Cognitive Impairment and the Long Arm of Childhood Education: Evidence from Europe

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Abstract:

Background: Recent strictly cross-nationally comparable and nationally representative data on cognitive health are essential for our understanding of the dementia-related challenges in healthcare but have been missing in Europe. The Survey of Health, Ageing and Retirement in Europe (SHARE) fills this gap for 27 European countries and Israel.

Methods: The SHARE parent sample included 47,773 individuals 65 years and older with identical indicators of cognition across the 28 countries. Results from an extended cognition measurement using standard diagnostic criteria for a subsample of 2,687 participants were used to weigh the indicators of the main sample to obtain prevalence estimates of mild cognitive impairment (MCI) and severe cognitive impairment (SCI) potentially related to dementia.

Findings: Across all 28 countries, prevalence of MCI was 23.9% (95% CI, 23.5-24.3), of SCI 11.0% (10.7-11.3). Rates vary greatly across Europe. SCI ranges from 4.5% in Switzerland to 22.7% in Spain, MCI from 17.2% in Sweden to 31.1% in Portugal. Every 5-year increase in age was associated with a higher probability of SCI ($p<0.0001$). Better education was associated with a dramatic decrease of MCI and SCI ($p<0.0001$).

Interpretation: New data and a strictly harmonized approach of measuring and validating cognition produced internationally comparable prevalence rates of MCI and SCI for 27 European countries and Israel in 2022 that exhibit a much larger variation of cognitive impairment across Europe and Israel than previously known. Most of this variation can be explained by differences in education when respondents were young. This finding underlines the importance of education as a pathway to prevent dementia or at least postpone the onset of cognitive decline.

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Research in context

Evidence before this study

Multi-country prevalence studies of dementia in Europe are rare. Recent prominent examples include the 2019 Global Burden of Disease (GBD), the European collaborative prevalence study of Dementia (EURODEM), European Collaboration on Dementia (EuroCoDe), the 2015 World Alzheimer Report, the 2019 Alzheimer Europe report, and studies by the Organisation for Economic Co-operation and Development (OECD). They mainly rely on epidemiological or clinical studies in each of the included countries. However, the underlying studies used are not harmonized in applied methodology, selected population, criteria for diagnosis, age groups covered, and study year. There is also a small set of studies that used earlier waves of harmonized data from the Survey of Health, Ageing and Retirement in Europe (SHARE). However, the measures in these studies suffer from a lack of a threshold defining dementia and mild cognitive impairment (MCI) that has been validated for the European context. We provide such a validation using the extensive battery of the Harmonized Cognitive Assessment Protocol (HCAP) with its standard diagnostic criteria.

Added value of this study

This study is based on the most recent harmonized SHARE data. This allows us to avoid artifacts due to differences in methodology which may bias the association between cognitive performance and socioeconomic characteristics of the individuals, specifically the respondents' educational achievements when they were young. Moreover, our measures are validated against the neuropsychological battery of HCAP to classify respondents into normal, MCI and severe cognitive impairment (SCI). Using these diagnostic criteria makes our prevalence estimates comparable to those of epidemiological and clinical studies.

Implications of all the available evidence

The geographical variation in the prevalence of MCI and SCI across Europe and Israel is substantially larger than previously estimated. The prevalence of SCI is particularly large in Spain, Portugal and Romania. These findings should raise our awareness of the large human and economic burden of

dementia which is in many European countries larger than documented so far. Most of the international variation can be explained by the large differences in education across Europe, reflecting the differences in national education systems when the respondents were young. An important pathway to prevent dementia or at least postpone the onset of cognitive decline is therefore education, in particular because education in early life puts individuals on different occupational, economic and lifestyle paths during mid and later life which have their own effects on cognition.

1. Introduction

The human burden of Alzheimer's disease (AD) and AD-related dementias (ADRD) is large. According to the Global Burden of Disease (GBD) 2019 report, AD/ADRD is the 4th leading cause of disease burden among people aged 75 years and over, and accounts for 5.6% of years lived with disability. GBD estimates 57.4 million people with dementia in 2019, the numbers nearly doubling every 20 years, to 83.2 million in 2030 and 152.8 million in 2050.[1] However, AD/ADRD does not strike countries equally. GDB 2019 reports 2270 cases per 100 000 inhabitants in Italy, 1864 in Germany and only 1698 in France.

GBD and other prevalence studies of dementia like European collaborative prevalence study of Dementia (EURODEM[2], European Collaboration on Dementia (EuroCoDe[3]), Prince et al.[4], Alzheimer Europe[5], and the Organisation for Economic Co-operation and Development (OECD[6,7]) mainly rely on systematic reviews of epidemiological or clinical studies, where inclusion and exclusion criteria are applied to select eligible studies and standardized criteria are used to diagnosis of dementia. Despite strict selection of studies, the studies used are not harmonized in applied methodology, selected population, criteria for diagnosis, age groups covered, study year and other issues that threaten the international comparability of the presented prevalence rates. These issues threaten the international comparability of the presented prevalence rates and may bias cross-national associations with risk factors for dementia, such as age, sex and education, due to artefacts generated by the lack of comparability across the involved countries.

