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DISCUSSION PAPER

RELEASE NOTE 1.0 TO SHARE-HCAP DATA

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1. Introduction

This note describes the first release of the raw data and the cognitive status of selected SHARE respondents in five European countries, together with robustness checks, caveats and an application to estimate dementia prevalence rates for all 28 SHARE countries. This note is part of the Survey of Health, Aging, and Retirement in Europe's Harmonized Cognitive Assessment Protocol (SHARE-HCAP) project that is supported by the US National Institute of Aging under grant R01 AG056329 with Principal Investigators Axel Börsch-Supan and Project Coordinator Salima Douhou. SHARE-HCAP is a sub-study of SHARE, the largest social science longitudinal study in Europe (Börsch-Supan et al., 2013), and aims to assess cognitive status in five countries: Czech Republic, Denmark, France, Germany, and Italy.

HCAP stands for the Harmonized Cognitive Assessment Protocol that has been developed by the US Health and Retirement Study in order to harmonize the measurement of cognition in a global network of sister studies spanning North and South America, Asia, and Africa (Weir et al., 2014, Langa et al., 2020). SHARE-HCAP was developed to address the need for a standardized assessment of cognitive impairment in the European context.

SHARE-HCAP is comprised of an in-depth battery of cognitive tests that assess several cognitive domains, including memory, executive functioning, language and fluency, visuospatial skills, and orientation to time and place. SHARE-HCAP also includes an interview conducted with a family member or friend that assesses informant-reported cognitive functioning and ability to perform activities of daily living. Results from SHARE-HCAP can be linked with economic, health, and social data from the core SHARE study, and global data from other HCAP sister studies.

In addition to the raw data, this release provides an estimate of the cognitive status measured by three categories: normal, mild cognitive impairment (MCI, sometimes also referred to as CIND, cognitively impaired but not demented) and severe cognitive impairment (SCI), most probably caused by the presence of Alzheimer's disease (AD) or AD-related dementias (ADRD) (Albert et al., 2011, McKhann et al., 2011, Manly et al., 2022). We prefer the term "SCI" to "demented"

since our classification is based on an algorithm rather than a diagnosis through clinical assessment.

This note describes the methodology that has been used to compute an estimate of cognitive status and its shortcomings. It is structured as follows. Section 2 describes the selection of test items. Section 3 summarizes the main outcomes of the data collection. Section 4 presents the confirmatory factor analysis that was used to condense the items enumerated in Section 2. Section 5 details the classification algorithm that produces the three-category cognitive status. Sections 6, 7 and 8 provide several caveats for users of our results. Finally, as example for an application of the SHARE-HCAP data, Section 9 presents prevalence estimates for all 28 SHARE countries based on the probability of MCI or SCI for about 47,000 respondents of age 65 and older in SHARE Wave 9.

2. Item selection

The SHARE-HCAP substudy was initiated in 2017. It consisted of in-depth cognitive testing of the respondent, including other respondent data, and an informant interview data (Douhou et al., 2024). All tests were based on the Harmonized Cognitive Assessment Protocol (HCAP) from the U.S. Health and Retirement Study (HRS), which has been successfully adapted for samples in England, Mexico, India, China, and South Africa. The adaptation process for the five European countries (Czech Republic, Denmark, France, Germany, and Italy) included consultation with the SHARE-HCAP Project Advisory Board, local cognition experts and native speakers within each SHARE country team.

SHARE-HCAP cognitive tests were divided into five broad domains representing memory, executive functioning, visuospatial skills, language and fluency, and orientation. These domains were selected based on prior theoretical and empirical work and are widely accepted categories of cognitive functioning (Lezak, 2004).

Tables 1 and 2 show the tests included in the respondent and informant interviews of SHARE-HCAP:

Table 1: Respondent tests of SHARE-HCAP
MMSE
HRS TICS (3 items: Object naming; naming president)
CERAD Word List – Recall: Immediate and delayed, Recognition
Semantic Fluency (Animal Naming)
Symbol cancellation test
Timed Backward Counting Task
Brief Community Screening Instrument for Dementia (CSI-D; 4 items)
Story recall – immediate, delayed and recognition
CERAD Constructional Praxis – immediate and delayed
Symbol Digit Modalities Test (SDMT)
HRS Number Series
Raven's Standard Progressive Matrices
Trail Making Test (Part A and Part B)

Table 2: SHARE-HCAP informant report items
Background information
Jorm IQCODE
Blessed Dementia Rating Scale
HRS Activities
10/66 Dementia Research Group Informant Questionnaire (4 items)
CSI-D Cognitive Activities

The orientation domain consisted of two scores comprised of 11 items. One score was the sum of 10 items assessing orientation to time and place selected from the Mini-Mental State Exam (MMSE; Folstein, 1975). The second score came from an item that asked the name of the country's current primary political leader (e.g., prime minister, president), which was adapted from the Telephone Interview for Cognitive Status (TICS; Brandt, Spencer, & Folstein, 1988).

The memory domain consisted of 11 scores from the immediate, delayed, and recognition recall of a 10-word list from the Consortium to Establish a Registry for Alzheimer's Disease (CERAD; Morris et al., 1989), and the immediate, delayed, and recall of a logical memory test from the Wechsler Logical Memory Scale Fourth Edition (WMS-IV; Wechsler, 2009) and the East Boston Memory Test (i.e., Brave Man story) (Scherr et al., 1988). Additionally, the delayed recall of shapes was included and taken from the CERAD constructional praxis test (Morris et al., 1989; Rosen et al., 1984).

The executive functioning domain consisted of 8 scores, including performance on the Raven's Standard Progressive Matrices (Raven, 1981, 1989, 2000) as adapted by HRS, Trail Making Test Parts A and B (TMT; Reitan, 1992), symbol cancellation test (Mesulam, 1985), Symbol Digit Modalities Test (SDMT; Smith, 1982), backward counting (Agrigoroaei & Lachman, 2011), HRS Number Series (Fisher, McArdle, McCammon, Sonnega, & Weir, 2013), attention and calculation from MMSE.

The language and fluency domain consisted of 4 scores, including performance on animal naming (Woodcock et al., 2001; Schrank & Flanagan, 2003; Weir et al., 2014), naming described objects from the TICS, and naming common objects from Community Screening Instrument for Dementia (CSI-D; Hall et al., 1993; Hall et al., 2000). Additionally, several items from the MMSE were selected including object naming, writing a sentence, repeating a phrase, following a three-step oral command, and reading and following written instructions.

The visuospatial domain consisted of two scores representing performance on the CERAD constructional praxis copy task, and the MMSE drawing task.

3. Outcomes of the data collection

SHARE-HCAP's sampling strategy has been inspired by the strategy used in the HCAP study of the English Longitudinal Study of Aging (ELSA-HCAP) (Cadar et al., 2021). Briefly, respondents hypothesized to be at greater risk of cognitive impairment based on prior performance on the word recall test in the core SHARE in an earlier wave were oversampled to ensure adequate number of respondents with mild to severe cognitive impairment. For more details, see Douhou et al. (2024).

