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Institutional Contexts and Cognitive Health Inequalities: An Analysis of Educational Gradients and Gender Differences in Cognitive Health Expectancy in Europe

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Institutional Contexts and Cognitive Health Inequalities: An Analysis of Educational Gradients and Gender Differences in Cognitive Health Expectancy in Europe

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Authors' contributions

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Variations in the accumulation and decline of cognitive reserve across different cultural and institutional contexts, as well as selective survival processes that influence which population groups remain at risk for cognitive impairment, may contribute to the heterogeneity of educational disparities in cognitive health across European countries and between genders. We explore how educational disparities in Cognitive Health Expectancies (CHE) for men and women vary across different contextual settings in Europe, with a particular focus on Central and Eastern European (CEE) countries. Applying multivariate life table approach and the Sullivan methods to the Survey of Health, Ageing and Retirement in Europe (SHARE) data, we estimated CHE by gender and education at age 50 and the proportion of CHE relative to remaining life expectancy, across 10 European countries. We found that educational inequalities in cognitive health are significantly influenced by national context, with some of the most pronounced effects in CEE countries, particularly for women. Despite higher overall educational attainment in CEE countries, the benefits typically associated with education did not translate equally across groups. The key divergence, which is most pronounced for women, occurs among those with low educational attainment, who appear to be highly disadvantaged. Substantially smaller disparities, such as observed in Northern European countries, suggest untapped potential for mitigating educational inequalities in cognitive ageing.

Keywords: Cognitive Impairment; Health Disparities; Education; Gender; Country Differences; Cognitive Health Expectancies

Institutional Contexts and Cognitive Health Inequalities: An Analysis of Educational Gradients in Cognitive Health Expectancy in Europe

Introduction

Cognitive decline, marked by a gradual loss of attained cognitive abilities, is a growing concern in aging populations. While some decline is a natural part of aging, more pronounced impairments can lead to dementia (Sachdev et al., 2014) and pose profound societal and healthcare implications (Prince et al., 2015). Currently, around 57 million individuals globally are affected by dementia, a number expected to increase to 152 million by 2050 due to population aging (Nichols et al., 2022). In Europe, dementia disproportionately impacts women, with about 45% of women and 30% of men aged 90 years or older living with dementia (Alzheimer Europe, 2019). Understanding the factors influencing impaired cognitive functioning, particularly modifiable ones (Livingston et al., 2020), is crucial for effective policy and healthcare planning in aging societies.

Among these factors, education serves as a critical determinant of health, with individuals of lower educational levels exhibiting increased vulnerability to adverse health conditions across diverse populations and contexts (Masters et al., 2015). Higher educational attainment is also associated with lower levels of cognitive impairment (Livingston et al., 2020). The impact of education on cognitive health operates through multiple pathways, both direct and indirect. Directly, education helps build cognitive reserve (Stern, 2009), a concept that explains the educational gradient in the clinical manifestation of dementia for the same level of pathology (Brayne et al., 2010). Education indirectly affects life trajectories by influencing factors such as occupational opportunities and income levels, enhancing awareness of the importance of behaviors, and facilitating access to health services (Cutler & Lleras-Muney, 2010; Ross & Mirowsky, 2010). These factors, in turn, contribute to cognitive stimulation and promote overall health throughout life.

Gender is another critical stratifier of cognitive health. Women generally experience a delayed onset of cognitive decline (Hale et al., 2020), yet a stronger association with physical impairment compared to men (Sharma et al., 2023). This gender disparity arises from a complex interplay of biological and socio-cultural factors, including women’s survival advantage and men's higher levels of education (Bertogg & Leist, 2023; Bonsang et al., 2017; Subramaniapillai et al., 2021). Therefore, it is important to consider how gender and education jointly shape cognitive health.

While empirical evidence has predominantly emphasized mechanisms linking educational level to cognitive health outcomes from an individual's perspective, emerging evidence suggests a more complex interplay of contextual determinants. Orsholits et al. (2022) demonstrates that the association of education with the level of cognitive functioning and cognitive decline are dependent on the context. Their findings show that cognitive decline was more pronounced in Scandinavian than in Bismarckian countries. This highlights that macro-level advantages may not persist in maintaining cognitive health as individuals age, suggesting a context-dependent role of education.

To better understand how contextual circumstances influence the interplay between education and cognitive health, we propose adopting an approach that considers how education and context affect overall health and survival in older adults. Two theoretical frameworks merit consideration in explaining the variation in the size of educational disparities in cognitive health across different populations. First, selection effects, including survival bias (Sakkeus et al., 2023) and marginalization of a small group size, may significantly influence the observed relationships between education and health outcomes by shaping the composition of at-risk populations. Second, contextual factors such as the landscape of the healthcare system, labor market and gender equality, can either mitigate or exacerbate health disparities (Beckfield et al., 2015; Gkiouleka et al., 2018).

Indeed, while education directly affects cognition promoting cognitive reserve, the indirect effects of education that accumulate and manifest in later life are context dependent. In other words, the extent to which education functions as a powerful protective factor for health depends on the context which allows individuals to reap the typical benefits associated with education. To date, most of the evidence on variations in cognitive functioning across education levels comes from studies conducted within individual countries. However, recent studies by Myrskylä et al. (2024), Orsholits et al. (2022), and Rehnberg et al. (2024) showed that a more nuanced understanding of the relationship between education and cognitive decline can be achieved by examining diverse samples and documenting cross-country differences. Comparative studies can help us better understand the complexities of this relationship, which is essential for improving cognitive health for many individuals.

This study enhances our understanding of educational disparities in cognitive functioning, accounting for differential survival at older ages, by estimating cognitive health expectancies across European countries. Special emphasis is placed on contrasting the disparities in Central and Eastern European countries with countries of other European regions, each representing unique contextual environments due to their historical, political, and cultural contexts. To our knowledge, this is the first study to calculate gender- and education-specific Cognitive Health Expectancies (CHE) within a comparative European framework.

Background

Education as a Modifiable Risk Factor for Cognitive Impairment

Educational attainment is widely recognized as one of the most significant early life determinants of dementia risk, with a robust inverse association between education and dementia incidence (Livingston et al., 2020). This relationship operates through two primary pathways: direct and indirect.

Education has the potential to improve brain function by creating enriched environments that offer a variety of opportunities (sensory, cognitive, and social) for engagement and learning, and thus increasing the number of synapses. Through this direct pathway, often referred to as cognitive reserve (Stern, 2009), education offers a coping mechanism that allows individuals with higher education to delay the clinical onset of dementia, despite having equivalent neuropathology (Brayne et al., 2010). However, the relationship between early-life education and the state of cognitive functioning in later life is complex, with research showing mixed results on whether education is effective in impeding the rate of cognitive decline once it begins (Orsholits et al., 2022). Hence, it is equally plausible that higher educated individuals might initially delay cognitive decline but eventually experience a steeper cognitive deterioration, similar to falling off a cognitive cliff.

At the same time, education fosters essential skills and attributes that can contribute to the development of human capital. This indirect pathway highlights education's role in shaping socioeconomic trajectories and life experiences that influence cognitive health. Higher educational attainment often leads to better occupational opportunities, which can provide continuous cognitive stimulation and promote better cognitive functioning in later years (Fisher et al., 2014). Additionally, individuals with more education are likely to earn higher incomes, which facilitate access to healthcare, quality nutrition, and improved living conditions, all of which indirectly support cognitive resilience (Aranda et al., 2021; Klee et al., 2024; Zhao et al., 2021). Education also fosters health literacy, enabling individuals to adopt health-promoting behaviors and effectively navigate complex healthcare systems, further reducing the risk of cognitive decline (Berkman et al., 2011).

