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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. We explore 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, we followed a sample of 6803 older adults, aged 60+ years at baseline, 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, 36.84% of the sample were 'good health realists', 33% were 'poor health realists', 14.54% were 'health optimists', and 15.62% 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. Subsequently, the proportion of health optimists in the sample 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) becomes more prevalent over time, in later life. Future research should investigate if promoting positive SH appraisals among health pessimists and poor health realists can optimise health and survival outcomes.

1. Introduction

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 (Idler and Benyamini, 1997; DeSalvo et al., 2006; 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; Singh-Manoux et al., 2005; Layes et al., 2012; 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) and the likelihood of developing acute or chronic conditions increases (Burge et al., 2007; Calderón-Larrañaga et al., 2018; Vetrano et al., 2018; Speh et al., 2024). 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 (Idler, 1993; Chen et al., 2007), but not with the same rate of change as would be expected from age-related OH decline (Kunzmann et al., 2000; Henchoz et al., 2008; Graf and Hicks Patrick, 2016). Among the

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oldest-old (i.e. 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; Wettstein et al., 2016; Hansen and Blekesaune, 2022), 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 and Sprangers, 1999). 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 (Ruthig et al., 2011a; Galenkamp et al., 2012). 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, 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 (Ruthig and Chipperfield, 2007; Rai et al., 2019) 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 (i.e., health optimists) tend to live longer, have fewer depressive symptoms, experience slower functional decline and use healthcare services less than others (Chipperfield, 1993; Ruthig and Chipperfield, 2007; Viljanen et al., 2021; Calvey et al., 2023). In contrast, those whose SH scores are worse than their OH would indicate (i.e., health pessimists) experience higher levels of depressive symptoms, have longer and more frequent hospital visits and are more likely to die (during a 12-year follow-up) (Chipperfield, 1993; Ruthig and Chipperfield, 2007; Calvey et al., 2023). 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 and 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, 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. (2011a) 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.

It is important to explore whether discrepancies between SH and OH change considerably throughout later life. 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, we hypothesise 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.

2. Methods

2.1. Study design and population

We used archived secondary data 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 March 1, 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). We utilised earlier ELSA waves, since they have a comprehensive amount of measures appropriate for computing an OH index (Marshall et al., 2015), and since there is safeguarding of age-related data (in those aged 90+) in latter waves. 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, we excluded participants who were younger than 60 years old (n = 4853). We also excluded participants who completed a partial or proxy interview during waves one, two and/or three (n = 237), to remove the possibility of proxy respondents providing an SH appraisal for another individual. Finally, we excluded those from analyses who dropped out at wave two but returned at wave three (n = 206), to ensure a parsimonious interpretation of transition probabilities in our models. Ultimately, we arrived at a final sample size of n = 6803 individuals (see Supplementary Materials 1). A total of n = 5298 participants were present in our analyses at wave two and n = 4458 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* = 0.35), had lower levels educational attainment ($p < .001$, *Cramer's V* = 0.06), higher depressive symptoms ($p < .001$, *Cohen's d* = 0.13), poorer OH ($p < .001$, *Cohen's d* = 0.33) and poorer SH ($p < .001$, *Cohen's d* = 0.48), 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 Supplementary Materials 2).

2.2. Measures

2.2.1. 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 (Cullati et al., 2018).

2.2.2. Objective health

A frailty index (FI) was used as a proxy for OH in this study. 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 (Wuorela et al., 2020; Calvey et al., 2022, 2023; Hosseini et al., 2022).

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.

We compiled a unique FI 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 Supplementary Materials 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.

2.2.3. Health Asymmetry

Our main outcome of interest was health asymmetry status. Similar to previous asymmetry metrics (Bondi et al., 2008; McHugh et al., 2017), health asymmetry derives a categorical variable from continuous data. Health asymmetry categorises older adults into one of four groups ('health optimistic', 'health pessimistic', 'good health realistic' or 'poor health realistic') based on the level of agreement between an older adult's SH and OH score. This 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 and Laiacona, 2017). SH scores were subtracted from OH scores, deriving a discrepancy score for each participant. One standard deviation of this discrepancy score was used as the cut-off point for categorisation within health asymmetry. We visualised the distribution of our baseline SH and OH scores (see Supplementary Materials 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. This ensured that health asymmetry categories were assigned at waves two and three were relative to their baseline status (Calvey et al., 2024).