Response rates by risk group in the corresponding earlier wave are shown in Table 3:

Table 3: Overall response rates and by risk group.

At risk of CI	Severe CI	Mild CI	Normal	Overall
Czechia	60.9%	75.6%	74.9%	72.4%
Denmark	67.4%	76.5%	73.5%	73.2%
France	61.3%	69.1%	75.9%	72.2%
Germany	67.4%	70.3%	78.7%	74.5%
Italy	67.9%	82.7%	83.3%	79.3%

The resulting SHARE-HCAP data comprises data from 2687 respondents in the Czech Republic, Denmark, France, Germany and Italy (Czech n = 502; Danish n = 573, French n = 528, German n = 547, and Italian n = 537). Pooled across these five countries, respondents were on average 75.4 years old and primarily female (54.5%). 63.4% completed secondary education as assessed by the International Standard Classification of Education (ISCED; United Nations Educational, Scientific and Cultural Organization, 1997).

Table 4: Number of observations per indicator.

Indicator	**Observations**	**% Missing**
CERAD word list immediate recall	2683	0.15 %
MMSE word list, immediate recall	2681	0.22 %
WMS-IV logical memory immediate recall	2664	0.86 %
Brave Man immediate recall	2679	0.30 %
CERAD word delayed recall	2656	1.15 %
WMS-IV logical memory delayed recall	2645	1.56 %
MMSE word list, delayed recall	2676	0.41 %
CERAD constructional praxis delayed recall	2587	3.72 %
Brave Man delayed recall	2645	1.56 %
CERAD word list recognition	2650	1.38 %
WMS-IV logical memory recognition	2098	21.92 %
Raven's Progressive Matrices	2609	2.90 %
Trail Making Test part B	2349	12.58 %
HRS Number Series	2273	15.41 %
SDMT	2431	9.53 %
Trail Making Test part A	2510	6.59 %
MMSE Attention	2684	0.11 %
Backward counting	2609	2.90 %
Symbol Cancellation test	2514	6.44 %
CERAD Constructional praxis, copy	2627	2.23 %

MMSE drawing	2599	3.28 %
MMSE Orientation	2685	0.07 %
TICS: naming president	2465	8.26 %
Animal fluency	2674	0.48 %
TICS: object naming	2684	0.11 %
MMSE Naming	2684	0.11 %
CSI-D Naming	2679	0.30 %

In general, item nonresponse is not a major concern in this study, as can be seen in Table 4, which lists the number of observations per indicator and the percentage missing across the SHARE-HCAP countries. The few indicators that stand out are the WMS-IV logical memory recognition (21.92%), the HRS Number Series (15.41%) and TMT part B (12.58%). In all three indicators, Italy accounts for roughly at least 40% of the missings per indicator. Recognition of story points followed right after the delayed recall of the two stories in SHARE-HCAP, which may point to respondent fatigue. The HRS Number Series was administered after WMS-IV logical memory recognition, and we see that a majority of respondents, who did not do the recognition test, also did not respond to the numeracy test. The Trail Making Test Part B is the last test in the SHARE-HCAP battery. Probably due to respondent fatigue, the percentage missing is relatively high for this test.

No imputation was used in the results presented in this note. We plan to use several imputation methods in our future work.

4. Confirmatory factor analyses

Confirmatory factor analysis models were used to examine the factor structure of SHARE-HCAP's cognitive test battery. Based on theory and prior empirical work, unidimensional models representing the cognitive domains of orientation, visuospatial skills, memory, executive functioning, and language & fluency were tested on the full sample. If fit was not adequate, models were re-specified based on modification indices and theoretical and/or methodological considerations. Details are provided in the paper by Otero et al. (forthcoming).

The cognitive status provided in the preliminary release is based on unidimensional models applied to the full SHARE-HCAP sample. There was one exception for the orientation and visuospatial domains, which were estimated as two correlated domains within a two-factor model given that the orientation and visuospatial were measured by two items each and therefore did not satisfy model identification requirements (Kline, 2011). Factor structures are shown in Figures 1-4.

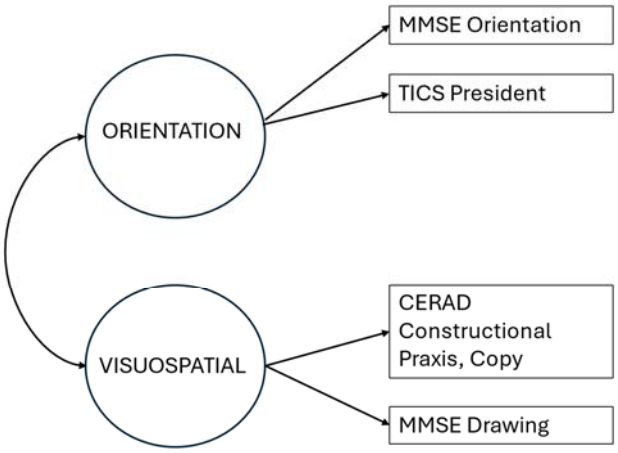


Figure 1. Diagram of correlated two-factor model for orientation and visuospatial domains.

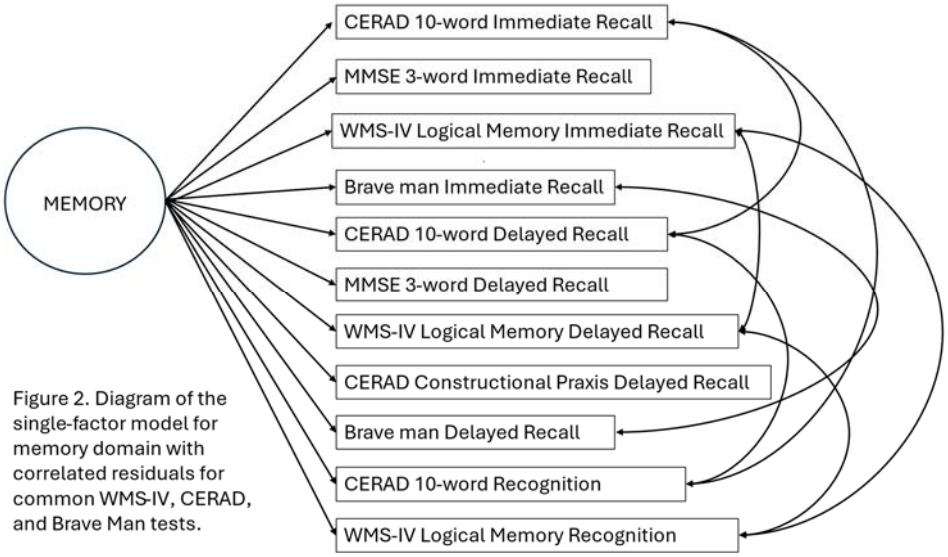


Figure 2. Diagram of the single-factor model for memory domain with correlated residuals for common WMS-IV, CERAD, and Brave Man tests.