Empirical evidence highlights significant educational disparities in cognitive health, primarily within the United States context. Crimmins et al. (2018) found that higher education levels are linked to a lower prevalence of dementia, more years of cognitive health, and fewer years affected by dementia. Similarly, Hale et al. (2020) reported that educational attainment reduces the numbers of years with impairment, lowers the risk of cognitive impairment, and delays its onset. Evidence also suggests that education postpones the incidence of dementia with a greater effect than that of lifespan extension, thereby resulting in the compression of the proportion of life spent with cognitive impairment (Reuser et al., 2011).

Although the European context has been less extensively explored, findings consistently demonstrate the importance of education to cognitive health. Between 2007 and 2017, education accounted for approximately 20% of the cognitive improvements observed among older Europeans (Rehnberg et al., 2024). While the expansion of education is consistently recognized as a primary contributor to positive cognitive trends in European populations, education alone might not provide a comprehensive explanation, as previous research has suggested the importance of broader social and contextual factors (Myrskylä et al., 2024).

Heterogeneity in Educational Health Disparities

Indeed, the importance of broader social and contextual factors becomes evident when examining how the relationship between education and health varies across populations. This relationship is likely to be modified by selection effects and contextual factors that influence how individual resources translate into health advantages. The East-West health divide in Europe presents a particularly compelling case for examining this heterogeneity.

Decades of political, economic, and social turbulence have created distinct contextual environments in Central and Eastern European (CEE) countries that may modify how education and gender relate to cognitive health compared to other European regions. CEE countries have persistently lagged behind Western Europe in most health domains, with life expectancy gaps of

5-7 years and higher rates of premature mortality (Mladovsky, 2009). However, cognitive health appears to deviate from this pattern, with some research suggesting that Eastern Europeans may have lower rates of cognitive impairment, potentially due to shorter life expectancy (Sakkeus et al., 2023). Despite this apparent advantage in cognitive health, CEE countries demonstrate larger educational disparities in mortality and other health indicators compared to other European regions, with some of these disparities being up to twice as large as those observed in the West (Mackenbach, 2017; Stonkute et al., 2023). To date, the evidence on cross-country variation of educational disparities in cognitive health in Europe, and more broadly, is limited.

However, there are compelling reasons to believe that educational inequalities in cognitive health differ across Europe, as various mechanisms influencing these disparities are at play. Some of these mechanisms may suppress educational inequalities, while others may expand them. One such factor that may suppress disparities in the CEE context is survival selection. It is well documented that CEE countries have long faced higher rates of alcohol-related disease and death (Jasilionis et al., 2011). More hazardous drinking patterns, such as binge drinking and consumption of high-alcohol beverages, are one of the main drivers (Popova et al., 2007). In connection to alcohol-related disease patterns, individuals with lower levels of education and particularly men are disproportionately affected by cardiovascular mortality (Fihel & Pechholdová, 2017). This selective survival may result in an apparent reduction in the educational gradient, as the most vulnerable individuals are unlikely to survive long enough to be part of the at-risk population for cognitive impairment (Sakkeus et al., 2023). On the other hand, it is more speculative to what extent educational disparities in cognitive health would manifest for women in CEE countries, where life expectancy and lifespan variation reflect a substantial female advantage (Zazueta-Borboa et al., 2023), albeit highly gendered opportunities for cognitive reserve accumulation (Bertogg & Leist, 2023; Fodor & Balogh, 2010). Specifically, due to re-traditionalization of gender norms, women in CEE countries may encounter labor market constraints that restrict their cognitive engagement.

Moreover, despite higher overall educational attainment, the direct economic advantages typically associated with higher educational attainment, such as better income and career opportunities, have not been observed in the CEE countries. The reasons for this can be traced back to Soviet-era policies characterized by strong wage regulations and a demand for manual over skills-intensive jobs (Kogan et al., 2011). Even after transitioning to market economies, the benefits enjoyed by highly educated individuals in CEE countries remain comparatively modest compared to their European counterparts (Cambois et al., 2016). Thus, against such backdrop of limited educational returns, one could hypothesize that the cognitive health of the highly educated might align closely with those of lesser educational attainment. However, since higher education is well-established to improve cognitive reserves, the effect of education on cognitive health in these contexts remains an empirical question, depending on the prevailing direct and indirect mechanisms linking education with cognitive health.

Indeed, other mechanisms can expand educational disparities, operating through two main mechanisms: disadvantage accumulation among the less educated and advantage accumulation among the highly educated. In the contexts of relatively weak health and welfare systems, the less educated lack the resources to compensate for institutional deficiencies (Beckfield et al., 2015), while the more educated are better able to navigate these and compensate for systemic healthcare deficiencies due to cultivated human capital and adaptive skills (Shkolnikov et al., 2006), thus maintaining a "disability advantage" (Cambois et al., 2016). Additional factors compound the disadvantage of less educated groups, such as higher exposure to risk factors like hazardous alcohol consumption (Jasilionis et al., 2011), a pattern exacerbated by historical difficulties in implementing effective public health campaigns in CEE countries (Meslé & Vallin, 2017). Lastly, the early educational expansion under socialism reduced the proportion of people with low educational attainment, leading to an increasing concentration of health disadvantage within this smaller group. Similar trends, driven by marginalization and selection effects (Mackenbach, 2019), are also observed in the Nordic countries (Mackenbach, 2017).

Gender, and in particular how it is socially constructed in different societies, is another contextual factor that can reinforce or suppress educational inequalities in cognitive health. In particular, in CEE countries, where education has been highly institutionalized, those with low levels of education have faced significant systemic disadvantages, not only in terms of cognitive reserve, but also in terms of access to wider health benefits, regardless of gender (Shkolnikov et al., 2006). This contrasts with Southern European countries, where low educational attainment was historically more common due to late educational expansion, with particularly low educational participation among women.

Furthermore, in CEE countries, gender-specific survival patterns show a much stronger advantage in life expectancy for women compared to other European countries. However, women in CEE countries often faced restricted opportunities for cognitive engagement due to re-traditionalized gender roles (Fodor & Balogh, 2010). The interplay between the accumulation of cognitive reserve, its differential depreciation through life course exposures, and selective survival due to competing causes of death created a complex pattern. Specifically, among men in CEE countries, those with low education levels were at higher risk of unhealthy behaviors, particularly excessive alcohol consumption (Popova et al., 2007). This led to high alcohol-related mortality among low-educated men (Fihel & Pechholdová, 2017), ultimately removing them from the at-risk population for cognitive decline, and leaving alive a selected of group of individuals (Sakkeus et al., 2023). In contrast, women's longer survival combined with restricted opportunities for cognitive engagement could amplify educational inequalities in cognitive health. Given this context, it can be hypothesized that the cognitive health disparity between low- and highly educated women in CEE countries is greater than that among men in CEE countries and greater than that in other European countries.

This study examines educational disparities in cognitive health across Europe by estimating gender- and education-specific Cognitive Health Expectancy (CHE) in 10 European countries. Our primary aim is to investigate whether the magnitude of educational disparities in cognitive health for men and women varies systematically across different European contexts, with a particular focus on comparing CEE countries to those in other regions. Given evidence on both suppressing and amplifying mechanisms of educational disparities in cognitive health, we explore the following questions:

1. How do gender-specific educational disparities in Cognitive Health Expectancies (CHE) within individual CEE countries compare to those observed in countries of other European regions?
2. How does the relationship between education level and CHE differ by gender within individual countries?