2.2.4. Confounders

We controlled our analyses for a set of confounders based on their established associations with SH and OH. We controlled for age, sex, educational attainment and depressive symptoms (Hong et al., 2004; Ruthig and Chipperfield, 2007; Calvey et al., 2023, 2024). Educational attainment was categorised into 5 groups, similar to previous investigations (Tsimpida et al., 2019, 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 (Steptoe et al., 2013; Karim et al., 2015). The CES-D showed good internal consistency at baseline ($\alpha = .78$).

2.3. Data analysis

All analyses were implemented in R (R Core Team, 2024). There were very few missing data points across our data. 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. We used the 'naniar' package 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). We identified patterns in the missing data that were explained by our covariates and other missing variables, thus satisfying the assumption of the data being 'missing at random'. Therefore, we imputed this missingness using the R package 'Multiple Imputation by Chained Equations' (Van Buuren and 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, we utilised a first-order Markov model (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 t_1 depends only on the current health asymmetry category at the previous time t_0. This is known as the Markovian property, which defines a first-order Markov chain (see Fig. 1).

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 t_1 to time t, depends only on the previous state. Mathematically, this can be written as:

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

with a, b $\in$ 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, we utilised an extension of a generalised logit model 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:

$$\eta(t) = \log\left(\frac{\pi_{ab}(t)}{\pi_{a1}(t)}\right) = \lambda_{b(t)} + \boldsymbol{\beta}_{b(t)}\boldsymbol{x} + \boldsymbol{\alpha}_{b(t)}\boldsymbol{y}_{(t-1)}, a, b \in S$$

where $\lambda_{b(t)}$ represents the intercept, $\boldsymbol{\beta}_{b(t)}$ is the vector of parameters for the effects of our confounders, here represented by the vector $\mathbf{x}$, $\boldsymbol{\alpha}_{b(t)}$ is the vector referring to the stochastic parameters that measure the effect of the previous health asymmetry category, $\mathbf{y}_{(t-1)}$, on the current health asymmetry category. Since health asymmetry is a nominal outcome, all parameters depend on b = 2, 3, 4, 5. We set 'good health realists' (category 1) and females as our reference categories for the estimation

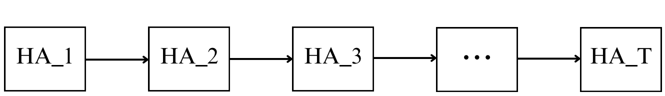

Fig. 1. A visual representation of a first-order Markov chain, where HA represents categorical health asymmetry status, and T represents timepoint.

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 were 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:

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

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

We conducted Chi-square tests and ANOVAs to compare the distribution of our baseline covariates across the four health asymmetry categories. We conducted Pearson's correlation tests to investigate how SH and OH scores were correlated across each ELSA wave, how their changes are correlated with one another, as well as how stable both measures were in terms of autocorrelations over time (see Supplementary Materials 5). Finally, we conducted a sensitivity analysis 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, we inputted five health indicators (most of which were objectively measured) into a latent factor analysis model to yield a latent OH score for each individual. Using the 'lavaan' package in R (Rosseel, 2012), we generated latent OH scores based on: 1) smoking status, 2) memory function, 3) executive functioning, 4) CES-D scores and 5) confirmed diagnoses of chronic illnesses. We recategorised participants into health asymmetry groups and yielded transitions probabilities, to compare with our main results.

3. Results

In a sample of 6803 older 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 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 ($p < .001$, $\eta^2 = 0.06$), sex ($p < .001$, *Cramer's V* = 0.11), education ($p < .001$, *Cramer's V* = 0.11), depressive symptoms ($p < .001$, $\eta^2 = 0.11$), SH ($p < .001$, $\eta^2 = 0.44$) and OH scores ($p < .001$, $\eta^2 = 0.56$). 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 1). We also visualised the distribution of sex and education levels across health asymmetry categories, incorporating post hoc analyses to identify significant group differences (see Supplementary Materials 6). 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 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.

Table 1
Baseline descriptives (mean and standard deviation or percentage and frequency) for the study sample and stratified by health asymmetry category.