This study makes four innovations to improve the quantification of cognitive impairment in Europe. First, we use a large cross-national dataset drawn from the most recent 2022 wave of SHARE, the Survey of Health, Ageing and Retirement in Europe (N=47,733) with identical measures of cognition. SHARE is a longitudinal population aging study that started in 2004 and is representative of the 50+ population in 27 European countries and Israel.[8] A key feature of SHARE is the strict ex-ante harmonization of instruments and protocols, which makes it a unique resource for cross-national comparisons of health and socioeconomic status.

Second, we use a new methodology to validate the measurement of cognition in the large SHARE parent study against an in-depth measurement in a smaller subsample using the Harmonized Cognitive Assessment Protocol (HCAP). HCAP has been developed by the US Health and Retirement Study (HRS) as part of an international collaboration funded by the National Institute on Aging (NIA) to harmonize the measurement of cognition in a global network of aging studies.[9,10] SHARE-HCAP is the European arm of the HCAP network of aging studies and includes an in-depth battery of cognitive tests and an informant report on cognitive functioning. It uses standard diagnostic criteria to classify respondents into normal, mild and severe cognitive impairment (SCI) associated with dementia. This validation approach sets this study apart from earlier studies using the SHARE data[11-13] which suffer from a lack of a validated threshold defining dementia for the European context whereas our approach using standard diagnostic criteria makes our estimates comparable to epidemiological and clinical studies.

The third contribution is to cross-nationally quantify mild cognitive impairment (MCI). Individuals with MCI are at an increased risk of developing dementia as age progresses.[14] Measuring MCI sets our study apart from other recent European-wide studies that focus on dementia diagnosis or are limited to selected countries in Europe. By addressing MCI, we contribute to a comprehensive understanding of preclinical stages of dementia.

Fourth, the richness of the combined data allows us to explore the associations of cognitive performance with the socioeconomic characteristics of the individuals in 27 European countries and Israel. Specifically, the SHARE data contains an internationally harmonized assessment of the respondents' educational achievements when they were young (International Standard Classification of Education, ISCED).[15] Since education early in life exhibits a large variation across Europe, this provides a valuable opportunity to better understand the international variation in cognitive performance and the risk factors for cognitive decline. Our finding suggest that education early in life is the main driver of the international variation MCI and SCI prevalence. Since education puts individuals on different occupational, economic and lifestyle paths during mid and later life,

each with their own effects on cognition, this finding is a potential anchor for preventative measures as detailed e.g. by the Lancet Neurology Commission.[16]

2. Methods

We classify cognitive performance into three categories: normal, MCI, and SCI, the latter most likely caused by AD/ADRD. We prefer the terminology “SCI” to “dementia” since our assessment relies on a classification algorithm and not a clinical assessment of the respondents.

Our main data is Wave 9 of the SHARE parent study, which is the most recently available wave of SHARE that took place between October 2021 and September 2022. SHARE is a nationally representative longitudinal study tracking over time individuals 50 years and older, who have their regular residence in the respective SHARE country and are not incarcerated, hospitalized or out of the country during the survey period and able to speak the country’s language(s). Current partners living in the same household are interviewed as well, regardless of their age. SHARE follows individuals when they move into nursing homes and similar institutions. Probability samples were drawn from population registers in all countries where these were available. SHARE performs proxy interviews for individuals who cannot answer themselves (3.1% in Wave 9, Appendix 1, Table S1). Mortality is ascertained by register checks and followed up by interviews with next of kin to document the final year of life. The SHARE parent study includes indicators of four domains of cognition (memory, executive functioning, language and fluency, and orientation to time and place) that are identical across the 28 countries.

Written informed consent was obtained from all individuals and the SHARE and SHARE-HCAP protocols were approved by the Ethics Committee of the Max Planck Institute in Germany.

We proceeded in three steps detailed below. (a) We drew a subsample (N=2,678) of the SHARE parent study in which we administered the extended SHARE-HCAP. (b) Based on these results, we classified respondents as normal, MCI or SCI.[17] (c) Based on this classification, we calculated weights for those cognition measures that have been available in the SHARE-parent sample and

predicted for each individual in the analytical SHARE parent sample (N=47,193) the probabilities of cognitive status “normal”, “MCI” and “SCI”.

