Identifying Predictors of Self-Perceptions of Aging Based on a Range of Cognitive, Physical, and Mental Health Indicators: Twenty-Year Longitudinal Findings from the ILSE Study

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Data availability

This study was conducted using secondary data from the ILSE study (https://www.maelstrom-research.org/study/ilse). ILSE data are available to investigators outside the ILSE team after request and approval.

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Authors' contributions

Serena Sabatini served as principal investigator of the research, designed the study, conducted data analyses, and took the lead in writing the manuscript.

Hans-Werner Wahl contributed to the design of the ILSE study, design of the current study, provided feedback and assistance with editing of the manuscript.

Jelena Sophie Siebert contributed to data collection, created the dataset for the current study and provided feedback on the draft of the manuscript.

The remaining co-authors provided feedback and assistance with editing of the manuscript.

Conflict of interest declaration

None

Preregistration

The current study design, hypotheses, and analytic plan were preregistered and circulated via email when requesting access to the ILSE dataset.

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Abstract

Research exploring whether health predicts self-perceptions of aging has mostly focused on single predictors and has been hampered by short observational intervals. We examined whether 20-year changes in cognitive functioning, physical and mental health predict self-perceptions of aging.

We used data of 103 German participants who remained of a sample of 500 participants born in 1930-32 enrolled in the Interdisciplinary Longitudinal Study of Adult Development (ILSE) in 1993/1996 (mean age at fourth measurement wave= 82.5 years). Health indicators included six cognitive tests, objective and subjective physical health, and self-reported depression. We used a new and multidimensional (awareness of age-related gains and losses) and a well-established (attitudes toward own aging) measure of self-perceptions of aging. Linear regression analyses showed that, among the cognitive tests, decline in information processing speed (Digit Symbol) predicted less awareness of age-related gains and more awareness of age-related losses but not attitudes toward own aging. Decline in subjective but not objective physical health, predicted more awareness of age-related losses and negative attitudes toward own aging, but not awareness of age-related gains. Increase in depressive symptoms predicted more awareness of age-related losses and negative attitudes toward own aging, but not awareness of age-related gains. The size of associations suggests that objective cognitive decline has limited influence on older adults' self-perceptions of aging and, if so, only when the decline is related to mental slowing. Similarly, perceived physical and mental health, but not objective health, have a small-to-moderate influence on awareness of age-related losses and attitudes toward own aging.

Keywords: Awareness of age-related change, AARC-gains, AARC-losses, attitude toward own aging, self-rated health, objective health, objective cognition, depression

Public Significance Statement

The present study suggests that, compared to those older individuals who describe their own aging more positively, those who perceive their own aging more negatively have been experiencing greater mental slowing and increased depressive symptoms. These individuals also perceive a greater decline in their physical health. Asking older people about their experience of getting older may help to identify those who would benefit the most from interventions promoting health and acceptance of aging.

Self-perceptions of aging (SPA) are important for successful aging. A prime example of a concept falling under the overarching term of SPA is the established attitude toward own aging scale (ATOA; Kotter-Grühn & Hess, 2012; Lawton, 1975), which captures affective and cognitive components of attitudes related to a person's own aging process. Compared to individuals with more negative SPA, those with more positive SPA are more engaged in health-related behaviors (Dutt et al., 2016b; Kornadt et al., 2019; Montepare, 2019; Sun & Smith, 2017) and, consequently, benefit from better cognitive functioning (i.e., performance on cognitive tests) and cognitive (i.e., brain health), physical, and mental health (Klusmann et al., 2017; Kornadt et al., 2019; Sabatini et al.; Sabatini et al., 2021d; Seidler & Wolff, 2017; Westerhof et al., 2014).

A better understanding of the factors that contribute to the formation of SPA across longer time intervals may help with identification of new ways of promoting healthy aging and more positive SPA in later life. Indeed, although empirical evidence extensively documented the effects of SPA on health outcomes (Brothers et al., 2019; Brothers et al., 2020), less is known about the extent to which changes in cognitive functioning and in health contribute to the formation of SPA (Diehl et al., 2021). To a large extent, relatively global and single indicators for cognitive functioning and cognitive, physical, and mental health have been used in previous research and observational intervals were relatively short. Moreover, most studies only considered unidimensional and/or global indicators of SPA. The lack of consideration of multiple indicators of health, as well as the lack of multidimensional measures of SPA at the outcome level, has hitherto prevented investigators from digging deeper into the identification of relevant predictors and their differential impact on SPA. Thus, this study focuses exactly on these issues by relying on long-term data of the Interdisciplinary Longitudinal Study of Adult Development (ILSE) spanning approximately 2 decades of observation. Furthermore, this study takes advantage of multiple indicators in each behavioral domain and considers two established indicators of SPA in parallel as outcomes. One of these outcomes was unidimensional whereas the other one was multidimensional.

Previous Research on Predictors of Self-Perceptions of Aging

First, the experience of cognitive decline is a major facet of the common understanding of aging (Heckhausen et al., 1989). Therefore, changes in cognitive functioning and the subsequent perception of cognitive decline may serve as important reminders of aging and may, therefore, influence a person's subjective interpretation of their own aging. Indeed, poorer cognitive functioning often goes along with more negative SPA (O'Brien et al., 2020; Sabatini et al., 2021b; Seidler & Wolff, 2017; Zhu & Neupert, 2020). However, perceived cognitive decline is not necessarily due to objective changes in cognitive functioning. Indeed, evidence on the association of perceived cognitive decline with objective cognitive functioning and cognitive health is inconsistent. On the one hand, several studies found that individuals reporting cognitive complaints are more likely to have experienced a decline in their cognitive functioning (e.g., poorer score on cognitive tests) and cognitive health (e.g., increased amyloid deposition in the brain) compared to those not reporting subjective cognitive decline (Amariglio et al., 2018; Sabatini et al., 2021e; Zimprich & Kurtz, 2015). On the other hand, several studies did not find statistically significant associations for poorer cognitive functioning and cognitive health with subjective cognitive decline (Burmester et al., 2016; Hertzog et al., 2018; Jonker et al., 2000). Hence, it may be that some individuals perceive their cognitive functioning as being poor followed by negative SPA despite having intact objective cognitive functioning.

Second, changes in physical health may also be interpreted by individuals as a consequence of their increased age and may therefore impact their SPA (Kornadt et al., 2019; Spuling et al., 2013; Steverink et al., 2001). Indeed, the occurrence of acute and chronic health problems, and the functional limitations that often accompany them, may increase individuals' general awareness of losses due to aging (Sabatini et al., 2021a; Sargent-Cox et al., 2012; Schönstein et al., 2021; Spuling et al., 2013; Zhang & Neupert, 2020).

Third, and less researched than the previous two domains, poorer mental health, such as increased depressive symptoms, has recently been found as a major predictor of more negative SPA (Schönstein et al., 2021). There may be several reasons for this association. At the action level, for example, depressive symptoms may impair everyday functioning in rather constant ways and, as a consequence, may increase the perception that aging is a negative experience (Kennedy et al., 2007; Stuck et al., 1999). In addition, at the emotional and mood level, the negative self and world views that characterize depressed individuals (Beck, 2002) may detract their attention from the positive experiences that can come with aging. Finally, increased depression may also make aging individuals more susceptible to ageism and may undermine their resilience against negative self-stereotyping (Bodner et al., 2018; Jeste et al., 2013; Wermelinger Ávila et al., 2017).