	Full Sample (n = 6803)	Good Health Realist (n = 2506, 36.84%)	Health Pessimist (n = 1063, 15.62%)	Health Optimist (n = 989, 14.54%)	Poor Health Realist (n = 2245, 33%)	p[d]	Effect Sizes (Cramer's V/η^2)
Age (years)	70.85 ± 7.44	69.02 ± 6.72[1]	69.52 ± 6.98[1]	73.1 ± 7.94[2]	72.55 ± 7.52[2]	p < .001	0.06
Sex							
Male	45.4% (n = 3089)	49.56% (n = 1242)	52.40% (n = 557)	38.82% (n = 384)	40.36% (n = 906)		
Female	54.6% (n = 3714)	50.44% (n = 1264)	47.60% (n = 506)	61.13% (n = 605)	59.64% (n = 1339)	p < .001	0.11
Education							
No Qualification	50.29% (n = 3421)	39.23% (n = 983)	51.18% (n = 544)	57.43% (n = 568)[3]	59.06% (n = 1326)		
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)	p < .001	0.11
CESD-D[a]	1.62 ± 1.96	0.84 ± 1.35[1]	1.6 ± 1.96[2]	2.04 ± 2.14[3]	2.33 ± 2.12[4]	p < .001	0.11
Objective Health[b]	0.2 ± 0.13	0.1 ± 0.03[1]	0.14 ± 0.07[2]	0.34 ± 0.16[3]	0.29 ± 0.10[4]	p < .001	0.53
Subjective Health[c]	2.89 ± 1.12	2.11 ± 0.67[1]	3.84 ± 0.68[2]	2.38 ± 1.22[3]	3.55 ± 0.87[4]	p < .001	0.44

[1 2 3 4] Post hoc analyses compared the scores for continuous variables across health asymmetry groups. Groups sharing the same superscript number are not significantly different from each other at p < .05. Post-hoc tests for categorical variables are reported and visualised in Supplementary Materials 6.
[a] CES-D scores (Centre for Epidemiological Studies – Depression) range from 0 to 8, with higher scores implying higher levels of depressive symptoms.
[b] Objective Health scores range from 0 to 1, with higher scores implying poorer health.
[c] Self-rated health scores range from 1 (excellent) to 5 (poor), with higher scores indicating poorer self-rated health.
[d] 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 (η^2) effect sizes (where relevant).

Table 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 1)	Health Asymmetry (Wave 2)				
	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 2)	**Health Asymmetry (Wave 3)**				
	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)

These estimated transition probabilities are unconditioned, i.e. they do not take the effects of confounders into account. Fig. 2 visualises these health asymmetry transitions using a river diagram (including an additional outcome of 'Death/Dropout' at waves two and three).

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 < .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 Tables 3 and 4).

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). We stratified our estimated transition probabilities by sex and age (as visualised in Figs. 3 and 4), illustrating the varying transition probabilities across different ages and across males and females. We also visualised estimated transition probabilities across varying levels of depressive symptoms (see Supplementary Materials 7).

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

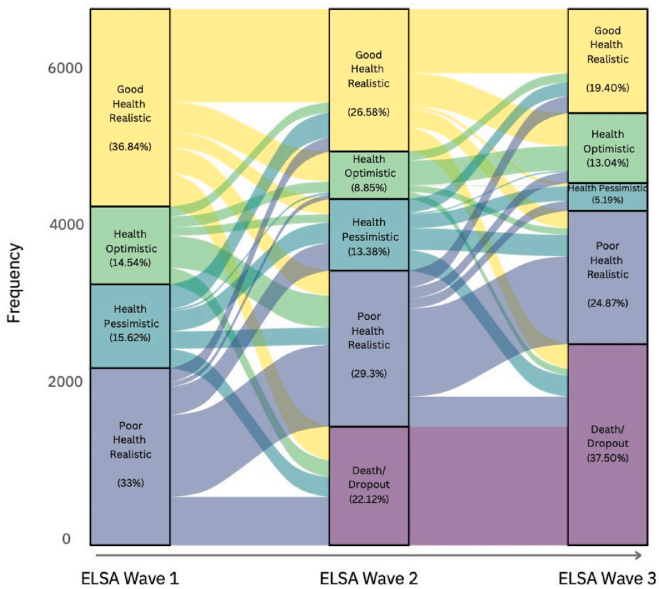

Fig. 2. A river diagram showing the observed frequencies of transitioning to and from health asymmetry categories at ELSA waves one, two and three.