(a) SHARE-HCAP data collection

SHARE-HCAP collected data on 27 cognitive indicators associated with standard diagnostic criteria (Appendix 1, Table S2) that represent five broad domains of cognition: memory, executive functioning, visuospatial skills, language and fluency, and orientation. These domains were selected based on prior theoretical and empirical work.[18] In addition, a member of the family or a friend was asked to provide an informant’s report.

We selected five countries to represent the East (Czech Republic), West (France and Germany), North (Denmark), and South (Italy) of Europe and drew a weighted subsample of individuals aged 65 years and older from these countries based on the performance in a word recall test in the SHARE parent study, heavily oversampling those with low test scores to ensure an adequate number of individuals with MCI and SCI.

Data was collected between May and November 2022, on average about five months after Wave 9 of the SHARE parent data collection. Of the 3,546 eligible individuals, 2,687 participated in the SHARE-HCAP study, resulting in an overall response rate of 75.8% (Table 1). They were on average (SD) 75.5 (7.5) years old and primarily female (56.2%). 65.1% completed secondary education as assessed by ISCED. Item nonresponse was low (<2.3%) except one of the story recall (recognition) (21.9%), the HRS Number Series (15.4%) and TMT part B (12.6%), all three concentrated in Italy. To address this item nonresponse on cognitive measures, we employed Full Information Maximum Likelihood (FIML) estimation in the factor analysis, ensuring that incomplete cases contribute to the estimation process proportionally to their available information. This approach has been shown to produce unbiased parameter estimates and standard errors.[19] Table 1 reports the main sample characteristics of SHARE-HCAP and SHARE parent Wave 9. It shows the large differences across countries in terms of age, gender, education, health, and income.

(b) Classification in the SHARE-HCAP sample

For the classification into normal, MCI or SCI we followed the approach that has been described in Manly et al.[17] who relied on diagnostic criteria from the National Institute on Aging and Alzheimer's Association.[20,21] We choose this approach to allow cross-HCAP study comparisons.[22,23] Details are described in Section S1 of Appendix 1. We first derived factor score estimates of the five domains of cognition for everyone and used a normative sample to set a benchmark for classification. We then classified as SCI when the factor scores of at least two cognitive domains were 1.5 SDs below the mean of the normative sample and functional impairment was reported by an informant. Individuals who did not meet the criteria for cognitive impairment in any domain were classified as normal. Moreover, individuals were classified as normal if one cognitive domain was in the impaired range and neither the individual nor the informant reported cognitive concerns. All other participants were classified as MCI.

(c) Probability of cognitive status in the SHARE parent sample

In assessing the cognitive status in the SHARE parent study, we distinguished between respondents who were able to complete the cognition items in Wave 9 (96.9%) and those for whom health information was obtained by proxies (3.1%). For the former group, we applied a regression-based approach developed by Hurd et al.[24] to our multi-country setting. It weighs the cognition items of the SHARE parent study by their weight in the SHARE-HCAP sample. First, using the SHARE-HCAP sample, we regressed the outcome of the Manly classification (normal, MCI, SCI) to a selection of demographic variables and cognitive and health measures that are available both in the SHARE-HCAP sample and the SHARE parent study. Details are provided in Section S2 of Appendix 1. Cognitive items included orientation in time, immediate and delayed word recall, serial 7s, and animal naming (Table S3 in Appendix 1). Health was measured by the sum of activities of daily living (ADL) and the sum of instrumental activities of daily living (IADL). Second, we used the regression equation to predict the probabilities of each individual being normal, MCI and SCI, based on the same set of demographic, cognition and health variables in the SHARE parent sample. In this way, we acknowledge the uncertainty in classification by predicting probabilities rather than a

cognitive class. The prevalence rates of normal, MCI and SCI are then calculated as the country-specific average probabilities of each category.

Finally, we added the informants' assessments of the cognitive status for the 3.1% of respondents who were not able to answer the cognition items in Wave 9, using a simple approach that was mainly based on the informant's assessment of the respondent's memory function. If the respondent's memory function was assessed poor (fair), the respondent was classified as SCI (MCI), else normal. Details are provided in Section S3 of appendix 1. All statistical analyses were conducted with Stata (version 14.2) and Mplus (version 8.10).

(d) Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

3. Results

Table 2 is based on the SHARE-HCAP sample and shows that the prediction by our regression model replicates the classification results of the Manly et al.[17] approach very well.

Table 3 is based on the full SHARE parent sample and summarizes the main result of this study: the estimated prevalence rates of MCI and SCI based on the cognition measures in Wave 9 of SHARE weighted by the SHARE-HCAP results.

The cross-national variation in Europe is very large. The probability of SCI among individuals aged 65 and older ranges from around 5% in Switzerland, Sweden, Denmark and Germany to more than 20% in Spain and Portugal. On average (SE) across all 28 SHARE countries, it is 11% (0.1), roughly comparable to the results by Manly et al.[17] for the US.