In conclusion, there is mounting longitudinal evidence suggesting that cognitive functioning and physical and mental health contribute to the formation of older adults' SPA. However, the longitudinal studies exploring the extent to which changes in health influence individuals' SPA are limited in a number of issues. First, research in the area needs a more fine-tuned approach to assess cognitive functioning. Most studies exploring whether cognitive functioning influences cognitive complaints did not assess several cognitive domains. Indeed, they either assessed solely one aspect of cognition (e.g. memory; Hertzog et al., 2018; Seidler & Wolff, 2017) or screened cognition (Burmester et al., 2016) with instruments such as the Mini-Mental State Examination (Folstein et al., 1975). However, cognitive performance essentially is the confluence of numerous abilities such as information processing speed, memory, and inductive reasoning (Hendrie et al., 2006). Exploring the associations of different cognitive abilities with SPA separately is particularly important as different cognitive abilities tend to decline at different rates and magnitude. In some cases, certain cognitive abilities (e.g. general knowledge) may show relatively high stability or may even increase (Christensen, 2001; Deary et al., 2009; Park & Reuter-Lorenz, 2009). Moreover, it could be that different cognitive abilities impact SPA differentially. For instance, decrease in cognitive speed and in working memory may become quite salient in aging individuals' daily life in the contexts of driving or shopping, whereas decline in verbal ability may not be relevant in these contexts (Conlon et al., 2017; Martyr & Clare, 2012; Royall et al., 2007).

Most studies exploring whether physical health influences SPA have used self-rated health as the indicator of a person's physical health (Sabatini et al., 2020a). However, self-rated health does not necessarily match objective levels of health (Schönstein et al., 2021; Staats et al., 1993; Wettstein et al., 2016). Also, Stephan et al. (2015) found that some of the "perceptible" biomarkers (e.g., lower peak expiratory flow, grip strength) in their study were associated with a higher subjective age, whereas imperceptible ones (i.e., blood pressure, telomere length) failed to show such an association. This suggests that individuals may draw on noticeable age-related changes to inform their SPA.

Second, most previous work relied on global and unidimensional assessments of SPA. Global measures, such as the single-item felt age indicator (Barrett, 2003), capture an overall evaluation of a person's aging and, therefore, assume that SPA do not vary across different life domains. Additionally, there is an ongoing discussion on whether feeling younger than one's chronological age may be seen as positive or eventually as a variant of ageism (Gendron et al., 2018). Further, important and widely used SPA measures such as the unidimensional Attitudes Toward Own Aging scale (e.g., ATOA scale; Lawton, 1975) treat positive and negative SPA as two ends of the same spectrum and assume that individuals hold either positive or negative SPA, but not both. Given the previous considerations, including available multi-dimensional measures of SPA in research studies is a major need when examining the antecedents of SPA.

In this regard, a more recently established concept has been the awareness of age-related change construct (AARC; Diehl & Wahl, 2010), that captures the co-existence of positive (AARC-gains) and negative (AARC-losses) age-related changes. Aside from overall scores for AARC-gains and AARC-losses, the AARC concept offers the assessment of awareness of aging in five different behavioral domains, including health and physical functioning, cognition, interpersonal relationships, social-cognitive and social-emotional functioning, and lifestyle and engagement (Diehl & Wahl, 2010). The perception of AARC-gains is expected to act as a potential facilitator of positive behavior, whereas perceptions of AARC-losses are expected to diminish developmental options in later life. Following tenets of lifespan developmental psychology (Baltes et al., 2006), both AARC-gains and AARC-losses operate in parallel, though not totally independently. This suggests that antecedents for AARC-gains and AARC-losses may be different.

Third, although previous longitudinal studies explored the impact of change in cognitive functioning and health on SPA (Brothers et al., 2020; Sargent-Cox et al., 2012), their observational intervals were limited and hardly longer than 10 years. Also, to the best of our knowledge, no one estimated the role of change in various health indicators that happen in the transition from young-old to very-old age. This transition is among the most critical ones in later life (Baltes & Smith, 2003; Wahl & Ehni, 2020) and is typically associated with a trend toward more negative SPA (Diehl et al., 2021). Still, it may be that long-term and short-term antecedents of SPA in very old age may be different than antecedents in young old age. Information in this regard may be helpful for informing prevention and intervention efforts with older adults.

The Present Study

The current study used data of the ILSE study (https://www.maelstrom-research.org/study/ilse) (see Hildesheim et al., 2019 for overview) and examined whether 20-year changes in cognitive functioning, physical, and mental health, that may happen in the transition from young old to very old age, explain variability in levels of AARC-gains and AARC-losses assessed at T4. We also considered the unidimensional ATOA scale for replication and extension purposes. At the independent variable level, we considered major areas of objective cognitive functioning independently. These included working memory, processing speed, perceptual reasoning, spatial ability, general knowledge, and reasoning. Furthermore, we considered indicators of both objective and perceived physical health. Finally, as indicator of mental health, we included self-reported symptoms of depression.

We proposed the following hypotheses. First, in terms of objective indicators of cognitive functioning, we expected that abilities with stronger relevance for functioning in everyday life (i.e., information processing speed and working memory) would have larger effects on older adults' SPA than those with lower salience for functioning in everyday life (i.e., verbal ability; Conlon et al., 2017; Martyr & Clare, 2012). We expected this to be especially true for the association of cognitive performance with AARC-losses as these capture perceived decline in everyday life due to getting older. Second, based on findings from previous studies showing that SPA were more strongly associated with self-rated health compared to more objective measures of health (Idler & Benyamini, 1997; Kaspar et al., 2019), we expected that subjective health ratings would show stronger predictive power with regard to participants' SPA compared to objective assessments of physical health. Third, in line with existing evidence (Schönstein et al., 2021), we expected that self-reported depression would predict ATOA, AARC-gains, and AARC-losses.

Fourth, we expected that associations between indicators of cognitive functioning, physical, and mental health and SPA would be significantly stronger for AARC-losses compared to AARC-gains and ATOA for several reasons. First, following tenets of lifespan developmental psychology, loss experiences increasingly outweigh gain-related experiences as people are getting older (Baltes & Smith, 2003; Heckhausen et al., 1989). Hence, increasingly dominating loss experiences in very old age should have a greater influence on AARC-losses compared to AARC-gains. Second, we expected AARC-losses to be more strongly related to health indicators compared to ATOA based on the assumption of a matching effect between the experience of losses in the cognitive, physical, and mental domains and the perception of age-related losses in these domains as confirmed by previous SPA studies (Diehl et al., 2021). Third, previous empirical work has shown that the association between AARC and various health-related variables is consistently stronger for AARC-losses compared to AARC-gains (Sabatini et al., 2020a; Sabatini et al., 2021b; Sabatini et al., 2020c).

Methods

Transparency and Openness

This study used data from the ILSE study conducted in Germany (see most recent study description in Hildesheim et al., 2019). The de-identified data on which the study conclusions are based are available to investigators outside the ILSE team after request and approval; requests should be directed to the corresponding author. Contact to the full ILSE data set can be made via one of the co-authors of this paper by means of a spelled-out data agreement (HWW; wahl@nar.uni-heidelberg.de). The analytic code to reproduce analyses is available after request to the corresponding author. The measures used in the ILSE study are publicly available and are described in Hildesheim et al. (2019)

Procedure

In the ILSE study, participants were randomly selected and recruited via city registers from two areas, located in former East and West Germany (Leipzig and Heidelberg). Potential participants were invited to take part in the study via mail. The invitation was followed by a short telephone interview collecting sociodemographic data. Those who agreed to come to the study center located either at the university of Heidelberg or Leipzig underwent a written informed consent procedure.

