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The role of education and income for cognitive functioning in old age: A cross-country comparison

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Abstract

Objectives: Previous studies have shown that higher education promotes cognitive health. This effect, however, is embedded in the living conditions of a particular country. Since it is not clear to what extent the country and its specific living standards are necessary preconditions for the observed effect, we investigated whether the impact of education and income on cognitive functioning differs between countries.

Methods: Analyses were based on harmonized data from the World Health Organization's multi-country Study on global AGEing and adult health, the Health and Retirement Study, and the Survey of Health, Ageing and Retirement in Europe of over 85,000 individuals aged 50 years and older. Analyses were conducted via multivariate regression analyses and structural equation modeling adjusted for age, gender, marital status, health status, and depression.

Results: The effect of education was twice as large as the effect of income on cognitive functioning and indirectly moderated the effect of income on cognitive functioning. The effect sizes varied strongly between countries. The country's gross domestic product per capita seems to influence cognitive functioning.

Conclusions: Our findings indicate that education has a dominant effect on cognitive functioning in people aged 50 years and older, which might even offset the adverse implications of living with low income on cognitive health. Therefore, expanding efforts to achieve universal education are essential to mitigate health disparities due to low income and early life disadvantages, including chances for good cognitive functioning over the life-span.

KEYWORDS
aging, cognitive functioning, cognitive reserve, cross-country comparison, deprivation, education, epidemiology, income, life-course, poverty

Key points

- We show large discrepancies between countries in the effect size of education
- Our findings emphasize the relevance of education over income on cognitive health

- Higher education might offset the implications of low income on cognitive functioning
- Small effect sizes in countries like Switzerland and Germany remain puzzling

1 | INTRODUCTION

Rising life-expectancy leads to aging of societies.[1] Older age, however, comes with a greater susceptibility to age-related cognitive impairment[2] so that the number of people with cognitive impairments is growing.[3] Protective factors, which promote better and longer cognitive functioning, are thus more relevant than ever before.

Cognitive reserve is a well-established protector against cognitive impairments in old age[4,5] that is built by intellectual activities, such as education.[6] People with higher education exhibit better cognitive functioning in adulthood,[7] a delayed rate of cognitive decline in old age,[8] and a reduced risk of dementia.[9] Education has also shown to be associated with better brain connectivity,[10,11] greater brain volume, and greater brain metabolism.[12] However, education needs to be investigated in a wider socioeconomic context.

Education and income-related aspects are intertwined in the socioeconomic concept.[13] Yet, disentangling the pathways through which they affect cognition is crucial to inform public policy. It is not clear how income contributes to the observed effects of education. Income constitutes mainly resources for living. A lack of resources such as in situations of malnutrition,[14] inadequate sanitation,[15] substandard housing,[16] contaminated drinking water,[17] and pollution[18] is associated with significant health problems. It is conceivable, that this may be reflected in a direct association with cognitive functioning, independent from education. However, direct evidence is lacking.

We therefore investigated how formal education and income are independently associated with cognitive functioning in people aged 50 years and older in countries with different income levels. Cross-country comparisons can provide valuable new insights because the majority of previous research studies have been conducted in highly developed countries. Living standards in a country may determine cognitive health through the environmental exposure of the individual to the country's standards.[19] As people in countries with lower income are exposed to a greater number of adverse environmental factors that increase the vulnerability for dementia,[20,21] it is possible that the association of income and education on cognitive functioning is different for them as it is for people in countries with higher income. Therefore, our study also considered the countries' gross domestic product (GDP) in the association.

2 | METHODS

2.1 | Study design

Three studies, the World Health Organization's multi-country Study on global AGEing and adult health (WHO SAGE[22]), the Health and Retirement Study (HRS[23]), and the Survey of Health, Ageing and Retirement in Europe (SHARE[24]), were harmonized. Descriptions of the studies can be found in the supporting information (Table S1). Data from the assessments in the years 2006/2007 were combined for a coherent cross-sectional comparison. Individuals were excluded if they were younger than 50 years old or had missing data ($n = 10{,}198$). The total dataset comprised data of $n = 86{,}027$ individuals from 22 countries (6 from the WHO SAGE, 1 from the HRS, 15 from the SHARE; see Table 1 for sample characteristics). Of those, $n = 23{,}372$ participants had incomplete information on income and $n = 9208$ on education. Analysis was conducted omitting cases with missings.

