004	Long-term illness
hearing	Hearing quality
Cognitive function and mental health	
Orienti	Impaired orientation to date, month, year and day of week
mh011	Loss of appetite

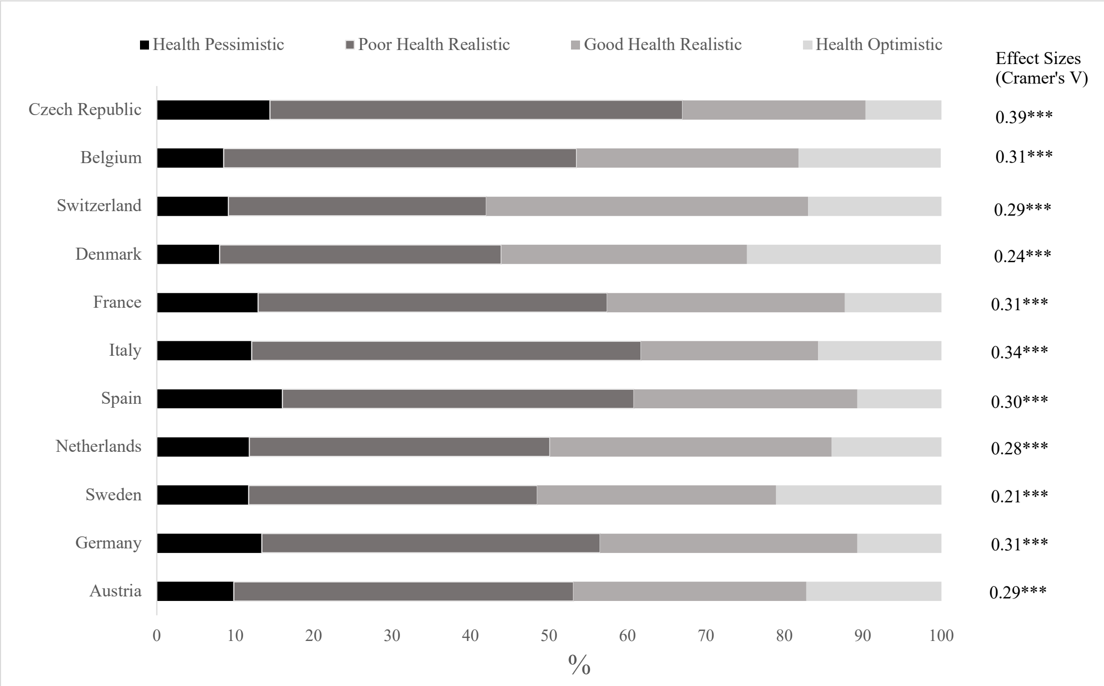
Appendix 4.2

A histogram illustrating the distribution of frailty scores (measured using the FI) across the SHARE Wave 2 participants included in our sample.



Appendix 4.3

Proportions of group membership (with Cramer's V effect size) within health symmetry at baseline, across the 11 countries included in the analyses.



Appendix 4.4

Full hierarchical growth curve models with EURO-D depressive symptomatology as an outcome and health asymmetry categories as the main exposure.

Model 1: Time as fixed effect		
	Estimate	**95% CI**
Fixed Effects		
Intercept	2.12***	(1.89, 2.35)
Time	0.08***	(0.06, 0.10)
Variance Components	σ^2	
Participant		
Random Intercept (σ^2_{p0})	1.46	
Random Slope (σ^2_{p1})	.20	
Country		
Random Intercept (σ^2_{c0})	0.39	
Random Slope (σ^2_{c1})	.03	
Residuals	1.52	
Marginal R^2 : 0.4%; *Conditional* R^2 : 53.6%		
Model 2: Time, Health Asymmetry and Interactions		
(Intercept)	1.47***	(1.25, 1.68)
Time	0.11***	(0.08, 0.13)
Health Asymmetry and Interactions	0.67***	(0.59, 0.76)
Health Optimistic		
Poor Health Realistic	0.86***	(0.79, 0.92)
Health Pessimistic	1.57***	(1.48, 1.67)
Time*Health Optimistic	-0.05***	(-0.07, -0.02)
Time*Poor Health Realistic	-0.02	(-0.03, 0.003)
Time*Health Pessimistic	-0.01***	(-0.12, -0.06)
Variance Components	σ^2	
Participant		
Random Intercept (σ^2_{p0})	1.94	
Random Slope (σ^2_{p1})	.04	
Country		
Random Intercept (σ^2_{c0})	0.13	
Random Slope (σ^2_{c1})	.0001	
Residuals	2.23	
Marginal R^2 : 4.1%; *Conditional* R^2 : 53.8%		