Participants

The ILSE study baseline assessment (first measurement wave) was conducted between 1993 and 1996, and three measurement waves were conducted 4 (1997/2000), 12 (2005/2008), and 20 (2014/2016) years after baseline assessment. The ILSE study included two age-homogenous subsamples, one born 1950-1952 and the other born 1930-1932. Due to a wider range of cognitive tests being administered only to the 1930-1932 cohort, the current study is based solely on this cohort. The old-age cohort included 500 participants at baseline; 148 participants completed all four measurement waves. Of these 148 participants, 45 individuals were excluded from the current study analyses as they either did not complete the AARC questionnaire (n = 44) or had more than 20% of missing data on the AARC questionnaire (n = 1). The final study sample (see Table 1) included 103 participants (50.5% of women) whose mean age at 20-year follow-up was 82.5 years (SD = 1.0; range: 80-85); mean years of education was 13.5 years. All participants were white Germans representing the German population behind the cohort samples included in ILSE diversity well. At baseline, compared to the study sample, individuals excluded from analyses (n = 397) rated their health as being poorer; scored more poorly on objectively assessed physical health and cognitive tests; were less well-educated; and had more negative ATOA (see Supplemental Online Table S1).

Because individuals who show mild levels of cognitive decline may be among those experiencing and, consequently, perceiving many age-related changes across several life domains (e.g. poorer cognition and mood, reduced social engagement) (Anstey, 2013; Hackett et al., 2019; Hill et al., 2016; Kessler et al., 2012; Mol et al., 2008), we kept those participants who, according to study criteria, were considered to have mild cognitive impairment (MCI; n = 1) at baseline in the study. Research has shown that people with mild cognitive impairment are fairly accurate when evaluating their cognitive performance (Clare et al., 2010).

No participants with a diagnosis of dementia were included. Indication of MCI or dementia were based on a consensus conference where at least two specialists in geriatric psychiatry examined participants' medical and neuropsychological data. In line with the criteria outlined by the International Psychogeriatric Association Working Party (Levy, 1994), MCI was diagnosed when cognitive impairment was reported either by the participant or an informant, or neuropsychological test performance (scores at least one standard deviation below normative levels) indicated objective impairment.

Measures

Dependent Variables: Self-Perceptions of Aging (SPA)

Awareness of Age-Related Change (AARC). To assess AARC-gains and AARC-losses, we used the AARC 50-item questionnaire (Brothers et al., 2019) which contains 25 items assessing AARC-gains and 25 items assessing AARC-losses. Out of the 50 items, there are 10 items for each of the five AARC life domains. The item stem "*With my increasing age, I notice that…*" precedes either an age-related gain or age-related loss statement. Example items include *"… my physical ability is not what it used to be*" (Health and Physical Functioning-Loss); "… *I am slowed in my thinking*" (Cognitive Functioning-Loss); "… *I appreciate relationships and people much more*" (Interpersonal Relations-Gain); "… *I have a better sense of what is important for me*" (Social-Emotional/Social-Cognitive Functioning-Gain); "… *I have more time for the things I enjoy*" (Lifestyle-Gain). Participants rated how much each item applied to them on a five-point scale (1 = *not at all*; 5 = *very much*). Separate scores for AARC-gains and AARC-losses were calculated by summing the 25 items falling into the respective subscales.

Higher scores indicate higher AARC-gains and AARC-losses, respectively, across life domains. For the current study sample, Cronbach's α for AARC-gains was 0.89 and for AARC-losses was 0.91.

Attitude Toward Own Aging (ATOA). We used the 5-item ATOA scale (taken from the Philadelphia Geriatric Center Morale Scale; Lawton, 1975) to assess participants' global SPA. For each statement, respondents were asked to make temporal comparisons about changes in energy level, perceived usefulness, happiness, and quality of life and to respond on a binary response format (*better* versus *worse*, *yes* versus *no*). An example item is "*things keep getting worse as I get older.*" A proportion-based score was obtained by summing participant's item scores and by dividing it by the number of responses (possible range: 1-2). Lower scores indicate more negative ATOA, whereas higher scores indicate more positive ATOA. For the current study sample Cronbach's α for ATOA was 0.64.

Independent Variables: Cognitive Functioning, Physical Health, Mental Health

Cognitive Functioning. Cognitive functioning was assessed with a cognitive battery including six paper-pencil tests. The Digit Symbol, Digit Span, and Block Design tests assessed aspects of fluid intelligence, including working memory, processing speed, perceptual reasoning, and spatial ability. The Digit Symbol test (Hoyer et al., 2004; Oswald & Fleischmann, 1995) consists of nine digit-symbol pairs (e.g., 1/V, 2/X…, 9/+) and a list of digits. Participants were given a coding table and were asked to match within 90 seconds as many single digits with corresponding symbols as possible. The number of correctly matched symbols served as the total score (possible range: 0-67).

In the Digit Span test (Oswald & Fleischmann, 1995), participants had to verbally repeat a series of single digits (e.g., “5, 6, 7”) either in the same order as they were presented by the interviewer (Part 1) or in reversed order (Digit Span backwards, Part 2). The number of digits increased by one at each trial until the participant consecutively failed two trials of the same length. Test scores were calculated by summing correct answers (possible range: 0-8).

The Block Design test was taken from the German version of the WAIS-R (Tewes, 1991; Wechsler, 1981). Participants were required to rearrange four or nine block designs according to abstract patterns. Both accuracy and time taken to complete the four or nine items were incorporated into the scoring of the test (possible range: 0-51).

The Information, Similarities, and Picture Completion tests assessed crystallized intelligence and were taken from the German version of the WAIS-R (Tewes, 1991; Wechsler, 1981). For the Information test, participants answered 24 questions on general knowledge topics (e.g., “*What is the capital of Turkey*?”). Every correct response was scored with 1 point (possible range: 0-24). In the Similarities test, participants were presented with 16 pairs of words and asked how the words in each pair were alike (e.g., egg-seed). Answers to each pair of words were rated with 0, 1, or 2 points, depending on the quality of the response, and summed up to obtain a total score (possible range: 0-32). In the Picture Completion test, participants were shown pictures with an important part missing (e.g., frog with only three legs) and were asked to identify the object of the picture. Correct answers were scored with 1 point and summed up to obtain a total score (possible range: 0-17). For each of the six cognitive tests higher scores indicated better performance.

Objectively Assessed Physical Health. To assess physical health a trained study physician conducted an in-depth clinical examination, comprised of a medical check-up, hearing and vision assessment, a laboratory blood test, and a geriatric assessment (see Miche et al., 2014a). At the end of the examination participants' health was rated on a 6-point scale (1 = "*Participant exhibits a serious medical condition, which is immediately life-threatening; professional healthcare is urgently needed;*" 6 = *"Participant exhibits very good health;*" i.e., no chronic disease, no chronic pain, all clinical assessments suggest nonpathological findings).

Subjective Health Rating. A one-item question asked participants to evaluate their health status on a 6-point scale (1 = *very bad*; 6 = *very good*) (Ware & Sherbourne, 1992).

Depressive Symptoms. Depressive symptoms were assessed with the 20-item Self-Rating Depression Scale (Zung, 1965). For each item, respondents indicated how frequently they experienced the symptom (1 = *never*; 4 = *always*). The mean of the total score (possible range: 1-4) was calculated by dividing the sum of single-item scores by the total number of items; higher scores indicated more severe depressive symptoms. Psychometric properties of the scale are good among older adults (Jokelainen et al., 2019).

Measures were administered at all four ILSE measurement waves with the exception of the AARC questionnaire which, due to being a more recently developed questionnaire, was administered only during the fourth ILSE measurement wave.

Covariates

Baseline sex, education, and depressive symptoms were used as covariates. Baseline depression was used as an additional covariate when exploring indicators of cognitive functioning and physical health. Education was assessed with a categorical variable including four answer options (1 = *up to 10 years of education*; 2 = *between 11 and 12 years*; 3 = *between 13 and 15 years*; 4 = *more than 15 years of school and university education*). These variables were used as covariates because SPA vary among men and women (Sabatini et al., 2021c), among individuals with different educational achievements (Sabatini et al., 2020b), and in relation to levels of depressive symptoms (Dutt et al., 2016a). Moreover, prevalence of cognitive and physical health decline differs between men and women and between individuals with different educational achievements (Anstey, 2013; World Health Organization, 2018).