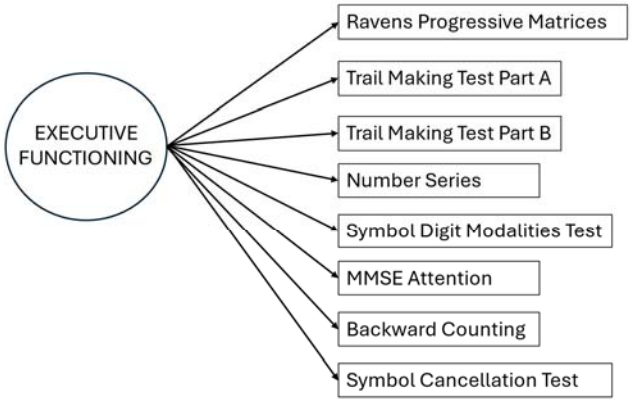


Figure 3. Diagram of the single-factor model for executive functioning domain.

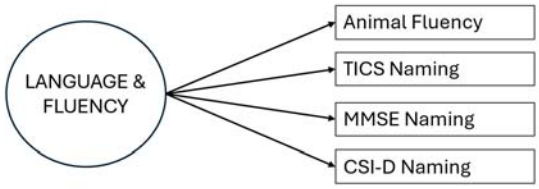
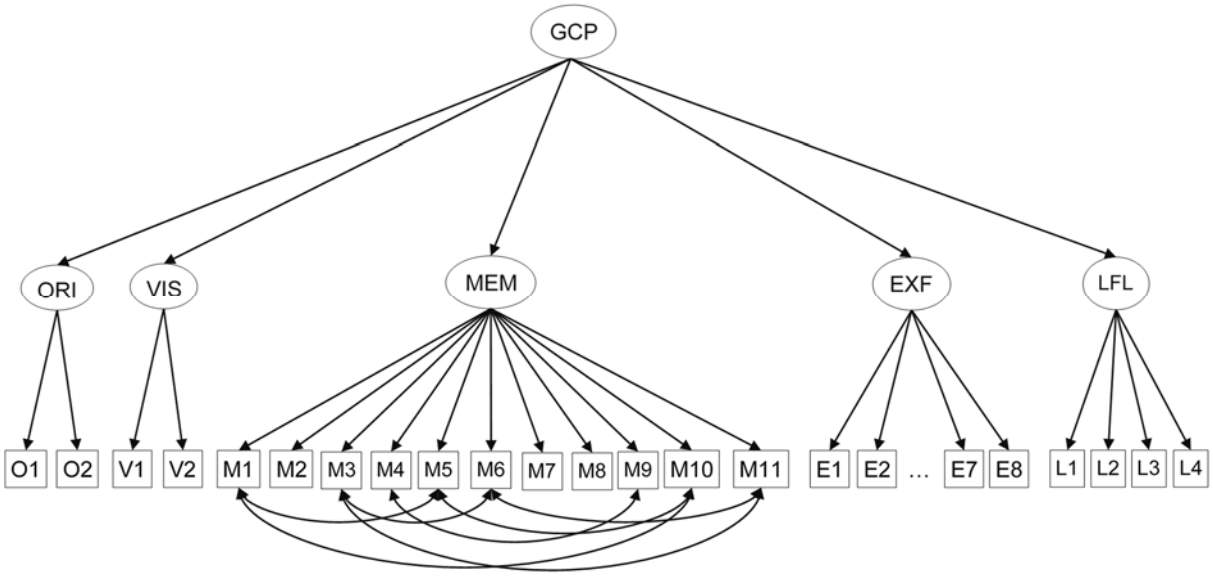


Figure 4. Diagram of the single-factor model for language and fluency domain.

Final model fits ranged from perfect (orientation and visuospatial domains) to adequate (memory, executive functioning, language & fluency) per Hu and Bentler's (1999) criteria for Comparative Fit Index (CFI), the Root Mean Squared Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR).

We also estimated a second-order correlated factor model, see Figure 5, in order to investigate whether the ultimate outcome – the classification of respondents in the three categories "normal, mild cognitive impairment and severe cognitive impairment" – is robust with respect to the correlation assumptions underlying the confirmatory factor analysis.

Figure 5: Second order correlated factor model



Note: GCP = General cognitive performance; ORI = Orientation; VIS = Visuospatial; MEM = Memory; EXF = Executive Functioning; LFL = Language and fluency.