realists being lost to attrition (see Figs. 3 and 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 during wave one were 3.70 times more likely to remain health optimistic at wave two, when compared to those who were good health realists in wave 1 transitioning to health optimistic in wave two (OR = 3.70, $p < .001$). However this decreased considerably 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 Fig. 3). 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 Figs. 3 and 4). 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, we generated a latent OH health score for each participant based on 5 health indicators, instead of generating an FI score (see Supplementary Materials 8). There was considerable agreement between our health asymmetry categories in this sensitivity model with the health asymmetry categories included in our final model. We also yielded relatively similar estimated transition probabilities across our main and sensitivity analyses.

Table 3
Odds ratios (95% Confidence Intervals) of transitioning from the 'good health realist' category to the other categories, calculated using generalised logit models.

Model 1 Health Asymmetry transitions from ELSA wave 1 to 2

Health Asymmetry (Wave 2)	Intercept	Sex: Male	Age	Depressive Symptoms	Education: Foreign/Other	Education: O levels CSE
Health Pessimistic	0.03*** (−0.80, 0.96)	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*** (−0.30, 0.34)	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)	0.26*** (−0.50, 1.02)	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 4
Odds ratios (95% Confidence Intervals) of transitioning from the 'good health realist' category to the other categories, calculated using generalised logit models.

Model 1 Health Asymmetry transitions from ELSA wave 2 to 3

Health Asymmetry (Wave 3)	Intercept	Sex: Male	Age	Depressive Symptoms	Education: Foreign/Other	Education: O levels CSE
Health Pessimistic	0.01*** (−1.33, 1.35)	0.96 (0.60, 1.31)	1.02 (0.62, 1.42)	1.35** (1.12, 1.56)	0.85 (−0.11, 1.81)	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*** (−0.45, 0.50)	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 3)	Education: A levels	Education: Degree/higher	Health Pessimistic	Health Optimistic	Poor Health Realistic	Death/Dropout
Health Pessimistic	1.58 (1.05, 2.11)	0.70(-0.16 1.55)	14.40*** (14.16, 14.65)	1.13 (0.24, 2.02)	8.71*** (8.47, 8.94)	1.19*** (−2.29, 2.52)
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*** (−5.56, 5.64)
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