Model 3: Time, Health Asymmetry and Interactions and Covariates		
Intercept	1.77***	(1.41, 2.12)
Time	0.11***	(0.08, 0.13)
Age	0.004***	(0.002, 0.006)
Sex (Male)	-0.74***	(-0.77, -0.70)
Education: Primary	-0.38***	(-0.49, -0.27)
Education: Secondary	-0.50***	(-0.62, -0.39)
Education: Tertiary	-0.49***	(-0.61, -0.37)
Income: €12,000 - €22,000	-0.16***	(-0.22, -0.10)
Income: €22,000 - €37,000	-0.13***	(-0.19, -0.07)
Income: > €37,000	-0.2***	(-0.27, -0.13)
Subjective Health (SH)	0.02	(-0.05, 0.1)
Objective Health (OH)	-4.1**	(-5.3, -2.90)
SH*OH	2.09***	(1.82, 2.36)
Health Asymmetry and Interactions		
Health Optimistic	0.47***	(0.36, 0.57)
Poor Health Realistic	0.14**	(0.07, 0.21)
Health Pessimistic	0.72***	(0.61, 0.83)
Time*Health Optimistic	-0.01	(-0.03, 0.01)
Time*Poor Health Realistic	-0.01	(-0.02, 0.01)
Time*Health Pessimistic	-0.1***	(-0.12, -0.06)
Variance Components	σ^2	
Participant		
Random Intercept (σ^2_{p0})	1.24	
Random Slope (σ^2_{p1})	.04	
Country		
Random Intercept (σ^2_{c0})	0.05	
Random Slope (σ^2_{c1})	.001	
Residuals	2.29	

*Marginal R^2: 17.6%; Conditional R^2: 53.4%; *significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$; Sex: Female (Ref); Education: None (Ref); Income: <€12,000 (Ref); Health Asymmetry: Good Health Realistic (Ref).*

Appendix 5.1

Cox proportional hazards and Laplace regression models for risk of injurious falls across a 10-year follow-up period. Estimates for all covariates included in the models.

	Hazard Ratio	95% CI	Median Years to Injurious Fall†	95% CI
Model 1				
Age	1.08***	(1.08, 1.09)	-0.39***	(-0.45, -0.33)
Sex: Female	1.14*	(1.03, 1.27)	-0.76	(-1.63, 0.10)
Education: High School	1.16**	(1.04, 1.29)	-0.62	(-1.38, 0.13)
Education: University	1.06	(0.93, 1.21)	-0.97	(-2.26, 0.32)
Living Alone: Yes	1.46***	(1.32, 1.62)	-1.63***	(-2.42, -0.85)
History of Falling	1.62***	(1.42, 1.86)	-3.45***	(-4.45, -2.45)
MMSE	1.01	(0.97, 1.04)	-0.08	(-0.31, 0.16)
Self-rated Health: Poor Health	1.18**	(1.06, 1.31)	-0.32	(-1.18, 0.54)
Model 2				
Age	1.07***	(1.07, 1.08)	-0.34***	(-0.39, -0.28)
Sex: Female	1.14*	(1.02, 1.26)	-0.84*	(-1.58, -0.09)
Education: High School	1.17**	(1.05, 1.30)	-0.62	(-1.36, 0.11)
Education: University	1.11	(0.97, 1.26)	-1.30*	(-2.32, -0.28)
Living Alone: Yes	1.44***	(1.30, 1.59)	-1.60***	(-2.35, -0.85)
History of Falling	1.57***	(1.37, 1.80)	-3.32***	(-4.13, -2.51)
MMSE	1.03	(1.00, 1.07)	-0.12	(-0.35, 0.11)
HAT: Poor Health	1.75***	(1.56, 1.96)	-2.27***	(-3.59, -0.95)
Model 3				
Age	1.08***	(1.07, 1.09)	-0.25***	(-0.36, -0.19)
Sex: Female	0.99	(0.84, 1.18)	-0.17	(-1.18, 0.84)
Education: High School	1.16	(0.98, 1.38)	-0.37	(-1.42, 0.69)
Education: University	1.08	(0.89, 1.33)	-0.69	(-2.28, 0.89)
Living Alone: Yes	1.48***	(1.26, 1.74)	-1.15*	(-2.28, -0.02)
History of Falling	1.25	(0.98, 1.59)	-2.41*	(-4.26, -0.56)
MMSE	1.02	(0.97, 1.08)	-0.12	(-0.60, 0.35)