Statistical Analyses

To maximize the use of data, mean imputation based on the group mean was computed when up to 20% of responses was missing in the ATOA scale; we did so for 10 participants. No missing data were present in the items of the remaining measures.

To explore between- and within-person 20-year change in the six cognitive tests, objectively assessed physical health, subjective health rating, and depressive symptoms, we subtracted the 20-year follow-up scores from the baseline scores. Hence, positive scores indicate a decline in cognitive functioning and physical health, whereas negative scores indicate an increase in depressive symptoms. We used matched paired t-test analyses to test the statistical significance of change between baseline and follow-up score in each of the nine health indicators. Descriptive analyses were conducted for main study variables and Pearson's *r* correlation coefficients were calculated among main study variables.

To estimate the individual predictive role of 20-year change in participants' performance in cognitive functioning, objectively assessed physical health, subjective health, and depressive symptoms on levels of AARC-gains, AARC-losses, and ATOA, we performed linear regression analyses. We checked the linearity of change in the health indicators over the study period (see

Figures 1-9). We adopted an exploratory approach where we first conducted nine univariate linear regressions with each of the nine indicators of 20-year change as the predictor and AARC-gains, AARC-losses, or ATOA as the outcome. For those indicators of change in health and cognitive functioning that were statistically significant predictors of SPA, we performed a second model adjusting for demographic variables (sex and education) and a third model adjusting for demographic and health-related variables. Health-related covariates varied depending on the predictive variable assessed. We adjusted for subjective health rating and depressive symptoms when exploring the predictive role of change in cognition; for depressive symptoms when exploring the predictive role of change in objectively assessed physical health and subjective health rating; and for subjective health rating when exploring the predictive role of change in depressive symptoms. Standardized regression coefficients are reported to indicate the size of effects; we considered coefficients ≤ .09 as negligible, .10–.29 as small, .30–.49 as moderate and ≥ .50 as large (Cohen, 1988). Significance level was set at .05.

To further explore between- and within-person variation in baseline levels of the nine health indicators, as well as in the rate of change of these indicators over 20 years (across four assessment waves), we fit latent growth curve models (LGCM). Compared to more classical ways of analyzing change over time, such as repeated-measures analysis of variance (R-ANOVA), LGCM have several advantages, including the incorporation of latent variables, the testing of different trajectories of change, and comparison of change across sub-groups (Preacher et al., 2008).

For each of the nine health indicators, we estimated four models. The first model (fixed intercept models) estimated average baseline level of the selected health indicator.

The second model (random intercept model) estimated both average baseline level of the selected health indicator and variation between individuals in the baseline level of the selected health indicator. The third model (random intercept, fixed slope model) estimated average baseline level of the selected health indicator, variation between individuals in the baseline level of the selected health indicator, and average linear change in the selected health indicator over 20 years. The fourth model (random intercept and random slope model) estimated average baseline level of the selected health indicator, variation between individuals in the baseline level of the selected health indicator, average linear change in the selected health indicator over 20 years, and between-person variation in the rate of change of the selected health indicator over 20 years.

In the models we took into account that the time interval between the first and second follow-up and between the second and third follow-up was twice as large than between baseline assessment and the first follow-up. As indicators of model fit we reported the Comparative Fit index (CFI), the Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). Generally, $CFI > .90$, $RMSEA < .08$ (95% CI: between 0 and .08), and $SRMR < .06$ indicate adequate model fit (Byrne, 2012). Power analysis for LGCM was conducted with an online sample size calculator for structural equation models (https://www.danielsoper.com/statcalc/calculator.aspx?id=89). Estimations suggested that for a model with power = .80, effect size = 0.3 (as found in previous research; Siebert et al., 2016), and probability level = 0.05, a sample of minimum 90 participants was needed.

Finally, although the main interest of our study was to explore predictors of SPA, we acknowledge that the associations between health indicators and SPA may be bidirectional. We therefore estimated cross-lagged panel models (CLPM) to explore the bidirectional influence between ATOA and those health indicators that resulted to be statistically significant predictors of ATOA. It was not possible to explore the bidirectional associations of health indicators with AARC-gains and AARC-losses as these were assessed only at 20-year follow-up. Each model consisted of two predictors (baseline scores on ATOA and on the selected health indicator) and two outcomes (20-year follow-up scores on ATOA and on the selected health indicator). In these models, ATOA was allowed to correlate with the selected health indicator. Each model estimated two autoregressive paths, representing how stable scores on ATOA and on the selected health indicator were over 20 years, and two cross-lagged paths, representing the extent to which baseline ATOA influenced follow-up scores in the selected health indicator and the extent to which baseline scores in the selected health indicator influenced follow-up levels of ATOA.

Except from LGCMs that were estimated using Mplus software (Muthén & Muthén, 2017), all remaining study analyses were conducted using STATA version 16 (StataCorp, 2017).

Results

Descriptive Analyses

Descriptive statistics for the study sample are reported in Table 1. On average, at 20-year follow-up participants reported moderate levels of AARC-gains (*M* = 78.31; *SD* = 13.79; range: 33-115; theoretical range: 25-125) and few AARC-losses (*M* = 61.02; *SD* = 14.37; range: 28-94; theoretical range: 25-125), and positive ATOA (*M* =1.57; *SD* = 0.31; range: 1-2). Mean scores for AARC-gains and AARC-losses across the five AARC life domains are reported in Supplemental Online Table S2. Over 20 years, participants' performance in the Digit Span, Digit Symbol, Similarities, Block Design, and Picture Completion tests declined, whereas participants' performance in the Information test improved; objectively assessed physical health and subjective health rating decreased; and depressive symptoms increased (see Table 2). Supplemental Online Figures 1-9 and Supplemental Online Table S3 show between- and within-person change in each of the nine health indicators over 20 years. The health and cognitive predictors with greater variability in the rate of change between persons were the Information and Block Design tests, objectively assessed physical health, and depressive symptoms. Although for the majority of participants scores on the Block Design test (see Figure 5) and on objectively assessed physical health (see Figure 7) declined, for some participants scores on these tests improved or stayed stable. Similarly, for the majority of participants scores on the Information test (see Figure 3) and depressive symptoms (see Figure 9) increased, but for a minority of participants performance on the Information test and depressive symptoms declined.

At 20-year follow-up more AARC-losses were correlated with more negative ATOA (r = -.58, $p < .001$), whereas the correlations between AARC-gains and ATOA (r = -.12, p = .22), and between AARC-gains and AARC-losses (r = -.12, p = .24) were not statistically significant. Correlations among follow-up levels of global and domain specific AARC-gains and AARC-losses and ATOA with baseline and follow-up scores on the nine cognitive and health indicators are reported in Table 3 and Supplemental Online Table S4. Most correlations were of either small or negligible size. Only the correlations for AARC-losses with subjective health rating and depressive symptoms were of moderate size.

Change in Cognitive Functioning, Physical and Mental Health as Predictor of AARC-Gains

From the univariate linear regressions (Table 4) with each indicator of 20-year change in cognitive functioning, physical, and mental health predicting AARC-gains, only a decline in participants' performance on the Digit Symbol test predicted fewer AARC-gains. The small size of the effect (R^2 = .07) remained statistically significant after controlling for the effects of demographic variables, subjective health rating, and depressive symptoms. Changes in any of the other cognitive tests failed to be significant predictors of AARC-gains.

Change in Cognitive Functioning, Physical and Mental Health as Predictor of AARC-Losses

From the univariate linear regressions (Table 4) with each indicator of 20-year change in cognitive functioning, physical and mental health predicting AARC-losses, poorer subjective health rating, greater decline in participants' performance on the Digit Symbol and Picture Completion tests, and an increase in depressive symptoms predicted greater AARC-losses. The association between decline in Digit Symbol and fewer AARC-gains is similar in size to that between decline in Digit Symbol and higher AARC-losses. Changes in the other cognitive tests as well as changes in objective health were not significant predictors of AARC-losses.