Our study makes three distinct contributions to the literature. First, we provide novel comparative evidence on educational disparities in cognitive health in Europe, accounting for the differential survival by education. We estimate cognitive health expectancies through a methodological approach that allows us to exploit the Survey of Health, Ageing and Retirement in Europe (SHARE) as a harmonized single data source. Second, by focusing on the European East-West divide, we shed light on how distinct historical, social, and institutional contexts may modify the relationship between education and cognitive health. Third, our gender-specific approach offers insights into how cognitive health differs between genders in contexts with strong female survival advantage but historically gendered opportunities for cognitive reserve accumulation.

Data and Methods

Study Population

This study utilizes data from the SHARE, a comprehensive cross-national longitudinal survey covering 28 European countries. A harmonized dataset was obtained from the Gateway to Global Aging Data (Gateway; g2aging.org). SHARE provides information on demographic, socioeconomic, and health measures, as well as vital status for individuals aged 50 and older in private households. Additionally, by conducting end-of-life interviews, it collects detailed information on deaths. The survey, initiated in 2004, has been conducted biennially, with the exception of Wave 3 (SHARELIFE), which focused on life histories. More details of the design and survey methods are described elsewhere (Börsch-Supan et al., 2013).

The use of a single data source for both mortality estimates and cognitive impairment prevalence offers a significant advantage by avoiding potential biases associated with dual data sources (Hendi, 2017). Although SHARE serves as the primary data source for both estimates, the analytical samples for mortality and cognitive impairment prevalence were prepared differently due to specific methodological requirements, as described below.

Mortality Sample

For mortality analysis, we combined data from either Wave 1 (2004) or Wave 4 (2010) to Wave 8 (2019), depending on when each country first participated in the survey. In this study we included only those countries where the population-level life expectancy estimates derived from SHARE mortality information closely matched those provided by the Human Mortality Database (HMD) (see Supplementary Materials Fig. S1). Additionally, countries were selected only if they had participated in the survey since at least Wave 4 and had not missed more than one consecutive round of participation, as this criterion was integral for estimating death probabilities. The final set of countries includes Austria, Belgium, Czechia, Denmark, Estonia, France, Italy, Slovenia, Spain, and Sweden.

To ensure compliance with the methods used, we restricted the analytical sample to individuals with survival information for at least two consecutive time points, excluding those with non-consecutive or single-time observations (N=30,547). Finally, we excluded individuals with a baseline age below 50 (N=2,908), leaving the final sample of 196,859 person-wave observations, corresponding to 59,439 persons.

Cognitive Impairment Sample

We use Wave 5 (2013) for our analysis of cognitive impairment prevalence. Proxy-assisted responses or impaired test conditions invalidate the direct measurement of individual cognitive function, compromising both internal validity and the reliability of cross-participant comparisons. Therefore, we excluded observations with proxy responses, impaired testing conditions, or missing cognitive test data (N=7,160). For more details, see Supplementary Materials Fig. S2. Additionally, 114 observations were removed due to missing weights, leaving a final sample size of 39,212.

The use of Wave 5 was chosen for several reasons. First, CEE countries joined the survey in later waves, thus using Wave 5 ensures that the cognitive test is not administered for the first time to all respondents in these countries, which is crucial for accurately adjusting for practice effects. Second, Wave 5 was conducted in 2013, which corresponds to a midpoint population of the analyzed mortality period, aligning with the interpretative framework of life tables and allowing for a cross-sectional assessment.

Measures

Cognitive function was assessed using a measure based on the modified Telephone Interview for Cognitive Status (TICS-m). The TICS-m has been empirically validated for cognitive screening in epidemiolocal research and as a reliable neuropsychological cognitive functioning metric (Plassman et al., 1994). The TICS-m measure is comprised of four tests: immediate (0–10 points) and delayed word recall (0–10 points), serial-7s substitution test (0–5 points), and counting backward (0–2 points). However, as SHARE data did not include the counting backward test, the composite score ranged from 0 to 25 points, with higher scores reflecting better cognitive function.

All analyses are stratified by gender and educational level, based on the International Standard Classification of Education (Unesco, 2012). The categories were as follows: low education (lower secondary education or less, ISCED 0-2); medium education (upper secondary or vocational training, ISCED 3-4); and high education (tertiary education or higher, ISCED 5-6).

Analytical approach

Prevalence of Cognitive Impairment

To estimate the prevalence of cognitive impairment, we first established thresholds for cognitive impairment, defined as a weighted 1.5 standard deviations (SD) below the weighted mean of cognitive scores for individuals aged between 50 and 69 years old. These thresholds were stratified by country and gender. Individuals scoring below this threshold were classified as having cognitive impairment. The 1.5SD threshold is consistent with the guidelines established by the International Working Group on Mild Cognitive Impairment (MCI) (Dunne et al., 2021) and produces prevalence of MCI consistent with previous findings (Langa et al., 2005) using a comprehensive neuropsychological assessment (Crimmins et al., 2011).

Next, to adjust for potential practice effects, we used inverse probability weighting (IPW). Country-specific logistic regression models estimated the probability of an individual taking the cognitive test for the second time or more, with age and the interaction between gender and education level as covariates. Such an approach aims at eliminating compositional differences in practice effects across the covariates entering the estimation of the cognitive impairment thresholds.

Finally, we estimated the prevalence of cognitive impairment across different gender and education groups using logistic regression. These estimates were weighted combining survey weights and IPW, ensuring representativeness of the underlying population.

Multivariate Life Table

To estimate the survival probability by age, gender and education, we used the mortality sample. The construction of multivariate life tables involved several steps, similar to Brown et al. (2012). First, we estimated discrete-time survival models for each country and gender separately using a complementary log-log link function. This link function is particularly well-suited for modelling events with increasing hazard rates over time, such as adult mortality, because it effectively captures the exponential nature of these hazards, similarly to the Gompertz distribution (Tutz et al., 2016).

The models included age, age squared, and education level as covariates. Using the fitted models, we predicted age-specific death probabilities for each education group. Given the biennial panel structure of the data, we employed two-year age intervals for these predictions.

Next, we used these predicted death probabilities to construct period life tables employing the multivariate life table approach (Teachman & Hayward, 1993). This approach enables us to simulate lifetimes within a synthetic cohort of 500,000 individuals and thus to calculate key life table quantities by gender and education. Each individual in the age interval [50-52) survives to the next age interval [52-54) if their predicted probability of death is lower than a random draw from a uniform distribution. This way we determined the number of survivors to the next age group and calculated other life table functions. We repeated this process for the remaining age intervals, closing the life table at the open age group of 86+. In this setup, the approach used is similar to a standard method for computing period life tables (Preston et al., 2001).

Health Expectancy

Finally, we used the Sullivan method (Sullivan, 1971) to estimate cognitive health expectancies (CHE) by combining the age-specific life table and the prevalence of cognitive impairment information. CHE represents expected number of years without cognitive impairment, while cognitively impaired life expectancy (CILE) – the difference between total life expectancy and CHE – shows expected years with impairment.

Confidence intervals were obtained using a nonparametric bootstrap approach (Cameron & Trivedi, 2005) by resampling the data 1000 times while maintaining the cohort structure. All the analyses were conducted using R language (version 4.1.1).

Results

The dataset used to estimate survival probabilities comprised 196,859 person-wave observations of individuals aged 50 and over from 10 European countries (see Table 1). Despite the later inclusion of Central and Eastern European (CEE) countries in SHARE, their sample size is large and the number of observations is comparable to other countries, with the exception of Slovenia, which had the fewest observations.