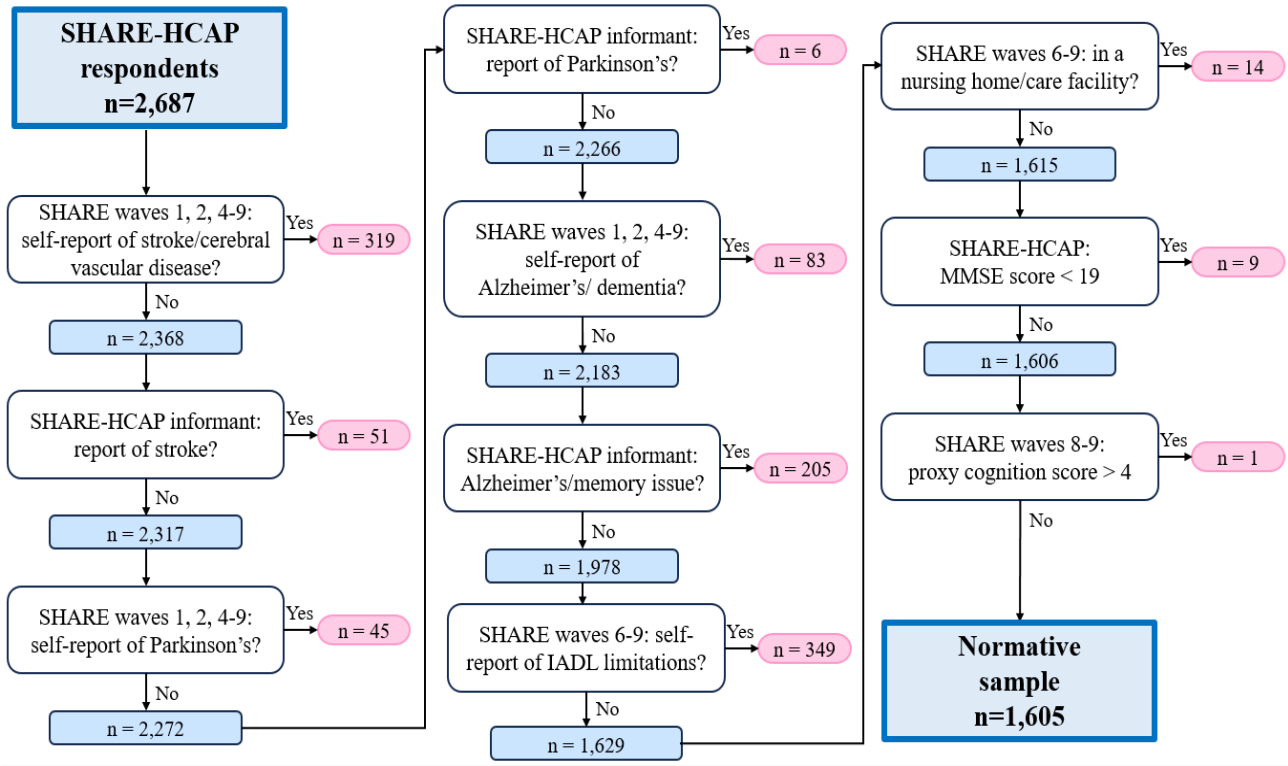
5. Classification

To compute the cognitive classification scores provided in this first and preliminary release (normal, MCI, SCI), we follow the approach that has been described in Manly et al. (2022). It has three steps. First, we selected a normative sample from the SHARE-HCAP sample. The exclusion criteria were based on conditions that have been found to be related to pathological cognitive

ageing. Specifically, individuals with neurodegenerative disease, stroke, or significant cognitive or functional impairment were excluded from the normative sample.

Figure 6 presents a more detailed flowchart with the criteria used for the selection of the normative sample from the SHARE-HCAP sample. Respondents excluded from the normative sample fulfilled one or more of the criteria for which we relied on information reported by a friend/family member of the respondent ("informant") and self-reported information in earlier core waves of SHARE. The criteria were inspired from Manly et al (2022) and discussions with our Project Advisory Board. The final normative sample includes 1,605 respondents from the SHARE-HCAP sample.

Figure 6: Flowchart of selection of normative sample

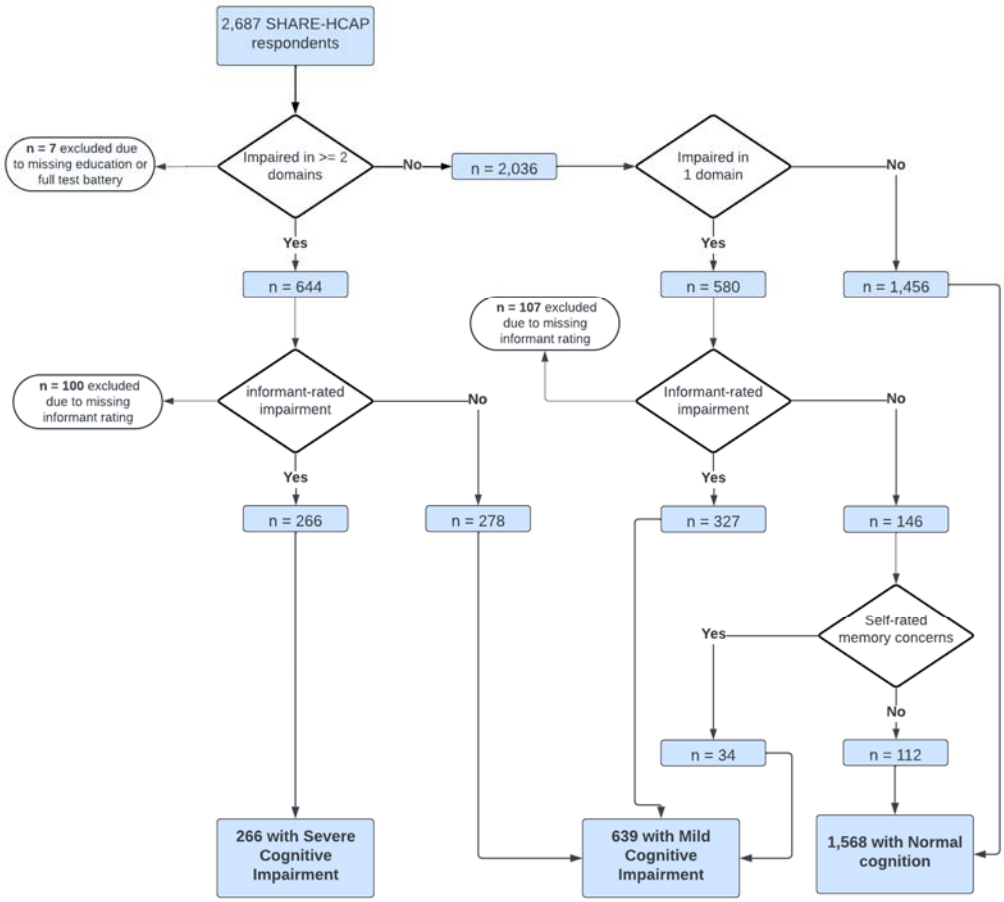


Second, we use factor analysis to derive factor score estimates in each of the five domains based on the measurement structure described in the previous section. In our preferred specification, we use the same factor structure for all five countries but allow for country-specific heterogeneity by estimating factor scores within each country's set of indicators. The factor score estimates within the normative sample were rank normalized and then a (linear) regression adjustment on the rank-based normalized scores was performed using age, sex, education and country of residence. Using the results from the regression, estimates of expected performance were generated for every combination of age, sex, education and country for the full SHARE-HCAP sample. For this, an adjusted score for every respondent was generated, which was standardized by dividing the standard error of estimate from the regression model. Following the Manly et al. approach, these were then placed on a T-score distribution (mean = 50, standard deviation =10) and rounded to the nearest integer.

A T-score of 50 indicates that a person is performing at the average level expected for an individual who is considered free from severe cognitive impairment, taking into account their age, sex, education, and country of residence. And a T-score below 35 suggests that a person performs 1.5 standard deviations below the mean, when compared to individuals with similar demographic characteristics who are considered free from severe cognitive impairment.

Third, we use a deterministic algorithm to classify respondents in three classes of cognition: normal, mild cognitive impairment and severe cognitive impairment. The classification algorithm is an exact replication of the one used by Manly et al. as shown in Figure 7 below.

Figure 7: Flowchart of SHARE-HCAP Classification Algorithm



214 observations could not be classified because essential information was missing. The distribution of their factor score estimate in each of the domains, as per CFA in section 4, resembles that of respondents that were classified as MCI.

In order to check the face validity of the classification, Table 5 shows descriptive statistics by country, age and education, measured by ISCED. Italy and the Czech Republic stand out with a markedly higher shares of respondents categorized as MCI and SCI. The age and education gradients show the expected pattern.