2.2 | Education

The highest level of education that was reported by the participants was categorized into three groups: (1) less education than high school, (2) completed high school, and (3) completed education at a college level or higher (according to International Standard Classification of Education [ISCED] coding[25]).

2.3 | Income

Income was operationalized as the total net value of household assets. Value instead of monetary income was selected because resources for living are not always monetarized, especially not in countries with lower income levels. In the WHO SAGE, the value of household assets was estimated via the wealth index (details described[26]). The wealth index was calculated on household level based on the information provided by the participants on absolute income, household ownership of assets, and access to services. Random effects modeling was conducted for each country separately and households were arranged in ascending order via Bayesian post-estimation in their respective country. In the HRS, the value of household assets was estimated as the total net value of wealth of an household that was calculated as the sum of all wealth components less the sum of all debt, a variable constructed by RAND.[27] In SHARE, the value of household assets was estimated as the total financial assets (sum of bank accounts, bonds, stock, mutual funds, and savings for long-term investments) minus liabilities. Imputations for missing data were provided by SHARE if feasible.[28] For purpose of analysis, quintiles for each country were used.

2.4 | Country-specific indicators

The country-specific indicators GDP and government health expenditure were derived from the World Bank World Development indicators database (https://databank.worldbank.org/home), a collection of time series data on a variety of economic and social

TABLE 1 Characteristics of the samples of each country (2006/2007)

Country	Country classification[a]	GDP per capita	Sample size	Age (M, SD)	Sex, male (%)	Education, high (%)
Austria	HIC	51,120	*n* = 1182	65.9, 14.1	44.8	22.9
Belgium	HIC	47,250	*n* = 3143	65.4, 21.3	45.9	25.9
China	MIC	5979	*n* = 13,424	62.6, 8.1	49.8	4.7
Czech Republic	HIC	32,466	*n* = 2671	63.8, 18.1	44.8	15.6
Denmark	HIC	53,449	*n* = 2548	64.5, 26.8	47.1	36.5
France	HIC	42,570	*n* = 2879	65.4, 8.7	45.0	20.0
Germany	HIC	45,606	*n* = 2585	65.5, 6.6	45.6	28.7
Ghana	MIC	3207	*n* = 5019	64.2, 28.5	49.7	3.6
Greece	HIC	36,816	*n* = 3239	65.9, 20.6	46.5	16.8
India	MIC	3447	*n* = 8825	61.5, 5.9	51.1	5.4
Ireland	HIC	58,214	*n* = 1007	64.0, 20.4	47.9	48.9
Israel	HIC	32,512	*n* = 2426	65.2, 24.9	46.1	31.1
Italy	HIC	45,138	*n* = 2931	65.9, 8.4	45.2	8.4
Mexico	MIC	18,347	*n* = 5266	63.0, 279.2	46.6	n/a
Netherlands	HIC	51,338	*n* = 2638	64.1, 16.0	47.1	23.9
Poland	HIC	20,118	*n* = 2426	63.7, 9.9	43.4	12.9
Russia	MIC	21,824	*n* = 5582	63.9, 7.1	38.8	18.3
South Africa	MIC	11,924	*n* = 4508	61.6, 14.8	44.1	6.0
Spain	HIC	38,935	*n* = 2382	65.8, 9.8	45.7	11.5
Sweden	HIC	48,012	*n* = 2761	65.7, 21.6	47.2	31.6
Switzerland	HIC	62,939	*n* = 1459	65.1, 17.9	46.2	29.1
United States	HIC	55,491	36,966	65.8, 10.5	45.6	24.2

Abbreviations: GDP, gross domestic product; HIC, high income country; LIC, low income country; M, mean; MIC, middle-income country; PPP, purchasing power parity; SD, standard deviation.