There was considerable variation in educational composition between countries. CEE countries were characterized by a high proportion of individuals with a medium level of education. In contrast, Southern Europe showed a highly skewed distribution, with about 80 per cent of both men and women having a low level of education. Other countries showed a more balanced educational composition. In all regions, women were generally more likely than men to report lower levels of education.

Table 1. Sample size and educational composition (%) of the analytical sample used for survival estimation.

	Women					Men				
	Person-wave observations	Deaths	Low	Medium	High	Person-wave observations	Deaths	Low	Medium	High
Czechia	11,342	573	44.8	44.8	10.3	8,098	628	39.4	43.7	16.9
Estonia	13,915	789	28.5	48.8	22.7	9,438	844	31.7	46.7	21.6
Slovenia	7,235	247	42.5	42.7	14.8	5,531	325	25.3	57.7	17.0
Austria	9,951	409	34.4	44.5	21.1	7,344	405	15.1	54.6	30.3
Belgium	14,133	584	44.4	26.9	28.7	11,828	638	39.9	26.1	34.0
Denmark	8,695	574	25.8	32.6	41.7	7,572	556	14.3	47.6	38.1
Sweden	9,532	547	40.8	29.8	29.4	8,399	643	44.5	29.5	26.0
France	11,298	429	50.2	30.1	19.7	8,711	488	39.2	38.3	22.5
Italy	10,995	462	74.1	19.7	6.2	9,320	560	71.0	21.5	7.5
Spain	12,833	763	84.5	7.8	7.8	10,689	872	79.0	10.5	10.4

Note: data came from a pooled sample of Waves 1, 2, 4, 5, 6, 7, and 8.

Despite having on average lower educational attainment, women generally had higher cognitive scores and higher thresholds for cognitive impairment, with the exception of Spain and Italy (see Table 2). Southern European countries exhibited the lowest cognitive scores and the lowest thresholds for cognitive impairment, which differed substantially from other countries. Countries from other regions, while having scores and thresholds higher than Southern European countries, did not exhibit any clear leading country, with average composite scores and thresholds falling closely together.

Table 2. Key descriptive statistics of the analytical sample used to estimate prevalence of cognitive impairment.

	Women			Men		
	N	Cognitive score, mean	Threshold	N	Cognitive score, mean	Threshold
Czechia	2,909	14.1	10.4	2,033	13.8	9.9
Estonia	2,979	14.1	10.3	1,823	13.4	8.7
Slovenia	1,457	13.0	8.7	1,135	12.8	8.0
Austria	2,171	15.5	11.2	1,557	15.0	10.7
Belgium	2,614	14.5	10.3	2,165	14.1	9.9
Denmark	1,916	15.3	11.0	1,665	14.4	10.4
Sweden	2,109	14.7	10.7	1,848	13.5	9.7
France	2,211	13.8	9.5	1,673	13.4	9.1
Italy	2,100	12.3	7.7	1,828	12.3	8.2
Spain	2,393	11.2	6.6	2,355	11.4	6.8

Note: data came from Wave 5. The mean cognitive score was estimated for all individuals aged 50 or over. The threshold was defined by 1.5 standard deviations below the mean cognitive score estimated for ages 50-69. Individuals with scores below this threshold within the respective countries were categorized as cognitively impaired.

Cross-country Heterogeneity in Educational Disparities in Cognitive Health Expectancies

CEE (Czechia, Estonia, and Slovenia) countries demonstrated one of the largest educational disparities in CHE at age 50 (for estimates, refer to Supplementary Materials Table S1). Slovenia exhibited the most substantial gap, particularly for women, with a 15.6-year difference in CHE between high and low education groups (see Fig. 1). Other CEE countries, Estonia and Czechia, also showed substantial disparities for both genders, with a range of 8.8 to 11.5 years observed between individuals with low and high levels of education. This disparity becomes even more pronounced when considering relative measures – the proportion of remaining life expected to be spent cognitively healthy (see Fig. 2). Low-educated Estonian women could expect to spend a much smaller portion of their remaining life in good cognitive health—around 65% compared to 86% for highly educated women.

Nordic countries demonstrated smaller educational disparities. Sweden demonstrated the smallest educational gap for women and the second smallest for men, after Belgium. In addition, regardless of education level or gender, individuals in Sweden could expect to spend between 80-90% of their remaining life cognitively healthy.

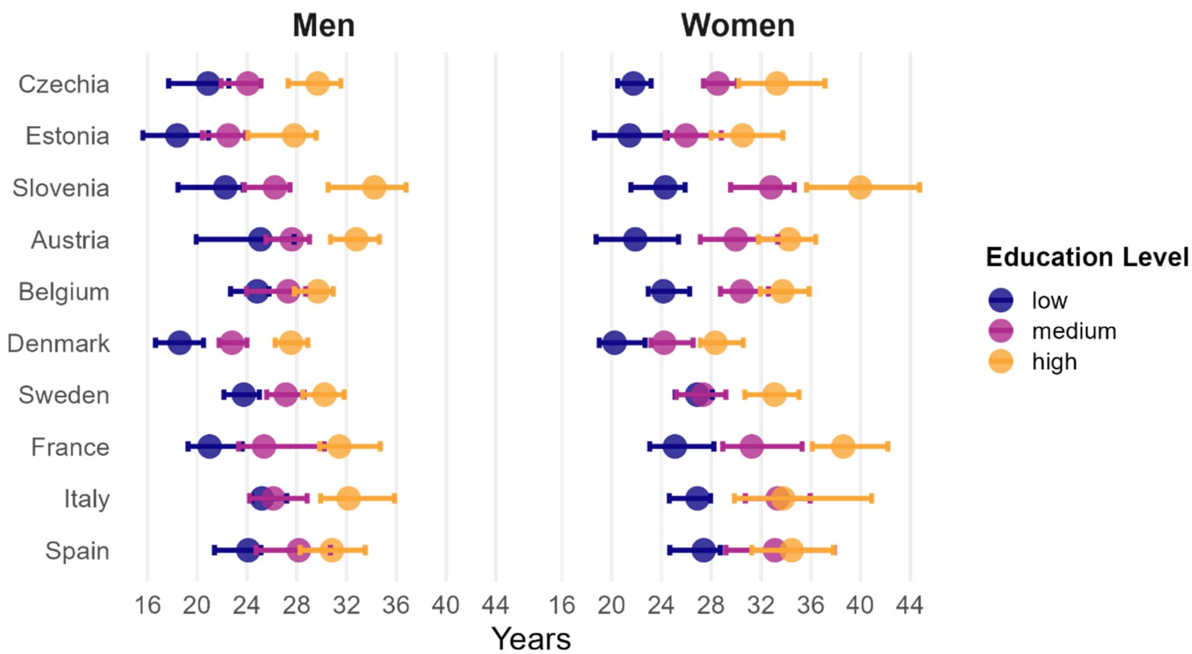

Fig 1. Remaining cognitive health expectancy (CHE) at age 50 with 95% CI, by education and gender.