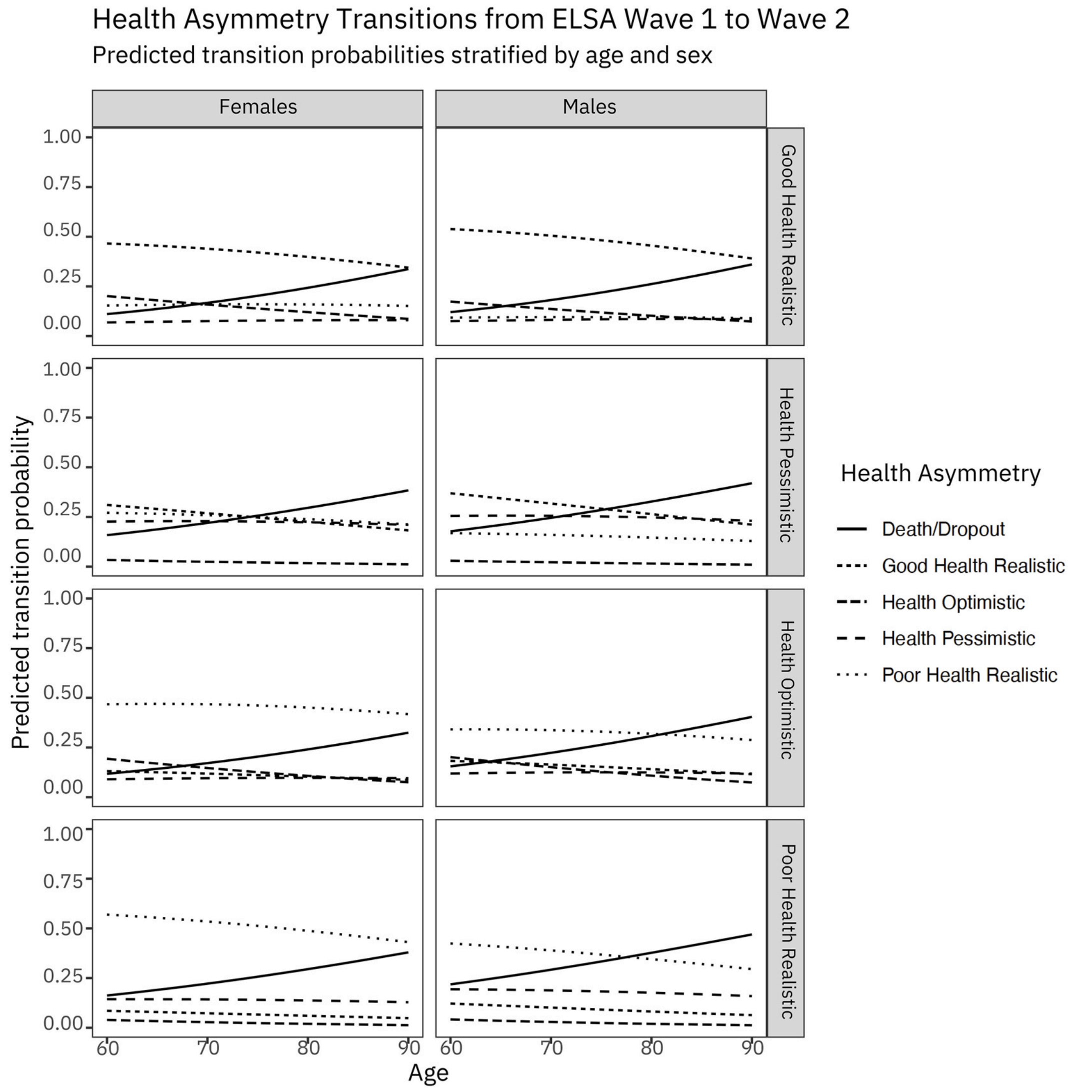

Fig. 3. Predicted transition probabilities for health asymmetry categories from ELSA Wave 1 to 2 (stratified by age and sex).

4. Discussion

We investigated transition trends in health asymmetry status over time in a sample of older adults resident in England. Notably, we found that 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., 2011a).

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 and 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 (Sargent-Cox et al., 2010; Gorini and Pravettoni, 2011).

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 (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 had low probabilities of becoming health optimistic and were more likely to