Table 5: Descriptive statistics (percentages)

Country	normal	MCI	SCI	Total (N*obs*)
Germany	74.76	20.04	5.20	100 (*519*)
Italy	58.51	22.75	18.74	100 (*523*)
France	73.13	18.96	7.92	100 (*480*)
Denmark	75.67	17.43	6.90	100 (*522*)
Czechia	54.44	32.22	13.33	100 (*450*)

Age	normal	MCI	SCI	all
65-69	26.23	20.00	6.95	22.85
70-74	24.93	23.45	12.36	23.3
75-79	20.71	18.91	22.78	20.53
80-84	15.61	20.00	24.32	17.48
85+	12.52	17.64	33.59	15.84
Total	100	100	100	100

Education	normal	MCI	SCI	all
Primary	32.34	39.27	55.60	36.29
Secondary	38.46	39.45	30.89	37.89
Tertiary	29.20	21.27	13.51	25.82
Total	100	100	100	100

Note: unweighted data

6. Heterogeneity across the five countries

Our measurement of cognitive status rests on a set of critical assumptions, so several caveats apply. Very generally, the cognitive status provided is not a diagnosis of mild or severe cognitive impairment of a responding individual but only an estimate that suffers from false positives as well as false negatives.

Furthermore, the estimation of the cognitive status has been based on the pooled data without distinguishing differences across the five countries due to the relatively small sample size in each country, i.e., we used the same model for the confirmatory factor analysis and the same thresholds in the categorization algorithm for all five SHARE-HCAP countries.

We checked for heterogeneity across the five countries in several ways. First, we ran Chow-type tests using OLS regressions of the indicators on the relevant factor score estimate (Bayesian plausible values) and a set of socio-demographic variables (age, age squared, sex, and ISCED) with 'country' as the grouping variable. The null hypothesis tested is whether the five country-specific intercepts and slopes are equal to those obtained in the pooled sample. Table 6 reports the p-values from the regressions. As can be seen, this null hypothesis is rejected for almost all indicators.

Table 6: Chow test p-values for equality of country-specific and pooled results.

Indicator	Constraint on intercepts	Constraint on Slopes	Constraint on intercepts and slopes
CERAD word list immediate recall	0.26	0.00 reject	0.00 reject
MMSE word list, immediate recall	0.80	0.00 reject	0.00 reject
WMS-IV logical memory immediate recall	0.11	0.22	0.02 reject
Brave Man immediate recall	0.02 reject	0.00 reject	0.00 reject
CERAD word delayed recall	0.00 reject	0.01 reject	0.00 reject
WMS-IV logical memory delayed recall	0.17	0.00 reject	0.00 reject
MMSE word list, delayed recall	0.76	0.00 reject	0.00 reject
CERAD constructional praxis delayed recall	0.21	0.29	0.36
Brave Man delayed recall	0.00 reject	0.00 reject	0.00 reject
CERAD word list recognition	0.53	0.00 reject	0.00 reject
WMS-IV logical memory recognition	0.85	0.00 reject	0.00 reject
Raven's Progressive Matrices	0.40	0.00 reject	0.00 reject
Trail Making Test part B	0.58	0.01 reject	0.04 reject
HRS Number Series	0.61	0.53	0.53
SDMT	0.01 reject	0.00 reject	0.00 reject
Trail Making Test part A	0.10	0.00 reject	0.00 reject
MMSE Attention	0.01 reject	0.00 reject	0.00 reject
Backward counting	0.81	0.04 reject	0.09
Symbol Cancellation test	0.36	0.01 reject	0.00 reject
CERAD Constructional praxis, copy	0.12	0.26	0.12
MMSE drawing	0.26	0.58	0.43
MMSE Orientation	0.61	0.00 reject	0.00 reject
TICS: naming president	0.44	0.00 reject	0.00 reject
Animal fluency	0.22	0.00 reject	0.00 reject
TICS: object naming	0.42	0.00 reject	0.00 reject
MMSE Naming	0.01 reject	0.00 reject	0.00 reject
CSI-D Naming	0.13	0.00 reject	0.00 reject

Second, we estimated five country-specific unidimensional factor analytical models in addition to the model for the pooled data. Using the same methodology as in Table 5, we find an even higher number of rejections.

A third way to assess whether the five countries are sufficiently similar to be described by a common factor analytical model is to use principal components analysis. We compared the coefficients associated with the first five principal components in the pooled sample with those coefficients that were estimated separately for each country. Except for Denmark, in all other

countries at least two coefficients deviated by at least two standard deviations from coefficients derived from the pooled sample.

Finally, we investigated how robust the classification results are with respect to the confirmatory factor analysis. We distinguish four cases along two dimensions: whether the factor analysis was done on the pooled sample (Panels A and B) or separately for each of the five countries (Panels C and D), and whether we use the unidimensional factor structure (Panels A and C) or the more involved second-order correlated model (Panels B and D) depicted in Figure 5. Table 7 shows the results.

Table 7: Robustness of classification results

	Factor analysis based on pooled sample							
A. Unidimensional model	Freq.	Percent	*StdErr*	CzechRep	Denmark	France	Germany	Italy
normal	1,680	62.52	*0.57*	49.20	68.06	66.29	70.75	56.98
mild cognitive impairment	554	20.62	*0.70*	28.49	16.58	17.23	19.20	22.35
severe cognitive impairment	259	9.64	*0.54*	12.15	6.11	7.39	4.94	18.06
missing	194	7.22	*0.48*	10.16	9.25	9.09	5.12	2.61
Total	2,687	100		100	100	100	100	100
B. Second-order correlated model								
normal	1,939	72.16	*0.46*	60.76	76.44	76.70	77.70	68.16
mild cognitive impairment	341	12.69	*0.60*	19.32	11.52	9.47	11.88	11.73
severe cognitive impairment	261	9.71	*0.54*	11.55	5.06	8.33	6.03	18.06
missing	146	5.43	*0.42*	8.37	6.98	5.49	4.39	2.05
Total	2,687	100		100	100	100	100	100
	Separate factor analyses on each country sample							
C. Unidimensional model	Freq.	Percent	*StdErr*	CzechRep	Denmark	France	Germany	Italy
normal	1,568	58.36	*0.61*	46.02	69.46	59.66	67.64	47.30
mild cognitive impairment	639	23.78	*0.72*	29.68	16.58	21.21	21.76	30.54
severe cognitive impairment	266	9.90	*0.55*	12.75	5.06	8.14	4.94	19.18
missing	214	7.96	*0.50*	11.55	8.90	10.98	5.67	2.98
Total	2,687	100		100	100	100	100	100
D. Second-order correlated model								
normal	1,778	66.17	*0.53*	54.38	75.92	64.2	75.14	59.59
mild cognitive impairment	450	16.75	*0.66*	22.71	11.69	17.42	14.63	18.06
severe cognitive impairment	283	10.53	*0.56*	12.95	5.24	9.09	6.22	19.74
missing	176	6.55	*0.46*	9.96	7.16	9.28	4.02	2.61
Total	2,687	100		100	100	100	100	100

While there is relatively little variation across methodologies in the share of respondents classified as severely cognitively impaired, Table 7 indicates that the current classification is not robust with respect to the estimation sample, nor to the assumptions about factor correlations, regarding the distinction between normal and mild cognitively impaired. This holds for the aggregate of all five countries (Column 3) as well as for each single country (Columns 5-9).