[a]Classification according to the World Bank database; GDP per capita based on PPP in 2006.

indicators compiled from officially recognized international sources. These indicators were used to model how income and education are generally associated with cognitive functioning in an analysis with all countries together.

2.4.1 | Gross domestic product

Data analysis used GDP per capita based on purchasing power parity in 2006. It is the sum of gross value added by all resident producers in the country's economy and any product taxes minus subsidies that are not an added value to the products in the respective year, which is converted to international dollars.

2.4.2 | Government health expenditure

Data analysis used domestic general government health expenditure from domestic sources as percentage of the GDP in 2006.

2.5 | Covariates

Gender and marital status were used as indicated by participants. For purpose of analysis, marital status was dichotomized with 1 for being married or living in a partnership and 2 for everyone living alone including mainly single individuals but also widowed and divorced. Health status was assessed as follows: In the WHO SAGE, participants were asked, "In general, how would you rate your health today?" In the SHARE study, the participants were asked, "Would you say your health is …" In the HRS, participants were asked, "Would you say your health is excellent, very good, good, fair, or poor?" Responses were recorded on a 5-point Likert scale in each study (lower values indicated better health). Depression was assessed as follows: In the WHO SAGE, participants were asked, "Have you ever been diagnosed with depression?" In the SHARE study, participants were asked, "Has there been a time or times in your life when you suffered from symptoms of depression which lasted at least two weeks?" In the HRS, we used the variable constructed by RAND that indicates

whether a participant ever had emotional psychiatric condition including depression.

2.6 | Cognitive functioning

Cognitive functioning was assessed by the 10 Word List Learning Test.[29,30] The participants were presented 10 words which they were asked to read out loud and to remember. Immediately after the presentation, the participants were asked what the 10 words were. The number of correctly remembered words is the immediate recall score. After a delay, the participants were asked to recall the 10 words again. The number of correctly remembered words after the delay forms the delayed recall score. In contrast to the HRS and SHARE, the WHO SAGE had three trials of reading out the 10 words before the delayed recall. All the scores were normally distributed.

2.7 | Statistical analyses

All analyses were performed on the pooled data of the three studies using STATA 16. All analyses used sampling weights for the respective study and country to achieve a close approximation to representativeness of the general population.

Differences in cognitive functioning (immediate recall, delayed recall) with respect to education and income were analyzed via linear regression modeling adjusted for age, gender, marital status, health status, and depression, first, for all countries together (Model 1: including education and covariates, Model 2: including income and covariates, Model 3: including education, income, and covariates) and, second, for each country separately. Regression models on delayed recall were additionally adjusted for a variable indicating whether it was part of the WHO SAGE, because participants of the WHO SAGE study had three instead of two repetition trials before they were asked to recall the words. Meta-analytic summary of the associations of education/income on cognitive functioning were estimated by comparing means and standard deviations of each country.

Pathways of income and education on cognitive functioning were modeled via structural equation modeling (SEM) in seven steps. Step 1: Based on the assumption that education is associated with better cognitive functioning according to the cognitive reserve theory,[31] we modeled a path from education to the two scores of cognitive functioning (immediate recall, delayed recall). Step 2: We added a path from immediate recall to delayed recall because the performance in the first recall trial is a predictor for the subsequent recall trial. We also added a path for SAGE to delayed recall as the participants of the SAGE study had three instead of one practice trials. All paths were $p < 0.05$. Step 3: Based on the assumption that education facilitates access to financial resources (i.e., income), we added a path from education to income, a path from income to cognitive functioning, and a direct effect of education over income to cognitive functioning. Step 4: We tested the role of GDP on cognitive functioning, education, and income by adding the respective paths. Step 5: We tested the role of government health expenditures on cognitive functioning and added a corresponding path as well as a path from GDP to government health expenditure. Step 6: We tested whether GDP moderated the association between education and income on cognitive functioning. Even though p was <0.05, the residual matrix had extremely high values for the interaction terms (between −6063.9 and 43255.7) so that we removed it again from the model. Step 7: We added the effects of all covariates on cognitive functioning. All paths remained $p < 0.05$ and all residuals in the residual matrix were small (between −1.327 and 0.329). We verified this final model using generalized SEM and factor variables and the results were nearly identical.