	Hazard Ratio	95% CI	Median Years to Injurious Fall†	95% CI
Good Health Realist (Reference)				
Health Optimist	2.16***	(1.66, 2.80)	-2.80***	(-4.39, -1.21)
Health Pessimist	1.66**	(1.21, 2.29)	-0.74	(-3.44, 1.96)
Poor Health Realist	1.77***	(1.50, 2.11)	-1.14*	(-2.27, -0.01)
Interaction Model				
Age	1.09***	(1.07, 1.10)	-0.29***	(-0.40, -0.19)
Sex: Female	1.06	(0.86, 1.21)	0.04	(-0.91, 1.00)
Education: High School	1.18	(0.97, 1.37)	-0.56	(-1.77, 0.64)
Education: University	1.12	(0.89, 1.33)	-0.98	(-2.91, 0.95)
Living Alone: Yes	1.47*	(1.26, 1.75)	-1.25*	(-2.30, -0.21)
History of Falling	1.21*	(1.06, 1.72)	-2.79*	(-5.09, -0.47)
MMSE	1.05	(0.95, 1.06)	-0.11	(-0.65, 0.43)
HAT	0.99	(0.89, 1.14)	-0.16	(-0.14, 0.82)
SRH	0.85	(0.62, 1.18)	-0.22	(-2.25, 1.82)
HAT*SRH	1.00	(0.95, 1.04)	0.08	(-0.28, 0.44)
Sensitivity Model: 1 SD cutoff for Health Asymmetry				
Age	1.08***	(1.07, 1.09)	-0.30***	(-0.38, -0.21)
Sex: Female	1.01	(0.85, 1.20)	-0.14	(-1.18, 0.89)
Education: High School	1.17	(0.98, 1.38)	-0.30	(-1.26, 0.85)
Education: University	1.10	(0.89, 1.35)	-0.62	(-2.27, 1.03)
Living Alone: Yes	1.49***	(1.26, 1.75)	-1.26*	(-2.42, -0.09)
History of Falling	1.27*	(1.00, 1.62)	-2.36*	(-4.40, 0.33)
MMSE	1.01	(0.96, 1.08)	-0.19	(-0.66, 0.28)
Good Health Realist (Reference)				
Health Optimist	1.67***	(1.33, 2.09)	-1.83***	(-3.21, -0.46)
Health Pessimist	1.20	(0.94, 1.52)	-0.21	(-1.48, 1.06)
Poor Health Realist	1.61***	(1.34, 1.93)	-0.82*	(-1.85, 0.22)