MCI is on average (SE) 24% (0.2) in the 27 European countries and Israel, again varying greatly between Austria, Germany, Sweden, Denmark and Switzerland on the lower side (about 17%) and the Mediterranean and Eastern countries on the higher side, reaching almost a third in Bulgaria, Cyprus, Greece, and Portugal.

Table 3 also compares our HCAP-refined prevalence estimates with estimates based on the Langa-Weir scale[25,26] that adds immediate and delayed word recall (0-20), serial 7s (0-5) and backwards counting (0-2). SCI is defined as (0-6), MCI (7-11) and normal (12-27). This scale has been validated against diagnostic information from the ADAMS study.[27] These prevalence estimates are generally lower than the HCAP-weighted estimates but exhibit a much larger variation as indicated by the coefficient of variation, with very low estimates e.g. in Switzerland and the Netherlands and much higher prevalence estimates e.g. in Spain and Portugal. We contribute the differences between HCAP-weighted and Langa-Weir scales to the larger breadth of cognition measures in the HCAP-weighted scale relative to the Langa-Weir scale, reducing the impact of each single measure and thus providing a more robust measure of cognition.

Table 4 shows that prevalence rates vary plausibly by age and education. The right-most panel shows the p-values of t-tests that compare each group (row) with the adjacent group (row below). Every 5-year increase in age increases the risk of SCI (all p-values below 0.0001). Women have an age-adjusted higher risk of MCI compared to men ($p<0.0001$) but there is no significant difference in SCI. Our main finding is the strong association on the international level between cognitive performance and the respondents' educational achievement when they were young. An increase in the age and sex-adjusted level of education is associated with a decrease in the risk of both MCI and SCI (all p-values below 0.0001).

This finding is corroborated by a multivariate regression which links the probability of SCI with the level of education, age and sex. Using this regression, Figure 1 shows how the probability of SCI would vary counterfactually across countries if education had been the same in all SHARE countries, namely the average of the 27 European countries and Israel. This variation is dramatically smaller than the actual variation, showing the strength of the association.

4. Discussion

This paper provides strictly cross-nationally comparable estimates of prevalence of MCI and SCI in 27 European countries and Israel, represented by a large sample of over 47,000 individuals aged

65 and older. It uses as primary input the cognition measures in Wave 9 of SHARE, weighted by the results of an in-depth cognitive assessment using a globally harmonized protocol (HCAP) and a classification algorithm that is adopted by similar aging studies across the globe.

Our main finding is the large variation in the prevalence of MCI and SCI across Europe and Israel. Much of this variation can be explained by the large international differences in education, reflecting the differences in national education systems when the SHARE respondents were young. This is an important result which has implications far beyond Europe. It may explain the disproportionate burden of dementia and MCI among African Americans in the US as well as the global differences in dementia reported by GBD and OECD. The extent to which the association between education and cognition is causal is a matter of controversy and interpretation, since education in early life puts individuals on different occupational, economic and lifestyle paths during mid and late life which in turn have their own causal effects on cognition.[28-30]

The study rests on a set of critical assumptions. First, we assume that the five SHARE-HCAP countries are sufficiently representative to act as validation for the European context and provide weights for the cognition items that apply for all of Europe and Israel. Since there is substantial inhomogeneity within these five countries, even more inhomogeneity may be expected for all 27 European countries and Israel. Future work thus needs to extend the number of countries covered by HCAP assessment.

A second assumption is that the Manly et al.[17] thresholds of the HCAP classification algorithm apply to all SHARE countries. Without a “gold standard” calibration target for the European countries and Israel such as the US ADAMS study[27], this approach has been chosen to maintain harmonization with the US and other global HCAP studies.

A third critical assumption is the validity of the regression-based refinement of the cognition indicators in Waves 8 and 9 with the help of the SHARE-HCAP classification results. Validity requires a sufficient accuracy of the prediction equation and a reasonable extent of consistency

between the cognition measurements in SHARE-HCAP and the SHARE parent study. We believe that Table 2 documents this validity.

Cognition measures in observational studies are noisy, exhibit substantial test-retest variation and often fail to correspond with respondent-reported doctor diagnoses. This noisiness limits the precision of the probability estimates for each individual but much less so for the country-specific prevalence rates due to the large sample size of the SHARE parent sample. This is indicated by the standard errors in Table 3.

Finally, our results may underestimate the prevalence of SCI because non-response tends to be higher for individuals with SCI. We have spent much effort to minimize such bias, most importantly by assessing the individuals' cognitive performance with the help of proxies (family members or friends) and by following individuals when they move into a nursing home or similar institutions where proxies include nurses.