3 | RESULTS

3.1 | Sample characteristics

The mean age was 63.9 years (standard deviation [SD] 10.1). Of the participants, 53.2% were female, 70.5% were married, 10.3% reported a history of depression, and the average health status was 3.0 (SD 0.9, signifying good). 54.8% had completed less than high school, 30.7% completed high school, and 14.6% had completed college or more. The level of formal education varied widely between countries: South Africa (85.0% less than high school), India (85.4% less than high school), Spain (79.8% less than high school), and Ghana (78.9% less than high school) had the lowest rate of education. Ireland (48.9%), Denmark (36.5%), Sweden (31.6%), and Israel (31.1%) had the highest rate of college completion. The difference in the rate of schooling between the lowest and the highest income groups was most pronounced in the United States and Ireland and least pronounced in Switzerland and Russia (details shown in the supporting information, Table S2).

3.2 | Cognitive functioning

The average level of cognitive functioning was lower for those who were less educated, older, male, not married, had a poorer health status or depression, and lower income (see Table 2). The average immediate recall score was 4.9 words (SD 1.8) and the average delayed recall score was 4.3 words (SD 2.2). Compared to those who did not complete high school, individuals who completed high school remembered on average half a word more and individuals with college or higher education remembered one word more. The difference between the lowest and the highest income groups was about half a word. The predicted means of the delayed recall task indicated that individuals in the lowest income group remembered almost one word and individuals in the highest income group half a word more if they had college education or higher (compared to those who did not complete high school). Performance in the immediate recall task was one and a half words more in the college-educated group,

TABLE 2 Effect estimates of the association of education and income on cognitive functioning, analyzed via linear regression modeling for all countries together with sampling weights (n = 86,027, 2006/2007)