*Note: *significant at p < 0.05, **significant at p <0.01, ***significant at p < 0.001. Self-rated Health was dichotomised into 'good' (good, very good and excellent) and 'poor' health (poor and fair). HAT was dichotomised into 'good' (median or higher) and 'poor' (lower than median) health. Education (Ref = Elementary); Sex (Ref = Male); Living Alone (Ref = Yes); History of Falls: No (Ref); Self-rated Health: Poor (Ref); HAT: Poor (Ref). Health Asymmetry category for Model 3: Health Pessimist (n=149), Poor Health Realist (n=903), Good Health Realist (n=1032), Health Optimist (n=138). Health Asymmetry category for Sensitivity Model: Health Pessimist (n=364), Poor Health Realist (n=687), Good Health Realist (n=810), Health Optimist (n=361). † Difference in Median Number of Years to Injurious Fall*

Appendix 5.2a

Cox proportional hazards and Laplace regression model for risk of injurious falls across a 10-year follow-up period stratified by age group. The younger cohort consists of older adults aged 60 – 72 years old, while the older cohort consists of adults aged 78+.

	Hazard Ratio	**95% CI**	**Median Years to Injurious Fall†**	**95% CI**
Younger Cohort (n=1,393				
Age	1.07***	(1.04, 1.10)	-0.01	(-0.53, 0.51)
Sex: Female	1.28	(0.97, 1.70)	-0.22	(-5.02, 4.59)
Education: High School	0.96	(0.67, 1.37)	-0.04	(-3.33, 3.26)
Education: University	1.1	(0.77, 1.61)	0.51	(-6.96, 7.99)
Living Alone: No	1.63***	(1.26, 2.13)	-2.03	(-12.43, 8.38)
History of Falls	2.80***	(1.71, 4.60)	-0.42	(-7.93, 7.08)
MMSE	0.93	(0.82, 1.04)	0.25	(-1.88, 2.38)
Good Health Realist (Reference)				
Health Optimist	3.39***	(1.85, 6.24)	-0.49	(-18.52, 17.55)
Health Pessimist	2.43***	(1.63, 3.64)	-0.28	(-3.90, 3.34)
Poor Health Realist	1.89***	(1.42, 2.53)	-0.01	(-1.54, 1.53)
Older Cohort (n=829)				
Age	1.05***	(1.04, 1.08)	-0.26**	(-0.44, -0.08)
Sex: Female	0.89	(0.72, 1.11)	0.26	(-1.35, 1.87)
Education: High School	1.25*	(1.03, 1.52)	-0.50	(-2.08, 1.08)
Education: University	1.04	(0.81, 1.35)	-0.59	(-5.74, 4.56)
Living Alone: No	1.45***	(1.18, 1.79)	-1.41	(-3.79, 0.98)
History of Falls	1.11	(0.85, 1.45)	-2.24	(-4.82, 0.33)
MMSE	1.03	(0.97, 1.10)	-0.33	(-2.33, 1.67)
Good Health Realist (Reference)				
Health Optimist	2.03***	(1.51, 2.72)	-2.75	(-6.83, 1.33)
Health Pessimist	0.97	(0.56, 1.68)	1.00	(-4.31, 6.31)
Poor Health Realist	1.63***	(1.32, 2.01)	-1.24	(-4.86, 2.37)

*Note: *significant at p < 0.05, **significant at p <0.01, ***significant at p < 0.001. Sex: Male (Ref); Education: Elementary School (Ref); Living Alone: Yes (Ref); History of Falls: No (Ref). Baseline Health Asymmetry sample size for Younger Cohort: Health Pessimist (n=126), Poor Health Realist (n=355), Good Health Realist (n=885), Health Optimist (n=27). Baseline Health Asymmetry sample size for Older Cohort: Health Pessimist (n=23), Poor Health Realist (n=548), Good Health Realist (n=147), Health Optimist (n=1,11). † Difference in Median Number of Years to Injurious Fall*

Appendix 5.2b

Cox proportional hazards and Laplace regression model for risk of injurious falls across a 10-year follow-up period stratified by sex.