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Data Sharing: Data for the Survey of Health, Ageing and Retirement in Europa is available for the scientific community at https://share-eric.eu/data/.

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Table 1. Sample characteristics of SHARE Wave 9 and SHARE-HCAP subsample, weighted[a]

Country	Total Sample, No.	Response rate[b], %	Age, mean (SD), y		Female, %	Male, %	≤ primary school[c], %	Some high school[c], %	High school or some college[c], %	≥ college degree[c], %	Health: ADL+IADL[d], mean (SD)		HH income[e], median in Euro (IQR)	
Germany	547	76.1	75.5	(7.2)	55.9	44.1	0.3	10.8	52.5	36.4	1.0	(2.2)	2300	(1600)
Italy	537	79.4	75.8	(7.5)	56.1	43.9	42.9	26.8	24.1	6.3	0.9	(2.2)	1400	(1350)
France	528	74.5	75.3	(7.7)	56.6	43.4	25.4	7.5	37.2	29.9	0.9	(1.9)	2200	(1800)
Denmark	573	76.3	75.1	(7.3)	53.9	46.1	9.4	10.0	35.1	45.6	0.6	(1.5)	2554	(2110)
Czech Republic	502	72.6	74.4	(6.9)	56.7	43.3	7.1	22.8	54.6	15.4	1.0	(2.3)	773	(571)
SHARE-HCAP subsample	**2687**	**75.8**	**75.5**	**(7.5)**	**56.2**	**43.8**	**20.0**	**14.9**	**39.8**	**25.3**	**0.9**	**(2.1)**	**2000**	**(1700)**
Austria	2204	60.8	75.7	(7.5)	55.8	44.2	9.8	12.0	49.4	28.8	1.1	(2.7)	2200	(1600)
Germany	2750	70.7	75.8	(7.5)	55.4	44.6	1.1	11.3	53.9	33.7	1.0	(2.4)	2400	(1700)
Sweden	2054	58	75.1	(7.4)	55.3	44.7	15.3	14.4	35.4	34.9	0.7	(2.1)	2258	(1878)
Netherlands	1760	48.9	74.9	(7.3)	54.7	45.3	7.5	33.5	27.4	31.6	0.7	(1.9)	2400	(1650)
Spain	1433	59	78.4	(8.0)	56.3	43.7	60.8	21.0	8.5	9.7	2.1	(4.1)	1200	(1010)
Italy	2825	75.1	76.3	(7.7)	56.8	43.2	44.3	26.6	21.9	7.2	1.3	(3.1)	1400	(1000)
France	2068	50.4	75.8	(7.9)	55.7	44.3	27.6	8.5	35.4	28.5	0.9	(2.3)	2300	(1900)
Denmark	1544	60.6	75.0	(7.3)	54.3	45.7	8.2	7.9	37.5	46.4	0.7	(1.9)	2688	(2231)
Greece	2360	67.5	76.0	(7.6)	54.8	45.2	46.2	10.8	25.0	18.1	1.3	(2.8)	850	(600)
Switzerland	1433	70.2	75.4	(7.8)	55.1	44.9	9.0	10.6	61.4	19.0	0.5	(1.6)	3981	(3683)
Belgium	2813	64.1	75.7	(8.0)	53.7	46.3	15.2	22.0	26.3	36.6	1.3	(2.8)	2200	(1600)
Israel	666	24.9	73.7	(7.1)	56.1	43.9	22.4	12.3	26.2	39.1	1.6	(3.5)	2829	(2942)
Czech Republic	2674	67.8	73.9	(6.8)	58.4	41.6	7.1	22.8	52.9	17.2	0.9	(2.4)	977	(733)
Poland	3165	79.1	74.1	(7.6)	60.0	40.0	14.7	18.4	55.2	11.7	1.3	(3.1)	640	(576)
Luxembourg	589	50.3	74.8	(7.5)	52.7	47.3	27.8	12.1	37.1	22.9	0.8	(2.4)	4000	(3300)
Hungary	1234	58.1	73.6	(6.8)	61.7	38.3	0.6	29.1	57.4	12.9	1.1	(2.3)	419	(332)
Portugal	933	64.4	75.9	(7.2)	60.6	39.4	67.1	9.5	9.8	13.6	2.0	(4.0)	850	(800)
Slovenia	2805	76.2	74.9	(7.7)	56.4	43.6	8.1	24.5	51.4	16.0	1.3	(3.2)	1200	(1070)
Estonia	2984	77.3	75.3	(7.6)	64.9	35.1	2.6	21.4	52.3	23.8	1.2	(2.7)	620	(581)
Croatia	2856	82.8	74.8	(7.3)	58.7	41.3	20.7	20.0	44.1	15.3	1.4	(3.2)	531	(597)
Lithuania	923	76.6	75.7	(8.0)	66.7	33.3	10.0	11.9	41.5	36.7	1.5	(3.3)	650	(590)
Bulgaria	575	75.4	74.4	(6.8)	60.1	39.9	9.6	28.6	49.6	12.2	1.2	(2.5)	276	(253)
Cyprus	553	63.7	74.5	(7.2)	55.4	44.6	48.4	10.0	25.6	16.0	1.2	(3.2)	4500	(14000)