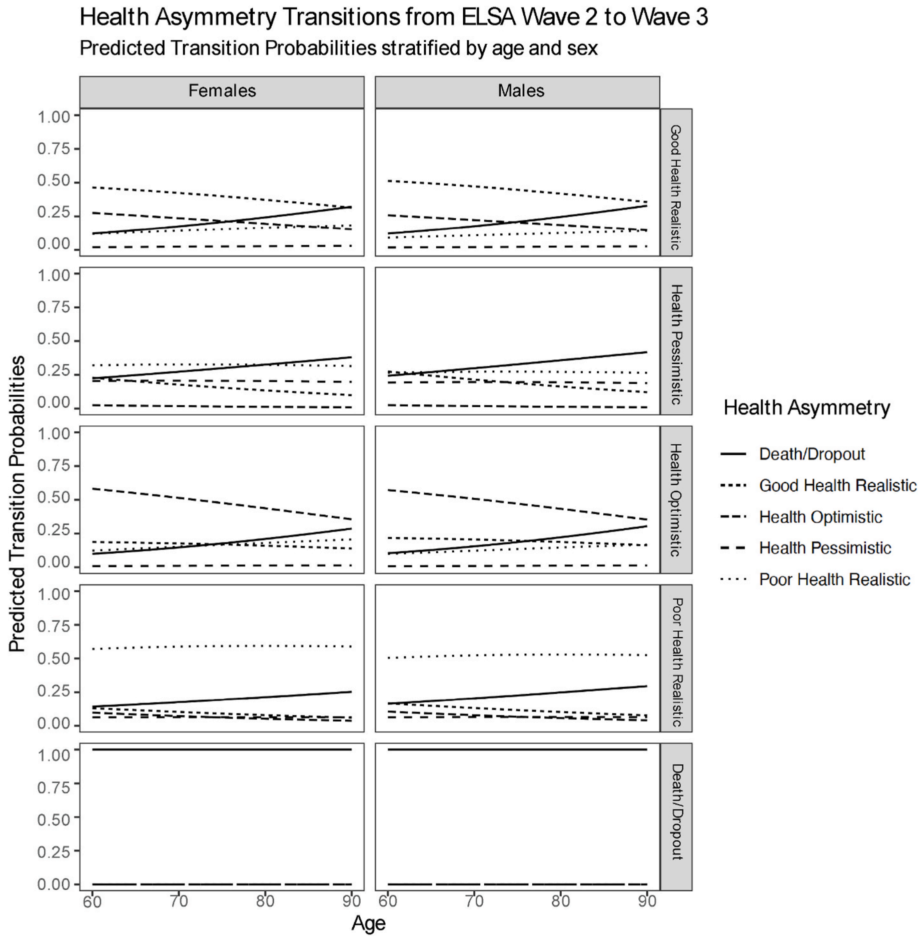

Fig. 4. Predicted transition probabilities for Health Asymmetry categories from ELSA Wave 2 to 3 (stratified by age and sex).

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 responses after comparing themselves to those who are worse off (Cheng et al., 2007; Henchoz et al., 2008; Wu and Zhang, 2023). This is also in despite of evidence that some older adults experience positive shifts in SH, even after serious health events (Wilcox et al., 1996; Spuling et al., 2017). 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., 2011a).

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 and 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 and 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 (Sadowski et al., 2011; Brassington et al., 2016). 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 and 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, functional and mental health benefits and overall adaptive outcomes associated with health optimism (Chipperfield, 1993; Hong et al., 2004; Ruthig et al., 2011b; Calvey et al., 2023). 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 (Morling and Evered, 2006; Ichida et al., 2013) 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 (Chipperfield, 1993; Hong et al., 2004, 2005; Ruthig and Chipperfield, 2007; Calvey et al., 2023). 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). Additionally, it is possible that overly health optimistic individuals might not seek medical treatment or engage with healthcare services less than others (Löckenhoff and Carstensen, 2004). As such, promoting health optimism should be carefully considered.

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 under-estimating the prevalence of such conditions (Mackenbach et al., 1996; Baker et al., 2004). Previous health congruence research also relied on self-reported chronic conditions for measuring OH (e.g. Chipperfield, 1993; Rai et al., 2019). However, we included objective cognitive tests and other aspects of physiological health, 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, we conclude that our 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 in older adults (Montoliu et al., 2020; Kang, 2023), traits such as neuroticism could help explain transitions from one health asymmetry status to another. However, we could not control for personality traits in our analyses as personality traits were not captured during ELSA waves one to three. Furthermore, we utilised a single item of self-rated health in our study, which is known to capture physical, functional, mental and cognitive aspects of health (Krause and 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 discrepancy between SH and OH at each wave.

We noted that 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.

CRediT authorship contribution statement

Bill Calvey: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Joanna McHugh Power:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Conceptualization. **Rebecca Maguire:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Conceptualization. **Rafael de Andrade Moral:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Idemauro Antonio Rodrigues de Lara:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors report no conflict of interest.

Ethical approval/statement

English Longitudinal Study of Ageing (ELSA) Wave 1 received ethical approval from the London Multi-Centre Research Ethics Committee on February 7, 2002 (MREC/01/2/91). ELSA Wave 2 received ethical approval from the London Multi-Centre Research Ethics Committee on August 12, 2004 (MREC/04/2/006). ELSA Wave 3 received ethical approval from the London Multi-Centre Research Ethics Committee on October 27, 2005 (05/MRE02/63). All original study procedures were conducted in accordance with the Declaration of Helsinki. Given the nature of secondary data analysis, no further ethical approval was sought.

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ELSA data are available to researchers after registration with the UK Data Service at https://beta.ukdataservice.ac.uk/datacatalogue/series/series?id=200011.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2024.117441.

Data availability

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