		Model 1		Model 2		Model 3	
		b	*p*	*b*	*p*	*b*	*p*
Immediate recall							
Education	<High school	REF				REF	
	High school completed	0.67 (0.61–0.73)	<0.001			0.60 (0.54–0.66)	<0.001
	College completed	1.06 (1.00–0.73)	<0.001			0.94 (0.88–0.99)	<0.001
Income	1st quintile			REF		REF	
	2nd quintile			0.18 (0.12–0.23)	<0.001	0.15 (0.09–0.21)	<0.001
	3rd quintile			0.28 (0.22–0.34)	<0.001	0.21 (0.16–0.27)	<0.001
	4th quintile			0.51 (0.44–0.59)	<0.001	0.39 (0.32–0.47)	<0.001
	5th quintile			0.63 (0.57–0.69)	<0.001	0.43 (0.37–0.49)	<0.001
Country	Austria	−0.04 (−0.16–0.07)	0.445	−0.12 (−0.23–−0.01)	0.034	−0.05 (−0.16–0.06)	0.353
	Belgium	−0.26 (−0.33–−0.19)	<0.001	−0.44 (−0.51–−0.37)	<0.001	−0.27 (−0.34–−0.20)	<0.001
	China	−0.63 (−0.69–−0.58)	<0.001	−1.16 (−1.21–−1.11)	<0.001	−0.68 (−0.74–−0.63)	<0.001
	Czech Republic	−0.18 (−0.27–−0.09)	<0.001	−0.39 (−0.48–−0.29)	<0.001	−0.20 (−0.29–−0.11)	<0.001
	Denmark	−0.08 (−0.15–−0.01)	0.023	−0.07 (−0.14–0.00)	0.062	−0.06 (−0.13–0.01)	0.079
	France	−0.55 (−0.62–−0.48)	<0.001	−0.76 (−0.83–−0.69)	<0.001	−0.57 (−0.65–−0.50)	<0.001
	Germany	−0.05 (−0.12–0.02)	0.192	0.01 (−0.06–0.08)	0.775	−0.03 (−0.11–0.04)	0.381
	Ghana	−0.20 (−0.27–−0.13)	<0.001	−0.69 (−0.75–−0.63)	<0.001	−0.25 (−0.32–−0.18)	<0.001
	Greece	−0.43 (−0.49–−0.36)	<0.001	−0.66 (−0.72–−0.59)	<0.001	−0.38 (−0.45–−0.32)	<0.001
	India	−0.89 (−0.96–−0.82)	<0.001	−1.44 (−1.50–−1.38)	<0.001	−0.94 (−1.01–−0.87)	<0.001
	Ireland	−0.38 (−0.49–−0.26)	<0.001	−0.43 (−0.55–−0.31)	<0.001	−0.36 (−0.48–−0.24)	<0.001
	Israel	−0.74 (−0.83–−0.65)	<0.001	−0.84 (−0.93–−0.75)	<0.001	−0.74 (−0.83–−0.65)	<0.001
	Italy	−0.52 (−0.62–−0.43)	<0.001	−0.88 (−0.97–−0.79)	<0.001	−0.55 (−0.64–−0.45)	<0.001
	Mexico			−1.47 (−1.65–−1.29)	<0.001		
	Netherlands	−0.03 (−0.11–0.05)	0.524	−0.23 (−0.31–−0.15)	<0.001	−0.03 (−0.11–0.05)	0.450
	Poland	−0.89 (−0.98–−0.82)	<0.001	−1.03 (−1.11–−0.95)	<0.001	−0.87 (−0.95–−0.79)	<0.001
	Russia	−0.01 (−0.18–0.16)	0.869	−0.12 (−0.28–0.04)	0.154	−0.04 (−0.21–0.12)	0.605
	South Africa	−0.06 (−0.16–0.04)	0.222	−0.59 (−0.68–−0.51)	<0.001	−0.11 (−0.21–−0.01)	0.024
	Spain	−1.18 (−1.27–−1.08)	<0.001	−1.61 (−1.70–−1.52)	<0.001	−1.22 (−1.32–−1.13)	<0.001
	Sweden	−0.03 (−0.12–0.05)	0.430	−0.18 (−0.26–−0.09)	<0.001	−0.03 (−0.11–0.06)	0.545
	Switzerland	−0.19 (−0.28–−0.09)	<0.001	−0.27 (−0.36–−0.18)	<0.001	−0.18 (−0.27–−0.09)	<0.001
	United States	REF		REF		REF	
Marital status	Married/partnership	REF		REF		REF	
	Single	−0.19 (−0.25–−0.14)	<0.001	−0.13 (−0.18–−0.07)	<0.001	−0.14 (0.19–−0.09)	<0.001
Age		−0.05 (−0.05–−0.04)	<0.001	−0.05 (−0.05–−0.05)	<0.001	−0.05 (−0.05–−0.04)	<0.001
Gender	Male	REF		REF		REF	
	Female	0.23 (0.18–0.28)	<0.001	0.16 (0.11–0.20)	<0.001	0.22 (0.18–0.27)	<0.001
Health status		−0.23 (−0.25–−0.22)	<0.001	−0.26 (−0.28–−0.24)	<0.001	−0.10 (−0.16–−0.04)	0.001
Depression	no	REF		REF		REF	
	yes	−0.11 (−0.17–−0.05)	<0.001	−0.08 (−0.14–−0.02)	0.010		

TABLE 2 (Continued)