These results provide strong indications that there is significantly more heterogeneity across the five countries than assumed by the pooled model presented in the previous section work. Heterogeneity may arise for several reasons:

- Frequency of missing data differs across countries. Imputation only partially resolves this problem as it may introduce other biases.
- While coders received strict instructions how to code, grey zones remain and coding habits may differ within and across countries. A possibility to minimize the influence of this by correcting for coder fixed effects.
- Interviewers received strict instructions to be "neutral". Nevertheless, interviewer habits may differ within and across countries. A possibility to minimize the influence of this by correcting for interviewer fixed effects.
- High quality translation cannot overcome a concept not traveling equally well across the different languages giving rise to "differential item functioning" within and across countries, which is a serious issue in any international survey. Respondents' understanding of items may vary across cultural backgrounds. A possibility to test for differential item functioning in the context of HCAP studies are described in e.g. Gross et al. 2023.

7. Test-retest variation

Another caveat concerns the relatively poor test-retest reliability, especially the inconsistencies between answers to same question across Wave 9 and HCAP, and within each of the two questionnaires. Panels A and B in the table below compare the same test between the SHARE core data in Wave 9 and SHARE-HCAP, which was conducted about five months later. Results of two tests (delayed word recall and serial7s) were divided into three categories: 0=lower 10%, 1=middle 15%, and 2=upper 75%, roughly corresponding to the prevalence of SCI. MCI and normal. We do not use absolute scores but relative ones to minimize the potential effects of learning between test and retest.

Table 8: Test-retest for delayed word recall and serial7s

A. Delayed word recall

		Wave9 0	Wave9 1	Wave9 2
HCAP	0	40%	20%	3%
	1	13%	18%	4%
	2	47%	62%	92%
	Total	**100%**	**100%**	**100%**
	Nobs	331	204	2058
	improve:	63%	worsen:	38%

B. Serial7s

		Wave9 0	Wave9 1	Wave9 2
HCAP	0	50%	37%	6%
	1	18%	26%	9%
	2	32%	38%	86%
	Total	**100%**	**100%**	**100%**
	Nobs	220	117	2186
	improve:	30%	worsen:	70%

C. Delayed word recall

		Wave8 0	Wave8 1	Wave8 2
Wave9	0	51%	24%	5%
	1	17%	17%	5%
	2	32%	59%	90%
	Total	**100%**	**100%**	**100%**
	Nobs	274	199	1615
	improve:	54%	worsen:	46%

D. Serial7s

		Wave8 0	Wave8 1	Wave8 2
Wave9	0	71%	28%	4%
	1	8%	17%	4%
	2	22%	55%	92%
	Total	**100%**	**100%**	**100%**
	Nobs	209	100	1832
	improve:	40%	worsen:	60%

Of the 331 respondents who did not score well on the delayed word recall test in Wave 9 (Panel A), only 40% did so in SHARE-HCAP. Astonishingly, more respondents changed to normal status as measured by this test. In the serial7s test (Panel B), only 50% of the respondents who did not score well in Wave 9 did so on average five months later. Other tests (orientation, immediate word recall, animal naming) produce similar results.

A comparison between lower off-diagonal elements and the upper off-diagonal elements shows more respondents improved in the delayed word recall test while their performance worsened in the serial7s test.

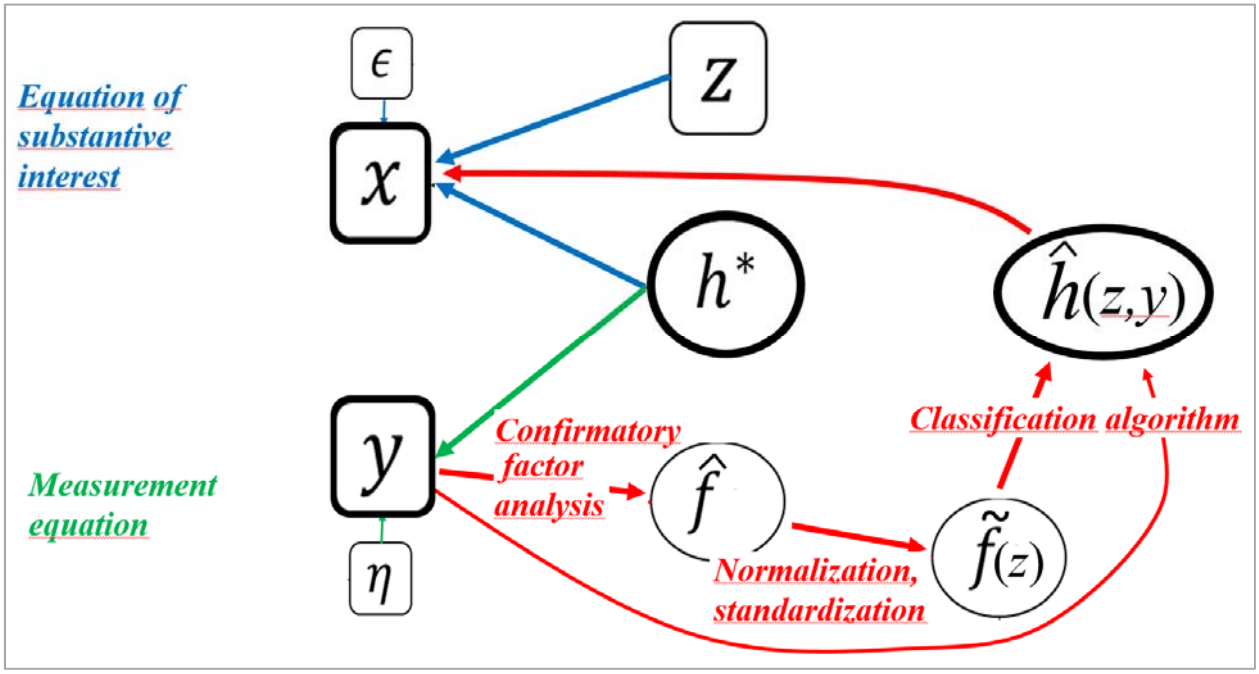
These large changes within five months are considerably larger than the changes between Wave 8 and Wave 9, and this in spite of a much longer distance between these two waves, which were slightly more than two years apart, see Panels C and D.