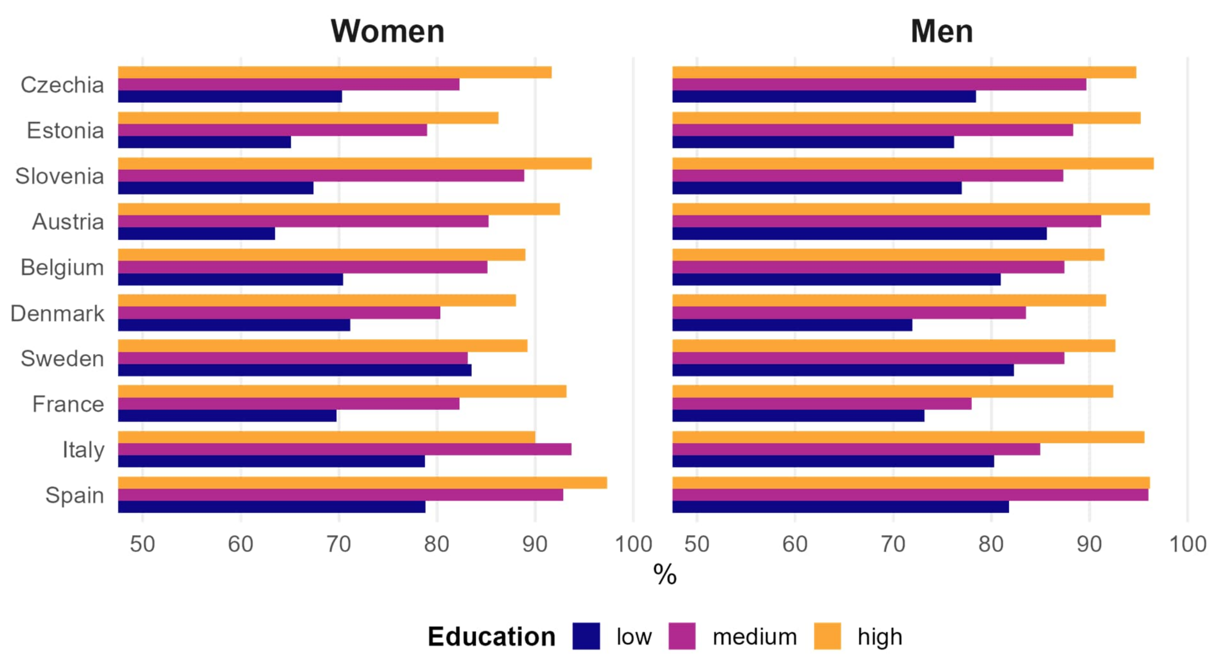

Fig 2. The percentage of remaining life expectancy without compromised cognitive health at age 50, by education and gender.

Southern European countries (Italy and Spain), indicated modest absolute educational disparities in CHE of around 7 years for both men and women. However, France presented a diverging pattern, particularly for women, where low-educated women at age 50 could expect 25.1 years of healthy cognitive life, compared to 38.6 years, for those with high education – a substantial 13.5-year gap.

The educational disparities in CHE observed in Western Europe (Austria and Belgium) were found to be mixed. On one hand, men in Belgium demonstrated the smallest educational gap in absolute measure of CHE (4.9 years), while men in Austria exhibited moderate magnitude of disparities (7.7 years). However, patterns for women were vastly different – Austria experienced the highest educational gap in relative length of cognitive health (29 percent point difference between women with low and high levels of education).

Gender Differences

Beyond variations across countries, our analysis revealed distinct patterns in how educational disparities in CHE manifested by gender. In Northern (Denmark and Sweden) and parts of Southern Europe (Italy and Spain) gender differences were relatively balanced. These countries either exhibited comparable levels of educational inequality for both genders or, in Denmark's case, a marginally larger educational gap (0.8 years) among than compared to women.

In other countries, however, the magnitude of educational disparities showed marked gender differences, with women facing larger disparities than men. This was particularly evident in CEE countries. In Slovenia and the Czechia, women experienced a 2.7-3.7-year greater educational gap in CHE between the low and high educated than men. A wider educational disparity was also observed when looking at the length of CHE relative to remaining life expectancy. In Slovenia, for example, low-educated women could expect to spend only 67.4 per cent of their remaining life without cognitive impairment, compared to 95.8 per cent for highly educated women.

However, it is important to note countries such as Austria, Belgium and France, where women experienced educational disparities in CHE that were almost twice as large as those experienced by men.

The estimates of CHE relative to residual life expectancy in Fig. 2. reveal a distinctive pattern in the distribution of cognitive health across education levels. For women with medium education, the share of remaining life without compromised cognitive health was slightly shorter compared to those with high education. However, women with low education demonstrated substantially lower relative estimates, highlighting a greater disadvantage at the lower end of the educational gradient.

For women with a low level of education this creates a double disadvantage: they live shorter lives and experience a greater share of their lives with cognitive impairment, compared their highly educated counterparts. In CEE countries, a pattern of cognitive disadvantage for low-educated women was particularly pronounced, though it was observed in nearly all countries

Discussion

This study investigated educational differences in cognitive health across ten European countries. Specifically, we contrasted Central and Eastern European (CEE) countries with countries from other regions. Furthermore, we assessed the role of gender on educational and regional differences in Cognitive Health Expectancies (CHE). Using data from SHARE, we estimated education- and gender-specific CHE at age 50 and analyzed educational disparities in both absolute and relative measures of CHE.

Building on previous research, this study expands current knowledge by helping us better understand cognitive health through demonstrating how educational disparities in cognitive health manifest heterogeneously across different contextual settings. The observed patterns of educational disparities in CHE reflect the interplay of historical, social, and demographic forces unique to each country. These variations may stem from differences in cognitive reserve accumulation and its depreciations across cultural and institutional settings, as well as from selective survival processes that determine which population groups remain exposed to the risk of cognitive impairment. Together, these factors highlight the structural and individual-level processes driving inequalities in cognitive health across Europe.

In line with this theoretical framework, one of the largest educational inequalities observed were in CEE countries. However, rather than indicating a general suppression of disparities due to limited educational rewards, these patterns suggest that individuals with medium to high educational attainment in CEE countries experience relatively favorable cognitive health outcomes, comparable to their counterparts in other European regions. The key divergence emerges among those with low educational attainment, who appear to be highly disadvantaged. This may reflect the selective nature of low education in CEE countries, where individuals with limited formal schooling are more likely to belong to marginalized populations facing individual-level barriers, such as lifestyle-related risk factors (Jasilionis et al., 2018), rather than structural constraints. By contrast, in Southern European countries (except France), where low education was historically widespread due to delayed educational expansion, observed educational disparities were comparatively smaller.

The shorter life expectancies in CEE countries, particularly among lower-educated men, shape the population surviving to older ages when cognitive impairment risks peak. In these countries, men and individuals with lower levels of education are disproportionately affected by health issues related to excessive alcohol consumption and smoking, contributing to higher rates of cardiovascular mortality (Fihel & Pechholdová, 2017) and larger inequalities (Di Girolamo et al., 2020). As cardiovascular and cardiometabolic conditions are significant risk factors for cognitive impairment and dementia (Livingston et al., 2020), the high cardiovascular mortality linked to deleterious health behaviors among low-educated men may result in them not surviving to experience cognitive impairment. This distinctive survival selection pattern becomes particularly evident when considering the proportion of remaining life expected to be spent cognitively healthy at age 50. While low-educated men and women have similar CHE, women's longer survival means they spend a higher share of their residual life with cognitive impairment than men. This pattern aligns with recent findings that, despite longer survival, women experience higher rates of dementia-related disability (Patwardhan et al., 2024; Sharma et al., 2023).

Beyond survival selection, the choice of our methodological approach also plays a role in interpreting the observed patterns of educational disparities in CHE. Our estimation of cognitive impairment uses country- and gender-specific thresholds (1.5 standard deviations below the mean), meaning these thresholds inherently vary across contexts. In countries with predominantly lower-educated populations, such as Southern Europe, the composite cognitive scores are lower, resulting in lower thresholds for cognitive impairment. While this means the absolute cognitive score representing impairment differs between countries, our focus is on comparing the magnitude of educational disparities rather than cross-national prevalence rates.