		Model 1		Model 2		Model 3	
		b	*p*	*b*	*p*	*b*	*p*
Delayed recall							
Education	<High school	REF				REF	
	High school completed	0.69 (0.61–0.77)	<0.001			0.59 (0.52–0.67)	<0.001
	College completed	1.11 (1.03–1.19)	<0.001			0.94 (0.85–1.03)	<0.001
Income	1st quintile			REF		REF	
	2nd quintile			0.09 (0.02–0.17)	0.015	0.07 (−0.01–0.15)	0.074
	3rd quintile			0.25 (0.17–0.32)	<0.001	0.18 (0.10–0.26)	<0.001
	4th quintile			0.53 (0.46–0.60)	<0.001	0.41 (0.34–0.49)	<0.001
	5th quintile			0.78 (0.69–0.87)	<0.001	0.58 (0.48–0.68)	<0.001
Country	Austria	−0.35 (−0.48−−0.23)	<0.001	−0.44 (−0.56−−0.31)	<0.001	−0.37 (−0.49−−0.25)	<0.001
	Belgium	−0.79 (−0.88−−0.72)	<0.001	−0.98 (−1.05−−0.89)	<0.001	−0.81 (−0.89−−0.73)	<0.001
	China	0.76 (0.69–0.83)	<0.001	0.22 (0.16–0.27)	<0.001	0.69 (0.62–0.76)	<0.001
	Czech Republic	−0.76 (−0.86−−0.67)	<0.001	−0.99 (−1.09−−0.89)	<0.001	−0.80 (−0.90−−0.71)	<0.001
	Denmark	−0.29 (−0.38−−0.21)	<0.001	−0.27 (−0.36−−0.19)	<0.001	−0.27 (−0.35−−0.18)	<0.001
	France	−0.96 (−1.04−−0.87)	<0.001	−1.17 (−1.26−−1.09)	<0.001	−0.99 (−1.08−−0.91)	<0.001
	Germany	−0.64 (−0.73−−0.55)	<0.001	−0.58 (−0.67−−0.49)	<0.001	−0.62 (−0.71−−0.53)	<0.001
	Ghana	0.66 (0.57–0.75)	<0.001	0.14 (0.06–0.22)	0.001	0.58 (0.49–0.68)	<0.001
	Greece	−0.86 (−0.94−−0.78)	<0.001	−1.12 (−1.19−−1.04)	<0.001	−0.85 (−0.93−−0.76)	<0.001
	India	0.32 (0.22–0.42)	<0.001	−0.25 (−0.33−−0.17)	<0.001	0.24 (0.14–0.34)	<0.001
	Ireland	−0.54 (−0.68−−0.40)	<0.001	−0.59 (−0.73−−0.44)	<0.001	−0.52 (−0.66−−0.38)	<0.001
	Israel	−1.07 (−1.18−−0.96)	<0.001	−1.19 (−1.30−−1.08)	<0.001	−1.09 (−1.21−−0.99)	<0.001
	Italy	−0.93 (−1.04−−0.82)	<0.001	−1.30 (−1.41−−1.20)	<0.001	−0.97 (−1.07−−0.86)	<0.001
	Mexico			0.11 (−0.15–0.37)	0.395		<0.001
	Netherlands	−0.31 (−0.40−−0.21)	<0.001	−0.51 (−0.61−−0.42)	<0.001	−0.32 (−0.41−−0.22)	<0.001
	Poland	−1.31 (−1.40−−1.23)	<0.001	−1.48 (−1.57−−1.39)	<0.001	−1.33 (−1.42−−1.24)	<0.001
	Russia	0.59 (0.38–0.79)	<0.001	0.48 (0.29–0.67)	<0.001	0.55 (0.36–0.75)	<0.001
	South Africa	1.44 (1.32–1.57)	<0.001	0.89 (0.77–1.01)	<0.001	1.37 (1.24–1.49)	<0.001
	Spain	−1.33 (−1.43−−1.23)	<0.001	−1.79 (−1.88−−1.69)	<0.001	−1.40 (−1.50−−1.30)	<0.001
	Sweden	−0.22 (−0.32−−0.13)	<0.001	−0.36 (−0.46−−0.27)	<0.001	−0.21 (−0.31−−0.12)	<0.001
	Switzerland	−0.56 (−0.68−−0.45)	<0.001	−0.64 (−0.75−−0.53)	<0.001	−0.55 (−0.67−−0.44)	<0.001
	United States	REF		REF		REF	
Marital status	Married/partnership	REF		REF		REF	
	Single	−0.16 (−0.24−−0.07)	<0.001	−0.07 (−0.15−−0.01)	<0.001	−0.08 (−0.16−−0.00)	0.064
Age		−0.06 (−0.06−−0.05)	<0.001	−0.06 (−0.06−−0.06)	<0.001	−0.06 (−0.06−−0.05)	<0.001
Gender	Male	REF		REF		REF	
	Female	0.30 (0.24–0.37)	<0.001	0.23 (0.17–0.29)	<0.001	0.29 (0.23–0.36)	<0.001
Health status		−0.28 (−0.30−−0.25)	<0.001	−0.29 (−0.32−−0.27)	<0.001	−0.25 (−0.27−−0.22)	<0.001
Depression	no	REF		REF		REF	
	yes	−0.17 (−0.24−−0.09)	<0.001	−0.13 (−0.21−−0.06)	<0.001	−0.16 (−0.23−−0.09)	<0.001