Country	Total Sample, No.	Response rate[b], %	Age, mean (SD), y		Female, %	Male, %	≤ primary school[c], %	Some high school[c], %	High school or some college[c], %	≥ college degree[c], %	Health: ADL+IADL[d], mean (SD)		HH income[e], median in Euro (IQR)	
Finland	1264	63.9	75.0	(7.3)	54.8	45.2	24.0	6.9	30.3	38.8	0.7	(1.9)	2200	(2000)
Latvia	1031	80.1	75.4	(7.3)	65.8	34.2	4.8	13.8	55.3	26.0	0.9	(2.1)	470	(462)
Malta	654	75.7	74.4	(7.3)	54.4	45.6	55.9	0.7	37.0	6.4	0.8	(2.5)	1150	(1500)
Romania	990	91.2	74.3	(7.6)	55.9	44.1	20.0	37.9	37.9	4.2	1.5	(3.4)	385	(416)
Slovakia	593	88.9	73.5	(6.8)	56.7	43.3	2.7	15.8	76.5	5.0	1.0	(2.5)	800	(580)
SHARE parent Wave 9	**47,733**	**68.4**	**75.6**	**(7.7)**	**56.6**	**43.4**	23.2	17.7	37.7	21.4	**1.2**	**(2.9)**	**1600**	**(1800)**

Abbreviations: ADL, Activities of Daily Living; IADL, Instrumental Activities of Daily Living; HH income, Household income

[a] Indicates sample characteristics using sampling weights.

[b] Response rates is calculated as the ratio of number of individuals that completed an interview to the number of individuals that were eligible for an interview in SHARE Wave 9.

[c] Educational attainment is measured using the International Standard Classification of Education (ISCED) 1997 [14]: ≤ primary school (ISCED level 0 and 1), Some high school (ISCED level 2), High school or some college (ISCED level 3 and 4), ≥ college degree (ISCED level 5 and 6).

[d] Combined measure of limitations in ADLs and IADLs, which are measured using self-report and reflect functional status and independence.

[e] Total household income per month (average), expressed in euros.

Table 2. Estimated prevalence of normal, MCI and SCI in the SHARE-HCAP subsample based on diagnostic criteria and estimation approach[a]

		Classified using Manly et al.[16]			Predicted[b] using Hurd et al.[23]		
	Total sample, No.	**Normal, % (SE)**	**MCI, % (SE)**	**SCI, % (SE)**	**Normal, % (SE)**	**MCI, % (SE)**	**SCI, % (SE)**
Germany	547	76.9 (1.8)	18.8 (1.7)	4.3 (.9)	77.6 (1.8)	17.6 (1.6)	4.8 (.9)
Italy	537	65.6 (2.0)	22.6 (1.8)	11.8 (1.4)	58.5 (2.1)	29.7 (2.0)	11.8 (1.4)
France	528	71.8 (2.0)	22 (1.8)	6.2 (1.0)	72.2 (1.9)	21.2 (1.8)	6.6 (1.1)
Denmark	573	77.1 (1.8)	18 (1.6)	4.9 (.9)	76.1 (1.8)	19.1 (1.6)	4.8 (.9)
Czech Republic	502	71.5 (2.0)	20.4 (1.8)	8.1 (1.2)	73.1 (2.0)	19.7 (1.8)	7.2 (1.2)
SHARE-HCAP subsample	2,687	72.6 (.9)	20.4 (.8)	7.0 (.5)	71.5 (.9)	21.5 (.8)	7.0 (.5)

Abbreviation: SE, standard error.

[a] Classification and estimation of prevalence are based on weighted data.

[b] Prevalence estimates generated from estimation equation, see section S2 of appendix 1.