This approach allows us to examine how individuals are positioned relative to their peers within their specific context, as the relationship between education and cognitive impairment is closely linked to the distinct challenges and expectations of an individual's environment. For instance, in a society where complex cognitive tasks remain common in late life, inability to perform such tasks would represent a significant disadvantage. Conversely, if such decline is normative within a context, it may not represent the same degree of relative disadvantage. These context-specific disparities align with Sharp and Gatz (2011) suggestion that education serves as a proxy for life-course trajectories influencing cognitive capacity and risk factors, beyond formal educational attainment.

Our interpretative framework is evident in Southern European countries, which reflect distinct historical and social contexts within Europe. In these countries, low educational attainment was normative for older cohorts, with a majority of the population having limited formal education. This educational composition means that having low education carried less social disadvantage, as it represented the common experience rather than a marker of marginalization. Additionally, these countries experienced a delayed socio-economic modernization, particularly evident in health behaviors. For instance, smoking retained social prestige longer than in other European regions, resulting in higher smoking-related mortality among the higher educated in older cohorts, contrary to the typical social gradient (Kulhanova et al., 2014). This combination - the normative nature of low education and the reversed social patterning of health behaviors - contributes to the smaller educational inequalities in CHE observed in Southern European countries, contrasting sharply with the patterns seen in CEE regions.

In contrast, contextual environments of CEE countries highlight how low-educated women substantially deviate from their medium- and higher-educated counterparts. Previous research has suggested that women's cognitive health at older ages is better in countries with more equal gender role attitudes, with this effect mediated through educational attainment and labor force participation (Bertogg & Leist, 2023; Bonsang et al., 2017).

The collapse of the Soviet Union and the subsequent transition period in the CEE countries had distinctly gendered implications. The re-traditionalization of gender roles (Fodor & Balogh, 2010) disproportionately affected women, especially those with lower educational levels, by limiting their access to cognitively stimulating activities and economic resource. Simultaneously, the restructuring of welfare systems in CEE countries often resulted in less comprehensive social safety nets compared to their Western European countries (Beckfield et al., 2015; Beckfield & Krieger, 2009). This reduction in social support left individuals, particularly those with lower levels of education, more exposed to health risks and with fewer resources to mitigate cognitive decline. The intersection of disadvantages in educational and occupational opportunities, shifting gender norms and varying social support shapes cognitive reserve accumulation and its depreciation over the life course, leading to compounded vulnerability for women across Europe, particularly in CEE countries.

Importantly, while our findings highlight the substantial disadvantage of low education for women, they also reveal the persistent protective effect of high education for both genders in CEE countries. Even in contexts where immediate occupational and income benefits of high education are limited, education, with its fundamental contribution in building cognitive reserve, may equip individuals with skills to better navigate complex systems, including healthcare, thereby mitigating cognitive risk factors such as cardiovascular conditions (Shkolnikov et al., 2006).

Strengths and Limitations

This study has several notable strengths. First, our use of a single harmonized data source (SHARE) enables robust cross-national comparisons of educational inequalities in cognitive health expectancies. This approach avoids potential biases associated with dual data sources (Hendi, 2017), enhancing the reliability of our findings. Second, we carefully selected countries based on mortality data quality, ensuring reliable estimates by comparing our calculations with Human Mortality Database (HMD) reference populations (see Supplementary Materials Fig. S1). Third, we implemented inverse probability weighting to adjust for practice effects in cognitive testing. This addresses a common methodological challenge in longitudinal studies of cognitive function. The sensitivity analyses conducted indicated that the failure to account for practice effects would have resulted in an overestimation of CHE in certain countries, with the overestimation being particularly pronounced for women, thus emphasizing the necessity for this adjustment (see Supplementary Materials Fig. S3).

However, some limitations should be acknowledged. As with all survey data, our study inherits certain selectivity issues. The SHARE sample likely represents a healthier subset of the population, as individuals with severe health problems are less likely to participate in surveys. Furthermore, SHARE's sampling frame only includes individuals in private households, systematically excluding those in institutions such as nursing homes or long-term care facilities. This limitation is particularly relevant for studying cognitive health, as institutionalized older adults are more likely to experience cognitive impairment. The resulting underrepresentation of individuals with severe cognitive decline could potentially affect the magnitude of educational disparities observed. If present, such bias would likely result in an *under*estimation of educational inequalities.

As a longitudinal survey, SHARE also faces the common challenge of participant dropout between waves. This attrition is unlikely to be random - individuals who drop out may systematically differ from those who continue participation. Of particular concern is that attrition rates often correlate with both educational level and cognitive status. Those with lower education and poorer cognitive function may be more likely to drop out. Cognitive impairment was measured using cross-sectional data from Wave 5 (2013), thereby effectively minimizing attrition concerns, as there was no requirement to track participants over time.

The more significant attrition challenges arise in the mortality analysis, which combines data across multiple waves. Of particular concern is that those with lower levels of education may be more likely to be lost to follow-up, potentially leading to underestimation of mortality rates among lower educational groups, and more so in some countries than others. To better understand possible biases due to selective attrition, we performed sensitivity analysis examining education-specific life expectancy estimates for each country-gender group by adjusting for attrition. In order to adjust for attrition, inverse probability weighting (IPW) was applied. Country-gender-specific logistic regression models were used to estimate the probability of the loss to follow-up (alive but non-respondent or unknown status) based on the interaction of education with age and the quadratic term of age as covariates. This methodological approach serves to eliminate compositional differences by covariates considered in the analytical sample between those lost to follow-up and those remaining in the sample. This process effectively mitigates any potential bias from differential dropout rates across subpopulations. We then replicated life expectancy estimates by incorporating IPW weights into discrete-time survival models. The resulting estimates are qualitative and quantitatively indistinguishable, indicating that attrition did not bias our life expectancy estimates (see details in Supplementary Materials Fig. S4).

It should also be noted that while differences in life expectancy between SHARE and HMD within a two-year range were accepted as reasonable given the biennial nature of the panel, life expectancy estimates for women in Slovenia and Denmark slightly deviated from the specified benchmark. This may influence the observed educational disparities therein.

Lastly, while the geographical coverage is substantial, it is limited to ten European countries that met specific data quality criteria, of which only three are CEE countries, potentially limiting the generalizability of the results.

Building on our findings, future research should further explore the impact of education on cognitive health in CEE countries. In particular, it will be crucial to disentangle the effects of mortality selection and to examine how the rates of cognitive decline differ by gender and educational attainment.

In summary, substantial educational inequalities in cognitively healthy life years across Europe reveal complex, context- and gender-specific patterns, challenging universal frameworks of educational disparities in cognitive health. Despite lower returns on education in Central and Eastern Europe, these countries exhibit one of the greatest disparities, particularly among women, reflecting compounded educational and gender disadvantages. In contrast, smaller disparities in Nordic and Southern Europe suggest that institutional contexts and social policies can mitigate these inequalities. Our findings also emphasize that the protective effect of education extends beyond immediate socioeconomic rewards, potentially equipping individuals with resources to better navigate health systems and maintain cognitive function throughout life. These findings highlight that large educational disparities in cognitive health are not inevitable and underscore the need for targeted policy interventions, especially in CEE countries, to promote more equitable cognitive aging across Europe.