Another aspect similar to the test-retest variation is the correlation between the HCAP measure of SCI and a doctor's diagnosis reported by the respondent ("Has a doctor ever told you that you had/do you currently have any of the conditions: Alzheimer's disease, dementia, organic brain syndrome, senility or any other serious memory impairment"). While it is generally agreed upon that the doctors' attitudes what to tell patients and their recall of medical conditions leads to imprecise measures of prevalence, and maybe especially so among those with cognitive impairment, the deviations are astonishingly large. 55% of those respondents who reported such a condition in Wave 9 did not report so in HCAP. Moreover, only 54% of respondents who reported such a condition in Wave 9 were classified as SCI in HCAP. Even within the HCAP interview, only 55% of respondents who reported such a condition in the HCAP interview were classified as SCI by the HCAP algorithm.

8. Independence assumptions needed to use SHARE-HCAP cognitive status as explanatory variable

A final caveat concerns the usage of generated variables in econometric analyses, especially as right-hand-side variables in multiple regressions. Strong independence assumptions are necessary to apply the estimated cognitive scores as explanatory variables in a regression that has some socio-economic variable as outcome variable. Figure 8 shows the general set-up of such regressions:

Figure 8: Typical application



There is first an equation of substantive interest, which measures the influence of cognition h^* (assumed to be a scalar such that it can be converted into the three categories normal, MCI and SCI) and other characteristics $\boldsymbol{z}$ (a vector with dimension M) on some outcome variable x (assumed to be a scalar), which varies across countries i and respondents n:

$$x_{in} = \beta\, h^*_{in} + \boldsymbol{\gamma}'\boldsymbol{z_{in}} + \epsilon_{in} \qquad \text{Equation of substantive interest}$$

For example, we want to understand the long-term care arrangement (x is the choice between nursing home, lives with children, home care) as a function of the individual's cognition h^* and other characteristics z such as age, sex, co-morbidities etc. β and $\boldsymbol{\gamma}$ may be common across countries or vary by country.

True cognition h^* is latent (hence the asterisk) and is estimated by the outcome $\hat{h}(\boldsymbol{z},\boldsymbol{y})$ of the deterministic classification algorithm

$$\hat{h}_{in}(\boldsymbol{z},\boldsymbol{y}) = j \text{ if } \left[\tilde{\boldsymbol{f}}_{\boldsymbol{in}}(\boldsymbol{z}) > \boldsymbol{\theta}^{\boldsymbol{j}}_{\boldsymbol{i}} \,\&\, \boldsymbol{y_{in}} > \boldsymbol{\omega}^{\boldsymbol{j}}_{\boldsymbol{i}}\right] \qquad \text{Classification algorithm}$$

where $j = \text{normal, MCI or SCI.}$

The classification algorithm is a sequence of conditions that involve observed indicators $\boldsymbol{y}$ (i.e., items of the SHARE-HCAP battery, a vector of dimension K) and a vector of the estimated factor scores $\hat{\boldsymbol{f}}$ that is produced by the confirmatory factor analysis and then standardized for age, sex, etc. (i.e., variables in $\boldsymbol{z}$) to generate $\tilde{\boldsymbol{f}}(\boldsymbol{z})$. Referring to Figures 1-4, we have assumed five factors (orientation, visuospatial skills, memory, executive functioning, and language & fluency) such that $\hat{\boldsymbol{f}}$ and $\tilde{\boldsymbol{f}}(\boldsymbol{z})$ are vectors with dimension 5. Each classification step imposes vectors of thresholds $\boldsymbol{\theta}^{\boldsymbol{j}}_{\boldsymbol{i}}$ and $\boldsymbol{\omega}^{\boldsymbol{j}}_{\boldsymbol{i}}$ on the standardized factor scores $\tilde{\boldsymbol{f}}(\boldsymbol{z})$ and indicators $\boldsymbol{y}$ as shown in Figure 7. The thresholds are specific for each cognition category j and may vary by country i (although they do not for our preliminary estimates).

The factor scores are derived from the confirmatory factor analysis that has been described in Section 3 and relate the latent cognition h^* to the observed indicators $\boldsymbol{y}$:

$$\boldsymbol{y}_{in} = \boldsymbol{\delta}' h^*_{in} + \boldsymbol{\eta}_{in} \qquad \text{Measurement equation}$$

While the classification algorithm is deterministic, both the equation of interest and the measurement equation are stochastic with error components ϵ_{in} and η_{in} that may vary across countries i and respondents n. The loadings δ may be common across countries (as we have done in our preliminary analysis) or vary by country (as we will do in our future work due to the indications in the previous section).

Replacing h^* by $\hat{h}(\boldsymbol{z},\boldsymbol{y})$ in the equation of substantive interest, as it is common practice, creates several statistical problems. First, while $\hat{h}(\boldsymbol{z},\boldsymbol{y})$ is an estimated variable via the confirmatory factor analysis and therefore has its own variability, users tend to treat $\hat{h}(\boldsymbol{z},\boldsymbol{y})$ as deterministic and ignore the additional variability in their assessment of statistical significance. Second, a regression of the equation of substantive interest will only generate unbiased results if the stochastic terms ε and η are independent from each other. This is not the case if similar unobserved components influence both the type of care and the indicators that measure cognition, a most likely case. Users should be aware of these statistical problems. They can be solved by approaches that combine the

estimation of both the equation of interest and the measurement equation, e.g., by using MIMIC models with correlated error structures and suitable instruments.

Users should use the appropriate weights provided by SHARE (cross-sectional or longitudinal). However, in spite of the relatively high response rates among eligible SHARE respondents (Table 3), there is additional sample selectivity in the SHARE-HCAP sample. The release provides propensity-score weights for the SHARE-HCAP sample based on a comparison between the SHARE-HCAP sample and the parent sample of Wave 9.

9. Extrapolation to obtain prevalence estimates for all 28 SHARE countries

An important application of the SHARE-HCAP classification is as a validation tool for cognition measurement and prevalence estimation in the much larger parent sample in Wave 9 which has about 47,000 respondents of age 65 and older. This is described in Börsch-Supan, Douhou and Tawiah (2025) in detail. In a first step, using the SHARE-HCAP sample, they regressed the SHARE-HCAP classification outcome to a set of demographic variables, general health variables and cognition measures that are available both in the SHARE-HCAP sample and the SHARE parent study. Cognition measures included orientation in time, immediate and delayed word recall, serial 7s, and animal naming. Health was measured by the sum of activities of daily living (ADL) and the sum of instrumental activities of daily living (IADL). Table 9 shows that the prediction by this regression replicates the classification results very well.

Table 9. Estimated prevalence of normal, MCI and dementia in the SHARE-HCAP subsample based on diagnostic criteria and estimation approach[a]

		Classified according to Section 5			**Predicted using regression approach**		
	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 (0.9)	77.6 (1.8)	17.6 (1.6)	4.8 (0.9)
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 (0.9)	76.1 (1.8)	19.1 (1.6)	4.8 (0.9)
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 (0.9)	20.4 (0.8)	7.0 (0.5)	71.5 (0.9)	21.5 (0.8)	7.0 (0.5)

Abbreviation: SE, standard error.