Table 3. Prevalence estimates for 27 European countries and Israel, using prediction model based on SHARE-HCAP and using cutoff based classification based on Langa-Weir method

		HCAP-weighted[a]		Langa-Weir[b]	
Country	**N**	**MCI, % (SE)**	**SCI, % (SE)**	**MCI, % (SE)**	**SCI, % (SE)**
Austria	2,176	16.9 (.8)	6.8 (.5)	9.7 (.6)	5.0 (.5)
Germany	2,708	16.8 (.7)	5.3 (.4)	11.4 (.6)	3.3 (.3)
Sweden	2,010	17.2 (.8)	5.0 (.5)	10.9 (.7)	2.7 (.4)
Netherlands	1,686	20.5 (1.0)	5.7 (.5)	11.8 (.8)	2.1 (.3)
Spain	1,458	29.1 (1.2)	22.7 (1.1)	28.7 (1.2)	29.1 (1.2)
Italy	2,761	24.9 (.8)	11.6 (.6)	21.7 (.8)	14.6 (.7)
France	2,035	19.9 (.9)	6.0 (.5)	13.9 (.8)	5.8 (.5)
Denmark	1,523	18.0 (1.0)	5.3 (.6)	9.8 (.8)	2.4 (.4)
Greece	2,351	30.4 (.9)	14.0 (.7)	21.0 (.8)	11.0 (.6)
Switzerland	1,425	17.8 (1.0)	4.6 (.5)	11.1 (.8)	2.1 (.4)
Belgium	2,783	21.1 (.8)	8.3 (.5)	14.1 (.7)	5.4 (.4)
Israel	660	24.7 (1.7)	19.5 (1.5)	17.2 (1.5)	15.3 (1.4)
Czech Republic	2,647	18.6 (.7)	5.9 (.4)	9.8 (.6)	3.3 (.3)
Poland	3,137	27.3 (.8)	14.0 (.6)	23.0 (.7)	12.3 (.6)
Luxembourg	546	19.2 (1.6)	7.2 (1.1)	10.8 (1.3)	6.4 (1.0)
Hungary	1,229	23.5 (1.2)	8.7 (.8)	9.6 (.8)	3.2 (.5)
Portugal	924	31.1 (1.5)	21.1 (1.3)	32.0 (1.5)	28.6 (1.5)
Slovenia	2,772	23.3 (.8)	11.1 (.6)	19.6 (.7)	8.9 (.5)
Estonia	2,950	20.1 (.7)	8.9 (.5)	15.7 (.7)	6.7 (.5)
Croatia	2,858	26.8	14.6	21.7	13.6

		HCAP-weighted[a]		Langa-Weir[b]	
Country	**N**	**MCI, % (SE)**	**SCI, % (SE)**	**MCI, % (SE)**	**SCI, % (SE)**
		(.8)	(.7)	(.8)	(.6)
Lithuania	921	26.4 (1.5)	13.9 (1.1)	23.0 (1.4)	13.5 (1.1)
Bulgaria	573	29.9 (1.9)	12.2 (1.4)	16.2 (1.5)	8.7 (1.2)
Cyprus	555	30.3 (2.0)	15.6 (1.6)	21.0 (1.7)	8.7 (1.2)
Finland	1,237	20.7 (1.1)	6.7 (.7)	16.7 (1.0)	3.8 (.5)
Latvia	1,026	27.0 (1.4)	10.1 (1.0)	22.1 (1.3)	12.3 (1.0)
Malta	654	29.3 (1.8)	12.2 (1.3)	24.6 (1.7)	11.8 (1.3)
Romania	994	28.5 (1.4)	16.7 (1.2)	25.1 (1.4)	16.1 (1.2)
Slovakia	591	28.7 (1.9)	11.2 (1.3)	25.3 (1.8)	7.7 (1.1)
SHARE Wave 9	**47,193**	**23.9**	**10.9**	**17.8**	**9.4**
		(.20)	(.14)	(.18)	(.13)
Coefficient of variation			**0.46**		**0.80**

Abbreviation: SE, standard error; Prob(SCI), probability of prevalence of SCI.

[a] Prevalence estimates generated from estimation equation using the Hurd et al approach.

[b] Prevalence estimates generated from the Langa-Weir summary score.2[24,25] Originally, Langa-Weir does not classify MCI but rather cognitive impairment without dementia (CIND), which overlap conceptually as intermediate stages of cognitive health.