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Supplementary Material

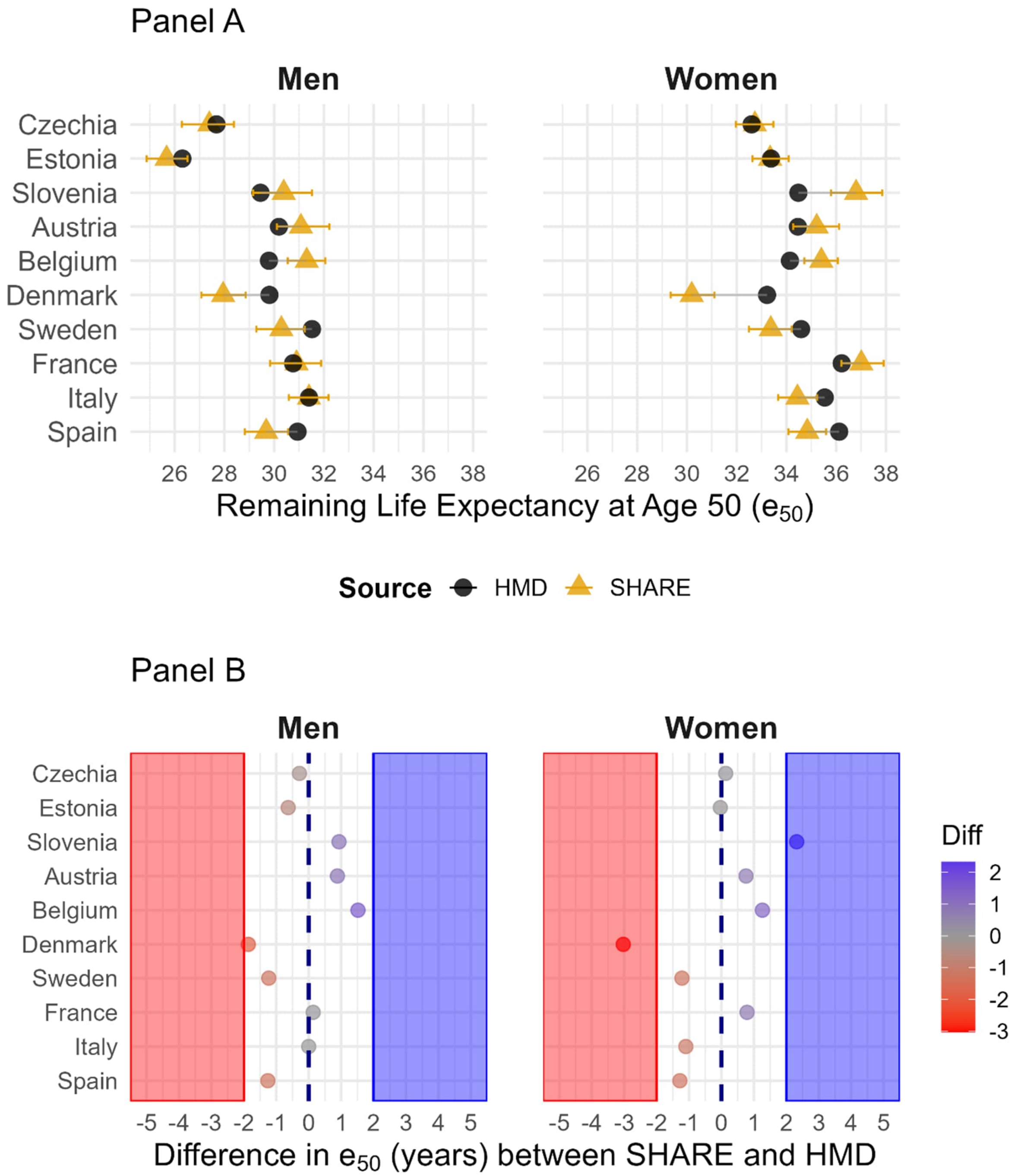

Fig S1. Remaining Life Expectancy at Age 50 Comparison and Differences between SHARE and HMD Estimates.

Panel A presents life expectancy estimates and 95% confidence intervals derived from SHARE data alongside corresponding estimates from the Human Mortality Database (HMD). To ensure comparability, we selected single-year complete life tables for a calendar year that best represented the midpoint population, based on each country's period of participation in the SHARE survey.

Specifically, for countries covered by SHARE data from 2004 to 2019, we used HMD life tables from the year 2012, whereas for countries with SHARE data from 2010 to 2019, we used HMD life tables from 2015. It is important to note that the HMD provides life tables in either single-year or five-year age groups. However, our analysis required life tables in two-year age intervals. To address this, we utilized single-year HMD data to modify life tables in the required two-year intervals, with open age interval of 86+.

Panel B illustrates the differences in life expectancy estimates (in years) between SHARE and HMD data. The x-axis represents the magnitude and direction of the difference, indicating whether SHARE over- or under-estimates life expectancy relative to the HMD benchmark. Given that SHARE is a biennial survey, we accepted differences within a two-year range as reasonable.

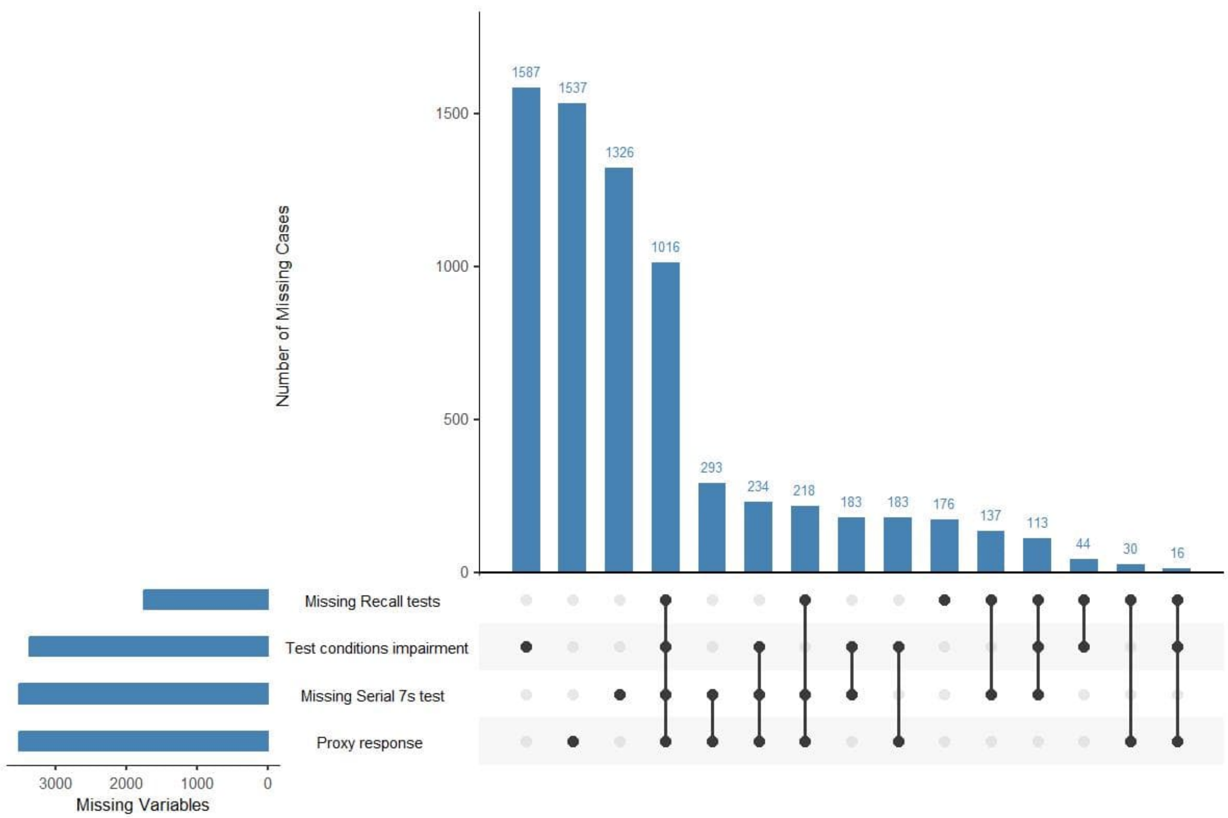

Fig S2. Information of Excluded Cases in the Cognitive Impairment Sample.