Results of multiple regressions with indicators of change in health as predictors of AARC-losses are reported in Table 5. Decline in participants' performance in the picture completion test was no longer a statistically significant predictor of AARC-losses after adjusting for demographic variables. The remaining associations remained statistically significant after adjusting for covariates.

Change in Cognitive Functioning, Physical and Mental Health as Predictor of ATOA

From the univariate linear regressions (Table 4) with each indicator of 20-year change in cognitive functioning, physical and mental health predicting ATOA, a decline in participants' subjective health rating and an increase in depressive symptoms were significant predictors of more negative ATOA. Changes in the cognitive tests were not significant predictors of ATOA.

The moderate relevance of a decline in subjective health and an increase in depressive symptoms for predicting negative ATOA remained in the full adjusted models (See Table 5).

Bidirectional Associations of ATOA with Physical and Mental Health

Results from the cross-lagged panel models exploring the bidirectional associations of ATOA with subjective health rating and depressive symptoms are reported in Supplemental Online Table S5. The autoregressive paths show that baseline levels of ATOA predicted variance in 20-year follow-up ATOA and baseline scores on health indicators predicted variance in 20-year follow-up scores on the same health indicator. Baseline subjective health rating and ATOA did not predict each other at 20-year follow-up. Baseline depressive symptoms and ATOA significantly predicted each other at 20-year follow-up.

Discussion

This study explored whether 20-year changes in cognitive functioning, objective physical health, subjectively rated health, and depressive symptoms predict levels of AARC-gains, AARC-losses, and ATOA in a sample of very old adults aged 80 to 85 years. We proposed four hypotheses: (1) Change in objective indicators of cognitive functioning with strong associations to cognitive functioning in daily life will have larger effects on SPA than those less salient in everyday life. (2) Subjectively rated health will be a stronger predictor of SPA than objectively assessed physical health. (3) Depressive symptoms will emerge as a significant predictor of SPA. (4) The associations between different predictors and SPA will be stronger for AARC-losses compared to AARC-gains and ATOA.

We found partial support for the first hypothesis as a decline in participants' performance in the Digit Symbol test, assessing information processing speed, predicted fewer AARC-gains and more AARC-losses. However, despite the fact that working memory becomes particularly salient in very old age with regard to everyday tasks such as driving or shopping (Conlon et al., 2017; Jonker et al., 2000; Martyr & Clare, 2012; Royall et al., 2007), we did not find a significant association between average decline in working memory and greater AARC-losses. We confirmed the second hypothesis showing that a decrease in subjectively rated health, but not in objectively assessed physical health, significantly predicted greater AARC-losses and more negative ATOA. In line with our third hypothesis, an increase in depressive symptoms was a significant predictor of greater AARC-losses and more negative ATOA, but not of lower AARC-gains. Finally, we found partial support for the fourth hypothesis because only some associations between the investigated predictors and SPA were stronger for AARC-losses compared to AARC-gains and ATOA. Specifically, subjectively rated health and depressive symptoms were more strongly associated with AARC-losses compared to AARC-gains, whereas the indicators of cognitive functioning were similarly associated with both AARC-gains and AARC-losses. Decline in the Digit Symbol test was more strongly associated with AARC-losses compared to ATOA, whereas subjective and objective health and depressive symptoms were similarly associated with both AARC-losses and ATOA.

Cognitive Functioning as Predictor of SPA

The small association found between a decline in participants' information processing speed and greater AARC-losses is in line with cross-sectional evidence, documenting either negligible or small associations between indicators of poorer subjective and objective cognitive performance and greater AARC-losses (O'Brien et al., 2020; Sabatini et al., 2020b; Sabatini et al., 2021b; Zhu & Neupert, 2020). Differently from cross-sectional evidence showing that poorer cognitive performance is negligibly associated with more AARC-gains (Sabatini et al., 2021b), the current longitudinal study found a small association between decline in cognitive functioning and lower AARC-gains. The discrepancy between cross-sectional and longitudinal evidence highlights the importance of linking AARC-gains and AARC-losses with the assessment of change in developmental outcomes, such as cognitive functioning. Indeed, AARC-gains and AARC-losses respectively very likely capture a trajectory of perceived cognitive improvement or decline rather than perceptions of current cognitive functioning.

Although on average participants' performance on the Digit Span, Block Design, Information, Similarities, and Picture Completion tests declined significantly over the study period, change in these cognitive domains did not predict levels of AARC-gains and AARC-losses. However, given the great between-person variability found in the rate of change of working memory (Digit Span) and knowledge (Information), it may be that our analyses linking average change in working memory and knowledge to AARC-gains and AARC-losses failed to detect significant associations among those who experienced grater decline in working memory and knowledge. Nonetheless, study results suggest that only change in information processing may be a risk factor for the perception of fewer AARC-gains and greater AARC-losses. Individuals reporting low AARC-gains and high AARC-losses may, therefore, benefit from further cognitive monitoring and from interventions aiming to delay or prevent the progress of age-related cognitive decline to levels of pathological cognitive decline (Hahn & Lachman, 2015; Rakesh et al., 2017).

Change in cognition did not predict ATOA. However, previous longitudinal evidence, including a study using data from the ILSE study, shows that more positive ATOA predicts better performance on cognitive tests (Levy et al., 2018; Robertson & Kenny, 2016; Seidler & Wolff, 2017; Siebert et al., 2020; Siebert et al., 2016). Hence, although ATOA is a well-established predictor of future cognitive ability, individuals' ATOA may not be influenced by objectively observed cognitive decline. An explanation for decline in cognitive performance being a significant predictor of AARC-losses but not of ATOA may be due to AARC capturing dynamic self-evaluations of cognition rooted in a person's everyday life (Miche et al., 2014b), whereas the ATOA scale assesses more global and overall perceptions of aging that are not necessarily linked to specific experiences (Hess, 2006; Lawton, 1975; Miche et al., 2014a).

Physical Health as Predictor of SPA

The finding that a decline in subjectively rated health predicted greater AARC-losses and more negative ATOA extends previous evidence showing that more negative subjective health ratings are a longitudinal predictor of more negative scores on other measures of SPA, such as an older felt age (Spuling et al., 2013). The lack of a significant association between decline in subjective health and fewer AARC-gains is in line with cross-sectional evidence showing that the association between better physical health indicators and greater AARC-gains tends to be negligible (Brothers et al., 2017; Sabatini et al., 2020a; Sabatini et al., 2020c). This result may be due to the fact that physical losses can still be apparent for a person who reports many AARC-gains, given that AARC-gains and AARC-losses tend be positively correlated (Sabatini et al., 2020d).

The lack of a significant association between a decline in objectively assessed physical health and SPA is not in line with cross-sectional evidence, supporting the associations of poorer physical health with fewer AARC-gains, more AARC-losses (Dutt et al., 2018a), and less positive ATOA (Westerhof et al., 2014). Our results may however support the "health paradox," stating that even though physical and functional health generally decline with aging, self-perceptions of health remain positive or change to a lesser extent (Idler & Benyamini, 1997;

Jylha et al., 2001). However, this is unlikely as in our study, assessing five AARC life domains, participants perceived the highest levels of losses in the health and physical functioning domain. Alternatively, the non-significant association between participants' average decline in objectively assessed physical health and AARC at follow-up may be due to participants experiencing, on average, only a minimal decline in their objective physical health. However, because we found great variance in the trajectory of objective physical health between participants, it may be that those few participants who experienced greater decline in their objective physical health perceived higher AARC-losses at follow-up. Future studies should explore this hypothesis as our sample size prevented us from testing it in the current study.