Table 4. Group differences in cognitive performance by age, sex and education

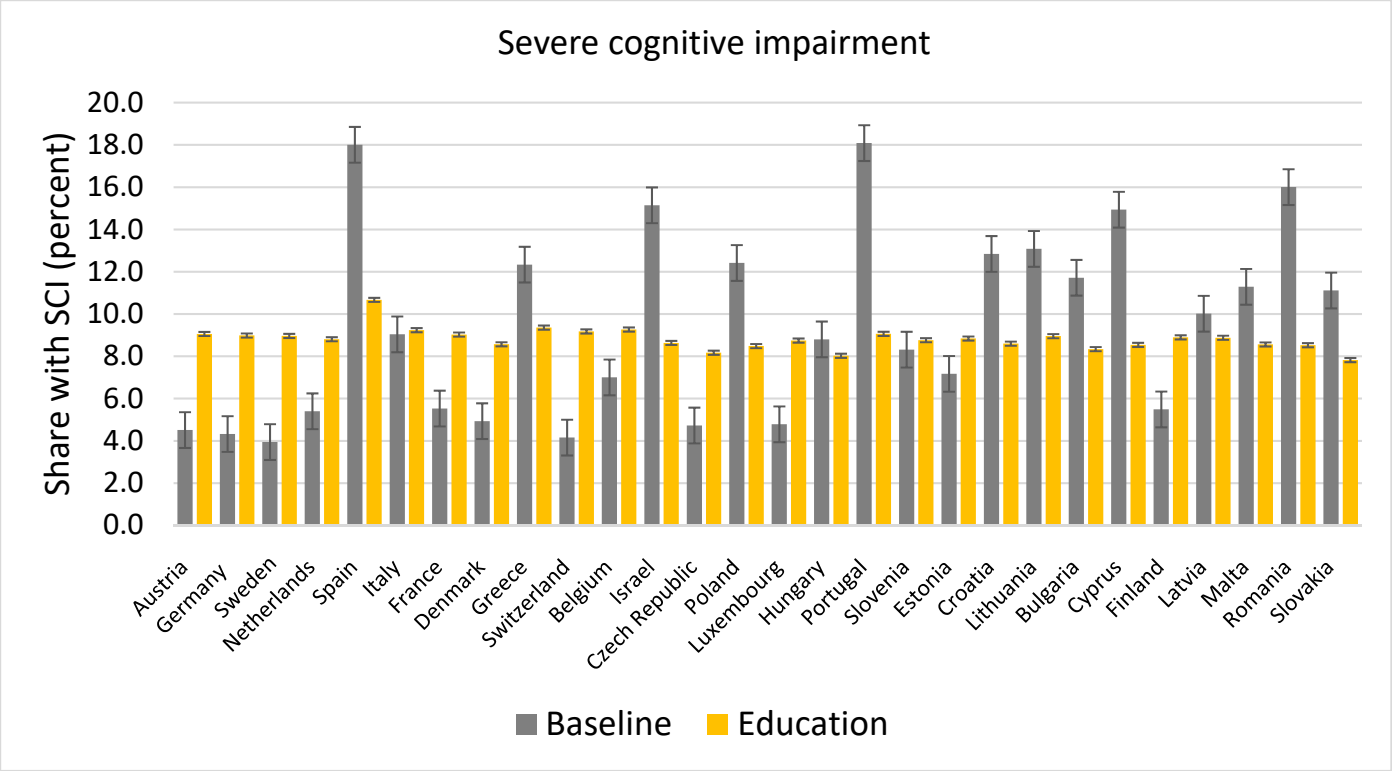
Group			Prevalence estimate, % (SE)			p-value of group differences[a]		
		Total sample, No.	Normal	MCI	SCI	Normal	MCI	SCI
Age, y	65-69	12,528	75.1 (.2)	19.8 (.2)	5.1 (.1)	0.000	0.000	0.000
	70-74	12,567	71.4 (.3)	22.3 (.2)	6.3 (.1)	0.000	0.001	0.000
	75-79	9,839	69.2 (.3)	23.1 (.2)	7.7 (.2)	0.000	0.000	0.000
	80-84	7,028	63.4 (.4)	25.6 (.2)	11.0 (.3)	0.000	0.000	0.000
	85-89	3,881	52.9 (.6)	29.8 (.3)	17.4 (.5)	0.000	0.288	0.000
	90+	1,890	44.2 (.9)	30.2 (.5)	25.6 (.9)			
Sex[b]	Female	27,015	69.3 (.2)	22.1 (.1)	8.6 (.1)	0.000	0.000	0.153
	Male	20,718	66.0 (.2)	25.1 (.1)	9.0 (.1)			
Education[c]	≤ primary school	8,745	58.2 (.4)	28.1 (.2)	13.7 (.3)	0.000	0.000	0.000
	Some high school	8,298	64.0 (.4)	25.7 (.2)	10.3 (.2)	0.000	0.000	0.000
	High school or some college	19,715	71.5 (.2)	21.7 (.1)	6.8 (.1)	0.000	0.000	0.000
	≥ college degree	10,852	74.7 (.3)	19.7 (.2)	5.6 (.1)			

[a] P-values represent the results of pairwise difference tests between two consecutive groups within each state of cognition (normal, MCI, SCI). For example, the first row of p-values is the pairwise difference test between the 70-74y group and 65-69y group.

[b]Age adjusted

[c]Age and sex adjusted

Figure 1. Prevalence of SCI for 27 European countries and Israel, actual and counterfactually had education been equal across all countries



The grey bars show the actual estimated share of individuals in each country with severe cognitive impairment. The yellow bars show the counterfactual share of individuals in each country with severe cognitive impairment if education in each country had been equal to the average of the 28 countries.