[a] Classification and estimation of prevalence are based on weighted data.
Source: Börsch-Supan, Douhou and Tawiah (2025)

In a second step, Börsch-Supan et al. used the regression equation to predict the probabilities of respondents in SHARE Wave 9 being normal, MCI and SCI, based on the common set of demographic, cognition and health variables in SHARE Wave 9 and SHARE-HCAP. Expressing the result as probability rather than a deterministic category acknowledges the uncertainty in the prediction. Prevalence rates of normal, MCI and SCI for each country can then be calculated as country-specific average probability of each cognitive status. Table 10 shows the results.

Table 10. Prevalence estimates for the SHARE countries (percentages)

		HCAP-validated prevalence rates[a]			
Country	**N**	**MCI, % (SE)**		**Demented, % (SE)**	
Austria	2,176	16.9	(0.8)	6.8	(0.5)
Germany	2,708	16.8	(0.7)	5.3	(0.4)
Sweden	2,010	17.2	(0.8)	5.0	(0.5)
Netherlands	1,686	20.5	(1.0)	5.7	(0.5)
Spain	1,458	29.1	(1.2)	22.7	(1.1)
Italy	2,761	24.9	(0.8)	11.6	(0.6)
France	2,035	19.9	(0.9)	6.0	(0.5)
Denmark	1,523	18.0	(1.0)	5.3	(0.6)
Greece	2,351	30.4	(0.9)	14.0	(0.7)
Switzerland	1,425	17.8	(1.0)	4.6	(0.5)
Belgium	2,783	21.1	(0.8)	8.3	(0.5)
Israel	660	24.7	(1.7)	19.5	(1.5)
Czech Republic	2,647	18.6	(0.7)	5.9	(0.4)
Poland	3,137	27.3	(0.8)	14.0	(0.6)
Luxembourg	546	19.2	(1.6)	7.2	(1.1)
Hungary	1,229	23.5	(1.2)	8.7	(0.8)
Portugal	924	31.1	(1.5)	21.1	(1.3)
Slovenia	2,772	23.3	(0.8)	11.1	(0.6)
Estonia	2,950	20.1	(0.7)	8.9	(0.5)
Croatia	2,858	26.8	(0.8)	14.6	(0.7)
Lithuania	921	26.4	(1.5)	13.9	(1.1)
Bulgaria	573	29.9	(1.9)	12.2	(1.4)
Cyprus	555	30.3	(2.0)	15.6	(1.6)
Finland	1,237	20.7	(1.1)	6.7	(0.7)
Latvia	1,026	27.0	(1.4)	10.1	(1.0)
Malta	654	29.3	(1.8)	12.2	(1.3)
Romania	994	28.5	(1.4)	16.7	(1.2)
Slovakia	591	28.7	(1.9)	11.2	(1.3)
SHARE Wave 9	**47,193**	**23.9**	(0.2)	**10.9**	(0.1)

Abbreviation: SE, standard error

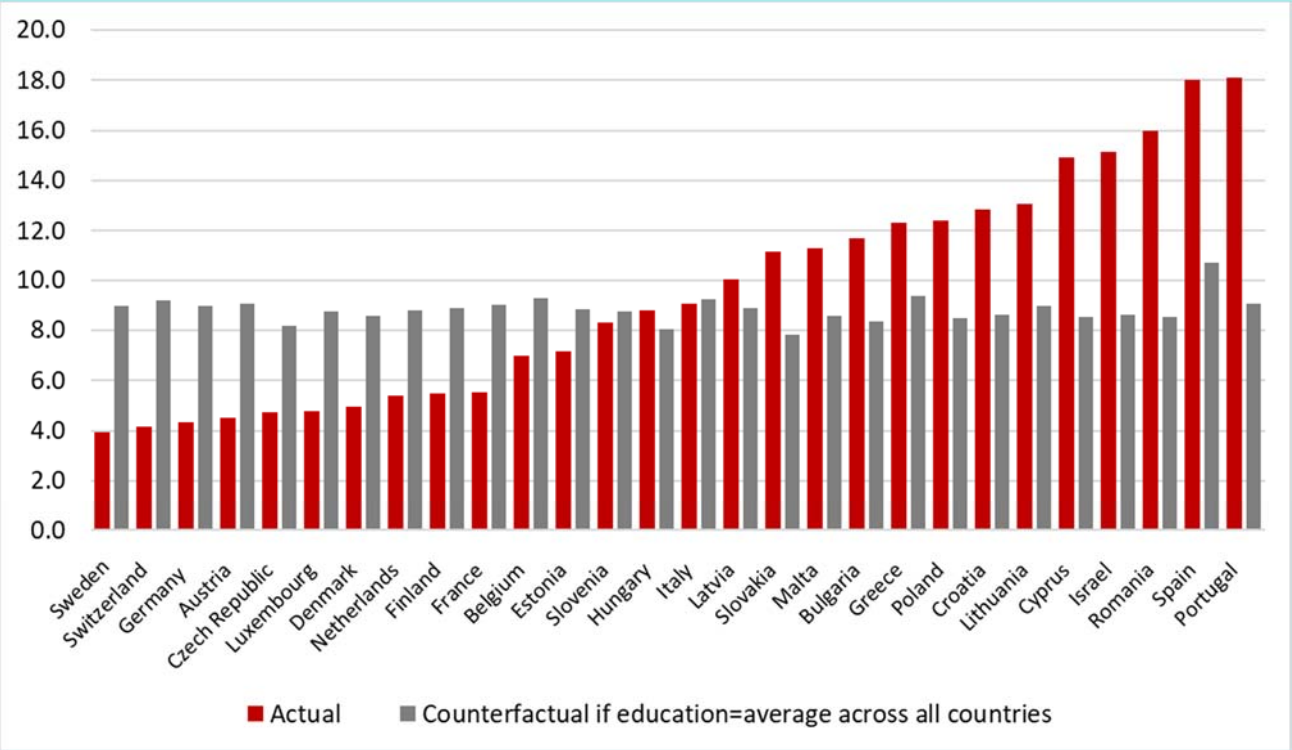
[a] Prevalence estimates generated from estimation equation using the Hurd et al. approach.
Source: Börsch-Supan, Douhou and Tawiah (2025)

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. MCI is on average 24% (SE=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 European countries on the higher side, reaching almost a third in Bulgaria, Cyprus, Greece, and Portugal.

A multivariate regression reveals that demographics (age and sex) and education have a great influence on the probability of SCI. Using this regression, Figure 9 shows how the probability of SCI would vary across countries if education were the same in all SHARE countries. The variation is substantially smaller if education is set to the average of the 28 countries.

Figure 9. Prevalence of SCI for the SHARE countries.
(actual and counterfactual if education had been equal across all countries)



The red bars show the actual estimated share of demented individuals in each country. The grey bars show the counterfactual share of demented individuals if education in each country had been equal to the average of the 28 countries.

Source: Börsch-Supan, Douhou and Tawiah (2025).

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