Although regression analyses showed that change in objectively assessed physical health did not predict follow-up levels of ATOA, previous longitudinal evidence showed that the presence of chronic health conditions at baseline predicted more negative SPA (Schönstein et al., 2021). Overall, it may be that although baseline objective assessments of physical health are informative of future levels of SPA, the assessment of a decline in objectively assessed physical health is not always informative of future levels of SPA. It may well be that small changes in objective health, as those experienced by the current study sample, are not noticed by individuals and that only the occurrence of severe changes in objective health leads to an increase in individuals' awareness of age-related losses and to more negative view of aging.

Mental Health as Predictor of SPA

Across the study period, participants reported a significant increase in depressive symptoms. Although an increase in depressive symptoms may be more likely when transitioning from young-old to very-old age, due to normative loss experiences, those individuals who experienced a more severe increase in depressive symptoms were more vulnerable to the experience of AARC-losses and negative ATOA. This pattern of results was expected as in older age depressive symptoms tend to go along with poor physical and functional health (Alexopoulos, 2005; Fauth et al., 2012), and awareness of physical and functional decline are assessed with items in the AARC-losses and ATOA subscale. The predictive role of change in depressive symptoms over more negative ATOA was in line with recent evidence (Schönstein et al., 2021). The findings of this study suggest a bidirectional influence between more negative ATOA and more depressive symptoms. Although in this study it was not possible to explore the bidirectional relationship between depressive symptoms and AARC-losses, due to AARC-losses having been assessed only at follow-up, there may be a bidirectional relationship also between AARC-losses and depression. Indeed, we found that an increase in depressive symptoms significantly predicted more AARC-losses at 20-year follow-up and longitudinal evidence showed that more AARC-losses at baseline predicted an increase in depressive symptoms (Dutt et al., 2016a). Overall, addressing depressive symptoms in older age may be a way of preventing and/or limiting negative SPA. At the same time, the emotional well-being of individuals reporting high AARC-losses and negative ATOA may be enhanced with psychological interventions promoting acceptance of negative age-related changes and ego-integrity (Collins & Kishita, 2018; Vailati Riboni et al., 2018; Vailati Riboni et al., 2020; Zanini et al., 2018).

Cross-sectional evidence on the association of depression with AARC-gains has been inconsistent (Sabatini et al., 2020a). Some studies reported a significant association between fewer depressive symptoms and more AARC-gains (Kaspar et al., 2019), whereas others did not (Dutt et al., 2016a; Dutt & Wahl, 2018; Dutt et al., 2018b). The findings from this longitudinal study suggest that a more severe increase in depressive symptoms does not necessarily predict lower AARC-gains. It may be that even though in the transition from young-old to very-old age an increase in depressive symptoms is more likely due to the experience of age-related losses (Alexopoulos, 2005; Palsson et al., 2001; Weyerer et al., 2013), loss-related depressive symptoms may not necessarily prevent individuals from having experiences and perceptions of age-related gains.

Although developmental theories postulate that in very old age losses tend to outweigh gains (Baltes, 1997), in the current study, participants reported more positive than negative ATOA, moderate levels of AARC-gains and only few AARC-losses. These levels of SPA were similar to those found in other cohort studies of community-dwelling older adults (Brothers et al., 2017; Sabatini et al., 2021b). Positive SPA among community-dwelling older individuals have also been reported by studies investigating other indicators of SPA such as felt age (Westerhof et al., 2003). The overly positive SPA reported in this and other cohort studies may be due to most samples comprising self-selective groups of older individuals who experience less than average decline in cognitive functioning, physical, and mental health. It may be that when very old individuals enjoy reasonably good health, they do not need to shift their resources away from growth and, as a consequence, positive age-related experiences and perceptions may still outnumber negative ones (Baltes, 1997).

In sum, by exploring, for the first time, changes in cognitive functioning as predictors of AARC-gains and AARC-losses, this study made it possible to extent previous cross-sectional and micro-longitudinal evidence on the associations of AARC-gains and AARC-losses with cognitive functioning (Sabatini et al., 2021b; Zhu & Neupert, 2020). We confirmed that the association between poorer cognition and more AARC-losses is consistently small also at the longitudinal level. Hence, in addition to cognition, many psychological variables, such as mood, self-efficacy, and beliefs about age-related cognitive changes, may shape adults' levels of AARC-losses (Dutt & Wahl, 2018; Sabatini et al., 2021b).

Moreover, the exploration of changes in mental and physical health as predictors of AARC-gains and AARC-losses made it possible to complement previous knowledge on the predictive role of higher AARC-gains and lower AARC-losses over better mental and physical health (Brothers et al., 2020). Indeed, as we found that AARC-losses were predicted by a decline in subjective health ratings and an increase in depressive symptoms, AARC-losses may not only be a predictor of poorer future mental and physical health (Brothers et al., 2020) but also be the outcome of decline in mental and physical health.

Although both AARC-losses and more negative ATOA were predicted by an increase in depressive symptoms and poorer subjective health, AARC-gains and AARC-losses were not predicted by change in objectively assessed physical health. This pattern of results may be due to AARC-losses and ATOA being measured with similar methods to those used to assess subjective health and depressive symptoms (i.e., self-reports) and with different methods compared to those used to assess cognitive functioning and objective physical health (i.e., behavioral measures of cognitive functioning and objective physical examination). Nonetheless, both the AARC-losses and ATOA subscales may be useful to identify those individuals who experience depressive symptoms and perceive their health as being poor but may not be useful to identify those individuals with poorer objective health. These individuals may benefit from intervention programs promoting health and more positive and realistic views of aging (Brothers & Diehl, 2017; Levy et al., 2014; Menkin et al., 2020; Sarkisian et al., 2007; Wolff et al., 2014).

Strengths and Limitations

This study has several strengths. First, the 20-year longitudinal study design is a strength because most available evidence to date on the association of AARC with health indicators comes from cross-sectional studies (Sabatini et al., 2020a) or relies on studies with shorter follow-up periods (Brothers et al., 2020; Dutt et al., 2018b). Moreover, the longitudinal study design made it possible to discover that change in health predicts AARC-gains and AARC-losses, providing empirical support for the value of the framework of AARC (Diehl & Wahl, 2010). Second, in contrast to most evidence that explored the association of AARC with physical health relying on ratings of subjective health, this study used both a subjective and an objective assessment of physical health. This is a strength as subjective and objective ratings of physical health are not interchangeable and often show divergent associations with outcomes (Althubaiti, 2016; Schönstein et al., 2021; Staats et al., 1993).

Third, because in ILSE the cognitive tests were administered by a trained researcher, it was possible to observe participants' behavior and engagement while taking the cognitive tests. Thus, participants' cognitive test scores were derived directly and were not based on proxy reports.

Fourth, as participants' change in cognitive functioning was assessed across six different domains, it was possible to take an exploratory approach and identify which aspects of cognition showed the strongest associations with individuals' SPA. Moreover, the comprehensive cognitive battery used in the current study provided a more accurate assessment of participants' cognitive functioning compared to that of similar studies that relied on simple screening measures of cognition (Schönstein et al., 2021).

This study has also several limitations. First, similarly to most studies collecting information about health and lifestyle among older individuals, the participants that were included in the current analyses, may have been a self-selected group of individuals with above average health and education compared to the broader German population of very old individuals (European Union, 2019; Gerstorf et al., 2006; Klaus et al., 2017; Puth et al., 2017). Hence, because the sample very likely included individuals who had aged more successfully than the average older adult, the association we found for a decline in cognition and subjective health and an increase in depressive symptoms with more negative SPA, may be stronger when investigated in a more heterogeneous sample with greater variability in these key variables. Second, although in the ILSE study several years passed between one assessment and the next, the administration of the same cognitive tests at baseline and at three subsequent follow-ups may have given rise to some practice effects (Goldberg et al., 2015) and may have obscured the magnitude of cognitive decline experienced by participants. However, a practice effect may be expected in cognitively healthy older individuals and lack of practice effect may indicate some sort of pathological cognitive decline (Duff et al., 2010; Duff et al., 2007).