The sample was drawn from Wave 5. Vertical bars represent the frequency of missing or excluded data for specific combinations, while horizontal bars show the total number of cases for each category. Taller bars reflect more frequent missing or excluded data patterns.

Table S1. Cognitive Health Expectancy (CHE), Life Expectancy (LE), and the Share of Life without Cognitive Impairment (%) at Age 50 for Men and Women by Educational Level, and Educational Gap Therein.

	Men			Women		
	CHE	LE	Share of CHE	CHE	LE	Share of CHE
Austria						
low	25.1	29.3	85.7	21.9	34.5	63.5
medium	27.6	30.3	91.2	30.0	35.2	85.3
high	32.8	34.1	96.1	34.2	37.0	92.5
high-low	7.7	4.8	10.5	12.3	2.5	29.1
Belgium						
low	24.8	30.7	80.9	24.2	34.3	70.4
medium	27.3	31.2	87.4	30.5	35.8	85.1
high	29.7	32.4	91.5	33.7	37.9	89.0
high-low	4.9	1.8	10.6	9.6	3.6	18.6
Denmark						
low	18.6	25.8	72.0	20.2	28.5	71.1
medium	22.8	27.3	83.5	24.2	30.1	80.3
high	27.5	30.0	91.7	28.3	32.2	88.1
high-low	8.9	4.2	19.7	8.1	3.7	16.9
Sweden						
low	23.7	28.9	82.3	26.9	32.2	83.5
medium	27.1	31.0	87.5	27.4	32.9	83.1
high	30.2	32.6	92.6	33.1	37.1	89.2
high-low	6.5	3.8	10.4	6.2	4.9	5.7
Spain						
low	24.1	29.5	81.8	27.4	34.8	78.8
medium	28.2	29.3	96.0	33.1	35.7	92.9
high	30.8	32.1	96.1	34.5	35.4	97.4
high-low	6.7	2.6	14.4	7.1	0.6	18.6
Italy						
low	25.2	31.4	80.3	26.9	34.1	78.8
medium	26.1	30.7	85.0	33.3	35.6	93.7
high	32.2	33.6	95.6	33.8	37.5	90.0
high-low	7.0	2.2	15.4	6.9	3.4	11.3
France						
low	21.0	28.7	73.2	25.1	36.0	69.8
medium	25.4	32.5	78.0	31.3	38.0	82.3
high	31.4	34.0	92.4	38.6	41.4	93.2
high-low	10.4	5.3	19.2	13.5	5.5	23.4

(continued on next page)

Table S1. *(continued)*

	Men			Women		
	CHE	LE	Share of CHE	CHE	LE	Share of CHE
Czechia						
low	20.9	26.6	78.4	21.8	30.9	70.3
medium	24.1	26.9	89.7	28.5	34.6	82.3
high	29.7	31.3	94.7	33.3	36.3	91.7
high-low	8.8	4.7	16.3	11.5	5.4	21.4
Estonia						
low	18.4	24.1	76.2	21.4	32.9	65.1
medium	22.5	25.5	88.4	26.0	32.9	79.0
high	27.8	29.2	95.2	30.5	35.4	86.3
high-low	9.4	5.0	19.0	9.1	2.4	21.2
Slovenia						
low	22.3	28.9	77.0	24.3	36.1	67.4
medium	26.2	30.1	87.3	32.8	36.9	88.9
high	34.2	35.5	96.6	40.0	41.7	95.8
high-low	12.0	6.5	19.6	15.6	5.6	28.4

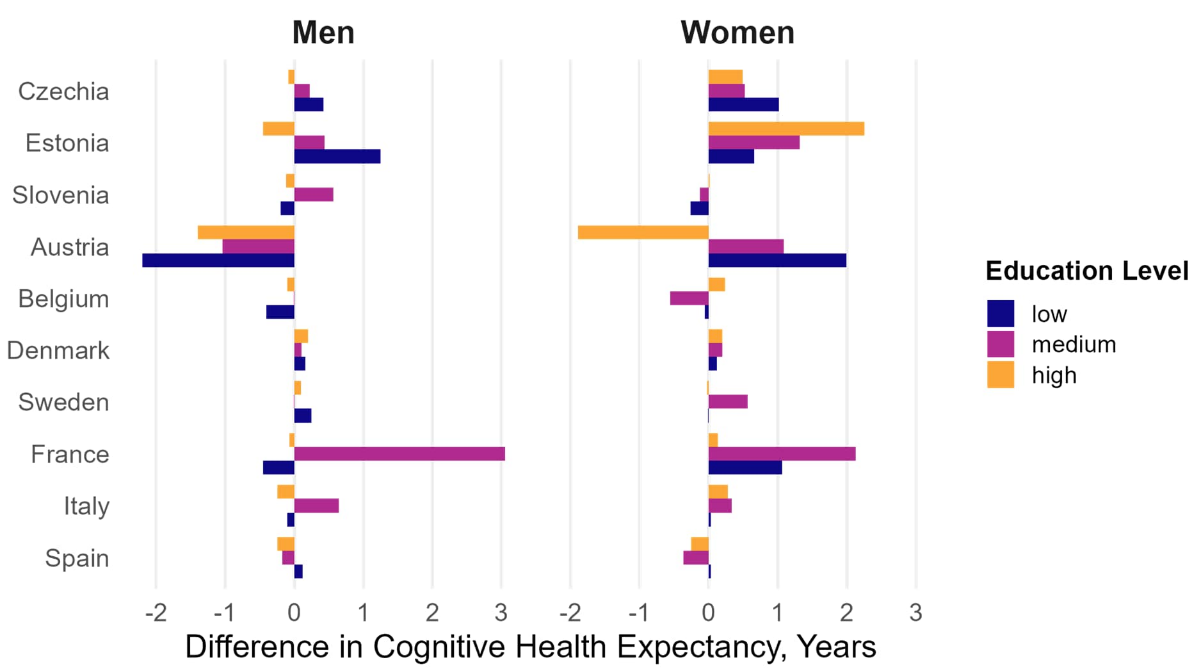

Fig S3. Differences in Cognitive Health Expectancy (CHE) at Age 50 due to Adjustments for Practice Effects in Cognitive Testing.

Differences are calculated as the subtraction of the adjusted estimates from the unadjusted estimates, with positive values indicating an overestimation of CHE before adjustment.

Fig S4. Differences in Life Expectancy at Age 50 due to Adjustments for Panel Attrition.

The impact of selective panel attrition on life expectancy estimates by country, gender, and educational level was estimated using inverse probability weighting (IPW). The analysis corrected for potential biases in mortality estimates due to differential dropout rates across subpopulations. Differences were calculated as the subtraction of the adjusted estimates from the unadjusted estimates, with positive values indicating an overestimation of CHE before adjustment.