	Hazard Ratio	95% CI	Median Years to Injurious Fall†	95% CI
Male (n=850)				
Age	1.09***	(1.08, 1.12)	-0.23***	(-0.34, -0.12)
Education: High School	1.19	(0.82, 1.73)	-1.58	(-3.45, 0.29)
Education: University	1.05	(0.72, 1.55)	-0.89	(-2.76, 0.98)
Living Alone: No	1.42*	(1.08, 1.88)	-1.38*	(-2.75, -0.01)
History of Falls	2.26***	(1.44, 3.53)	-3.39**	(-5.52, -1.27)
MMSE	1.02	(0.90, 1.15)	0.05	(-0.47, 0.57)
Good Health Realist (Reference)				
Health Optimist	2.66***	(1.67, 4.22)	-2.90*	(-5.50, -0.31)
Health Pessimist	1.95*	(1.14, 3.33)	-2.07	(-5.88, 1.74)
Poor Health Realist	1.62**	(1.18, 2.22)	-1.29*	(-2.40, -0.19)
Female (n=1,372)				
Age	1.07***	(1.06, 1.08)	-0.24***	(-0.37, -0.11)
Education: High School	1.15	(0.94, 1.40)	-0.23	(-1.55, 1.08)
Education: University	1.11	(0.87, 1.42)	-0.59	(-3.08, 1.89)
Living Alone: No	1.55***	(1.27, 1.90)	-1.20	(-2.48, 0.08)
History of Falls	1.10	(0.83, 1.45)	-2.00	(-4.50, 0.50)
MMSE	1.01	(0.96, 1.08)	-0.15	(-0.73, 0.43)
Good Health Realist (Reference)				
Health Optimist	2.05***	(1.50, 2.81)	-2.73*	(-4.89, -0.56)
Health Pessimist	1.54	(1.03, 2.29)	-0.59	(-113.22, 112.04)
Poor Health Realist	1.81***	(1.47, 2.22)	-1.16	(-3.10, 0.77)

*Note: *significant at $p < 0.05$, **significant at $p < 0.01$, ***significant at $p < 0.001$. Sex: Male (Ref); Education: Elementary School (Ref); Living Alone: Yes (Ref); History of Falls: No (Ref). Baseline Health Asymmetry category size for Males: Health Pessimist (n=64), Poor Health Realist (n=315), Good Health Realist (n=429), Health Optimist (n=42). Baseline Health Asymmetry category size for Females: Health Pessimist (n=85), Poor Health Realist (n=588), Good Health Realist (n=604), Health Optimist (n=96).*

Appendix 5.3

Cox proportional hazards and Laplace regression models for risk of injurious falls across a 10-year follow-up period excluding those with a previous history of fallig within 3 years prior to SNAC-K baseline (n=2,072).

	Hazard Ratio	**95% CI**	**Median Years to Injurious Fall**†	**95% CI**
Age	1.09***	(1.08, 1.10)	-0.28***	(-0.37. -0.19)
Sex: Female	1.06	(0.89, 1.28)	-0.18	(-1.38, 1.01)
Education: High School	1.28**	(1.06, 1.54)	-0.40	(-1.37, 0.56)
Education: University	1.26	(1.02, 1.57)	-0.79	(-2.43, 0.85)
Living Alone: Yes	1.51***	(1.28, 1.79)	-1.18	(-2.36, 0.004)
MMSE	1.07*	(1.01, 1.13)	-0.21	(-0.72, 0.30)
Good Health Realist (Reference)				
Health Optimist	2.25***	(1.71, 2.95)	-2.66***	(-4.21. -1.10)
Health Pessimist	1.60**	(1.15, 2.22)	-0.69	(-6.07, 4.68)
Poor Health Realist	1.78***	(1.49, 2.13)	-1.30*	(-2.32, -0.28)

*Note: *significant at p<0.05, **significant at p <0.01, ***significant at p<0.001. Education (Ref = Elementary); Sex (Ref = Male); Living Alone (Ref = Yes). Baseline Health Asymmetry category size: Health Pessimist (n=126), Poor Health Realist (n=355), Good Health Realist (n=885), Health Optimist (n=27). † Difference in Median Number of Years to Injurious Fall*