Third, due to the AARC questionnaire having been recently developed, a limitation of this study is that AARC-gains and AARC-losses were assessed only at 20-year follow-up. As a consequence, it was not possible to examine change in AARC nor whether change in AARC was related to changes in cognitive functioning, physical health, and mental health. Moreover, although we explored the bidirectional association of ATOA with health indicators, it was not possible to test the bidirectional associations between AARC (gains and losses) and health indicators. We therefore refrain from causal inferences on the relationship of AARC-gains and AARC-losses with cognitive functioning, physical health, and mental health. Fourth, exploring the associations of SPA with nine indicators of change in health may introduce a problem of multiplicity. However, the aim of study was to explore several indicators of change in cognitive functioning and health as a way of identifying a potential group of individuals at high-risk of negative SPA. Fifth, as there were many missing cases for objectively assessed physical health, estimates for the associations of change in objectively assessed physical health and SPA outcomes were less reliable. Sixth, although in Supplemental Online Material we report results for LGCMs exploring the rate of change in the health indicators over the study period, the limited statistical power of the current study prevented us from exploring AARC-gains, AARC-losses, and ATOA as outcomes in these LGCMs. Seventh, to explore the bidirectional associations of ATOA with health indicators we used CLPM (Selig & Little, 2012) although their use is currently being debated.

Conclusions

This study explored the predictive associations of 20-year change in objective cognitive performance, objective and subjective physical health, and depressive symptoms with levels of AARC-gains, AARC-losses, and ATOA. We found that the more individuals declined in their performance on the cognitive test “Digit Symbols”, perceived a decline in their physical health, and experienced an increase in their depressive symptoms, the more they were also likely to report negative SPA. Hence, more negative SPA may be useful indicators that may help to detect those individuals with poorer health and who would, therefore, benefit the most from health-promoting interventions.

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Table 1. Descriptive statistics of study variables

Characteristics	Study sample (N = 103)	Missing values
	N (%)	N
Women	51 (49.5%)	0
Education	13.53 (2.59; 9 to 18)	1
Up to 10 years of education	10 (9.8%)	
Between 11 and 12 years	33 (32.4%)	
Between 13 and 15 years	36 (35.3%)	
More than 15 years of school and university education	23 (22.5%)	
	Mean (SD; range)	
Age at baseline	62.77 (0.97; 61 to 64)	0
AARC-50 gains at follow-up	78.31 (13.79; 33 to 115)	0
AARC-50 losses at follow-up	61.02 (14.37; 28 to 94)	0
Attitude toward own aging		
Baseline	1.78 (0.28; 1 to 2)	2
20-year follow-up	1.57 (0.31; 1 to 2)	1
Objectively assessed physical health		
Baseline	3.83 (0.70; 2 to 5)	4
4-year follow-up	3.68 (0.51; 2 to 4)	0
12-year follow-up	3.76 (0.67; 2 to 5)	3
20-year follow-up	3.15 (0.89; 1 to 4)	57
Subjective health rating		
Baseline	3.96 (0.81; 1 to 5)	2
4-year follow-up	3.87 (0.85; 1 to 5)	0
12-year follow-up	3.75 (0.90; 1 to 5)	4
20-year follow-up	3.30 (1.02; 1 to 5)	2
Digit span		
Baseline	11.11 (1.65; 7 to 16)	0
4-year follow-up	10.92 (1.73; 8 to 16)	0
12-year follow-up	10.76 (1.95; 6 to 15)	4
20-year follow-up	9.88 (1.68; 6 to 14)	5
Digit symbol		
Baseline	47.69 (10.08; 27 to 67)	0
4-year follow-up	47.46 (10.43; 25 to 67)	0
12-year follow-up	43.54 (9.98; 24 to 67)	4
20-year follow-up	35.32 (9.97; 20 to 65)	8

Information		
Baseline	17.29 (3.69; 8 to 24)	0
4-year follow-up	17.48 (3.81; 8 to 23)	0
12-year follow-up	17.32 (3.65; 8 to 23)	4
20-year follow-up	22.671 (7.94, 0 to 44)	9
Similarities		
Baseline	26.63 (3.70; 16 to 32)	0
4-year follow-up	25.83 (4.86; 9 to 31)	0
12-year follow-up	25.96 (4.96; 7 to 32)	4
20-year follow-up	16.18 (4.23; 5 to 23)	9
Block design		
Baseline	29.20 (7.73; 13 to 47)	0
4-year follow-up	26.77 (8.27; 6 to 45)	0
12-year follow-up	26.91 (7.17; 11 to 40)	4
20-year follow-up	25.11 (4.58; 6 to 31)	10
Picture completion		
Baseline	12.77 (3.15; 1 to 17)	0
4-year follow-up	13.05 (2.91; 2 to 17)	0
12-year follow-up	12.99 (3.15; 1 to 17)	4
20-year follow-up	12.1 (3.50; 0 to 17)	12
Depressive symptoms		
Baseline	1.65 (0.32; 1.05 to 2.45)	3
4-year follow-up	1.63 (0.30; 1 to 2.4)	0
12-year follow-up	1.70 (0.33; 1.1 to 2.6)	5
20-year follow-up	1.87 (0.34; 1.25 to 3.0)	2

Table 2. 20-year change in indicators of cognitive functioning, physical health, and mental health

Health indicators	Mean change from baseline to 20-year follow-up (SD); 95% CI	t-test (df); *p*-value
Change in digit span	1.19 (1.60); 0.87 to 1.51	7.40 (97); < .001
Change in digit symbol	12.48 (8.16); 10.82 to 14.15	14.90 (94); < .001
Change in information	-5.32 (7.66); -6.89 to -3.75	-6.73 (93); < .001
Change in similarities	10.44 (4.21); 9.57 to 11.30	24.04 (93); < .001
Change in block design	4.09 (8.59); 2.32 to 5.85	4.59 (92); < .001
Change in picture completion	0.85 (3.08); 0.20 to 1.49	2.62 (90); .005
Change in objectively assessed physical health	0.61 (1.02); 0.30 to 0.92	4.00 (43); < .001
Change in subjective health rating	0.64 (1.02); 0.43 to 0.84	6.18 (98); < .001
Change in depression	-0.22 (0.36); -0.29 to -0.14	-5.93 (97); < .001

Table 3. Bivariate correlations among AARC-gains, AARC-losses, and ATOA at 20-year follow-up with baseline and 20-year follow-up scores on indicators of cognitive functioning, physical health, and mental health

Indicators of cognitive functioning, physical and mental health	AARC-gains	AARC-losses	ATOA
	r; p-value	*r; p*-value	*r; p*-value
Baseline digit span	.05; .61	-.26; .01	.25; .01
Follow-up digit span	.003; .98	-.29; .003	.25; .01
Baseline digit symbol	-.03; .79	.002; .98	.002; .98
Follow-up digit symbol	.10; .34	-.23; .02	.16; .13
Baseline information	.03; .79	.14; .17	.14; .17
Follow-up information	.12; .24	-.12; .24	.19; .07
Baseline similarities	.15; .12	.08; .44	.08; .44
Follow-up similarities	.12; .23	-.20; .05	.15; .15
Baseline block design	.02; .84	.03; .77	.03; .77
Follow-up block design	.18; .08	-.17; .10	.07; .47
Baseline picture completion	.07; .49	.18; .07	.18; .07
Follow-up picture completion	.14; .20	-.10; .36	.20; .05
Baseline objectively assessed physical health	.01; .89	-.25; .01	.39; .003
Follow-up objectively assessed physical health	-.12; .41	-.39; .04	.45; .002
Baseline subjective health rating	-.12; .23	-.25; .01	.60; .001
Follow-up subjective health rating	-.31; .002	-.61; .001	.28; .004
Baseline depression	.08; .46	.33; .001	-.34; .001
Follow-up depression	.05; .62	.55; .001	-.76; .001

Table 4. Univariate linear regressions with 20-year change in indicators of cognitive functioning, physical health, and mental health as predictors of AARC-gains, AARC-losses, or ATOA: Standardized regression coefficients

	AARC-gains		AARC-losses		ATOA	
Predictor	β (95% CI); *p*	R^2	β (95% CI); *p*	R^2	β (95% CI); *p*	R^2
20-year change in digit span	.08 (-.12 to .27); .451	1%	.01 (-.19 to .21); .907	0.01%	-.002 (-.20 to .20); .983	0%
20-year change in digit symbol	-.26 (-.45 to -.08); .005	7%	.18 (-.01 to .37); .070	3%	-.14 (-.34 to .05); .150	2%
20-year change in information	-.09 (-.29 to .11); .384	1%	.07 (-.13 to .27); .514	1%	-.13 (-.33 to .06); .188	2%
20-year change in similarities	.08 (-.12 to .28); .443	1%	.14 (-.05 to .34); .150	2%	-.11 (-.31 to .09); .287	0.1%
20-year change in block design	-.11 (-.31 to .09); .282	1%	.06 (-.14 to .26); .573	0.3%	-.02 (-.22 to .18); .838	0.002%
20-year change in picture completion	-.16 (-.36 to .04); .115	3%	-.20 (-.40 to -.01); .042	4%	-.07 (-.27 to .14); .532	0.03%
20-year change in objectively assessed physical health	.08 (-.21 to .37); .597	1%	-.01 (-.30 to .29); .959	0.01%	-.20 (-.48 to .08); .162	0.04%
20-year change in subjective health rating	.09 (-.10 to .29); .364	1%	.35 (.18 to .52); <.001	12%	-.40 (-.56 to -.24); <.001	0.15%
20-year change in depressive symptoms	.11 (-.09 to .30); .286	1%	-.28 (-.46 to -.10); <.001	8%	.43 (.28 to .59); <.001	19%

Notes*:* β = Standardized regression coefficient. Partial R^2 = Partial R-squared/coefficient of determination. Significant *p*-value after applying Bonferroni's correction = .002.

Table 5. Multiple regressions with 20-year change in indicators of cognitive functioning, physical health, and mental health as predictors of AARC-gains, AARC-losses, or ATOA: Standardized regression coefficients

20-year change in digit symbol as predictor of AARC-gains			
	Predictors	β (95% CI); *p*	R^2/Partial R^2
Simple regression	20-year change in digit symbol	-.26 (-.45 to -.08); .005	7%
Adjusted for demographic variables	20-year change in digit symbol	-.24 (-.43 to -.05); .012	6%
	Sex	.06 (-.14 to .25); .551	0.3%
	Education	-.11 (-.31 to .08); .258	1%
Adjusted for demographic variables, perceived health, and depression	20-year change in digit symbol	-.24 (-.43 to -.06); .011	6%
	Sex	-.02 (-.19 to .22); .871	0.03%
	Education	-.15 (-.35 to .05); .141	2%
	Subjective health rating	-.18 (-.38 to .02); .075	3%
	Depression	-.01 (-.22 to .20); .924	0.01%
20-year change in subjective health rating as predictor of AARC-losses			
Simple regression	20-year change in subjective health rating	.35 (.18 to .52); <.001	12%
Adjusted for demographic variables	20-year change in subjective health rating	.36 (.20 to .53); <.001	13%
	Sex	.05 (-.13 to .24); .570	0.3%
	Education	-.10 (-.28 to .09); .302	1%
Adjusted for demographic variables, subjective health rating, depression	20-year change in subjective health rating	.38 (.22 to .53); <.001	14%
	Sex	-.05 (-.22 to .13); .607	0.2%
	Education	-.05 (-.22 to .12); .573	0.2%
	Depression	.38 (.21 to .54); <.001	13%
20-year change in digit symbol as predictor of AARC-losses			
Simple regression	20-year change in digit symbol	.18 (-.01 to .37); .070	3%
Adjusted for demographic variables	20-year change in digit symbol	.20 (.01 to .39); .044	4%

	Sex	.09 (-.11 to .29); .383	1%
	Education	-.12 (-.32 to .08); .229	1%
Adjusted for demographic variables, subjective health rating, depression	20-year change in digit symbol	.20 (.02 to .38); .027	4%
	Sex	-.04 (-.23 to .15); .697	0.1%
	Education	-.07 (-.26 to .12); .473	0.4%
	Perceived health	-.18 (-.37 to .001); .051	3%
	Depression	.35 (.17 to .53); <.001	01%
20-year change in picture completion as predictor of AARC-losses			
Simple regression	20-year change in picture completion	-.20 (-.40 to -.01); .042	4%
Adjusted for demographic variables	20-year change in picture completion	-.19 (-.39 to .01); .064	3%
	Sex	.06 (-.14 to .26); .563	0.4%
	Education	-.08 (-.29 to .12); .429	1%
Adjusted for demographic variables, subjective health rating, depression	20-year change in picture completion	-.11 (-.31 to .08); .257	1%
	Sex	-.05 (-.24 to .15); .635	0.2%
	Education	-.04 (-.23 to .16); .707	0.1%
	Perceived health	-.17 (-.36 to .03); .100	2%
	Depression	.36 (.17 to .54); <.001	11%
20-year change in depressive symptoms as predictor of AARC-losses			
Simple regression	20-year change in depressive symptoms	-.28 (-.46 to -.10); <.001	8%
Adjusted for demographic variables	20-year change in depressive symptoms	-.30 (-.48 to -.12); .001	9%
	Sex	.10 (-.09 to .29); .311	1%
	Education	-.11 (-.30 to .08); .275	1%
Adjusted for demographic variables, subjective health rating, depression	20-year change in depressive symptoms	-.25 (-.43 to -.07); .006	6%
	Sex	.05 (-.14 to .24); .578	0.03%
	Education	-.10 (-.29 to .08); .277	1%
	Subjective health rating	-.25 (-.43 to -.07); .007	6%

Change in perceived health as predictor of ATOA			
		β (95% CI); *p*	*R^2/Partial R^2*
Simple regression	Change in subjective health rating	-.40 (-.56 to -.24); <.001	0.15%
Adjusted for demographic variables	Change in subjective health rating	-.45 (-.60 to -.30); <.001	20%
	Sex	-.07 (-.25 to .11); .462	0.4%
	Education	-.003 (-.18 to .18); .978	0%
Adjusted for demographic variables, subjective health rating, and depression	Change in subjective health rating	-.45 (-.59 to -.31); <.001	20%
	Sex	.01 (-.16 to .19); .875	0.02%
	Education	-.04 (-.21 to .13); .648	0.02%
	Depression	-.32 (-.48 to -.15); <.001	9%
Change in depressive symptoms as predictor of ATOA			
Simple regression	Change in depressive symptoms	.43 (.28 to .59); <.001	19%
Adjusted for demographic variables	Change in depressive symptoms	.46 (.31 to .61); <.001	21%
	Sex	-.15 (-.32 to .03); .107	2%
	Education	.02 (-.16 to .20); .841	0.03%
Adjusted for demographic variables, subjective health rating, and depression	Change in depressive symptoms	.44 (.38 to .59); <.001	18%
	Sex	-.12 (-.31 to .06); .178	1%
	Education	.02 (-.16 to .19); .856	0.03%
	Subjective health rating	.12 (-.06 to .30); .171	1%

Notes*:* β = Standardized regression coefficient. Partial R^2 = Partial R-squared/coefficient of determination.