Note: Model 1, including education and covariates; Model 2, including income and covariates; Model 3, including education, income, and covariates.
Abbreviation: REF, reference category.

irrespective of the income group they belonged to. We observed substantial differences between countries (Table 2).

3.3 | Per country analysis

A meta-analytic summary of the country-specific associations between formal education and income on cognitive functioning are shown in the supporting information (Figure S1). I^2 of 87%–97% indicated large heterogeneity between country differences. Hence, the previous regression analysis were repeated separately for each country to obtain country-specific coefficients (Table 3). The association between education and cognitive functioning was weakest ($p > 0.1$) in Ghana and strongest in the United States (difference in delayed recall between low and high educated groups: 1.4 words, Ireland 1.3 words, Italy 1.3 words, Czech Republic, China, France, and India 1.2 words). The association between income and cognitive functioning was weakest in Ghana and South Africa as well as most European countries (Czech Republic, Denmark, Germany, Italy, Poland, Spain, Sweden, Switzerland) and Russia. The difference between low and high income groups in delayed recall was strongest in Austria (1.4 words), Mexico (1.4 words), and the United States (1.1 words). The results are summarized in Figure 1.

3.4 | Structural equation modeling

Structural equation modeling confirmed the associations of formal education and income on cognitive functioning (see Figure 2 for effect estimates). Two important observations were made. First, the effect of education on immediate recall was much larger ($b = 0.25$; $p < 0.001$) than that of income ($b = 0.08$; $p < 0.001$). Second, in addition to its direct effect on cognitive functioning, education was also associated with income ($b = 0.29$; $p < 0.001$) and had an indirect effect on cognitive functioning via income (immediate recall $b = 0.06$, $p < 0.001$; delayed recall $b = 0.49$, $p < 0.001$). Further, the results suggested that the effect of education was dependent on GDP ($b = 0.43$; $p < 0.001$) and GDP was a strong predictor of cognitive functioning (immediate recall $b = 0.21$; $p < 0.001$; delayed recall $b = 0.19$; $p < 0.001$). Cognitive functioning was also strongly associated with age (immediate recall $b = -0.26$; $p < 0.001$; delayed recall $b = 0.12$; $p < 0.001$), and health status (immediate recall $b = -0.12$; $p < 0.001$; delayed recall $b = 0.06$; $p < 0.001$; Figure 2).

4 | DISCUSSION

The study evaluated how formal education and income were associated with cognitive functioning in people aged 50 years and older in different countries. Findings indicate that the effect sizes varied substantially between countries, being largest in the United States and Italy and smallest in Ghana and Sweden. In the United States, there was the strongest difference in schooling between low and high income groups and the largest effects for education and income on cognitive functioning. Moreover, our findings indicate that the effect of formal education on cognitive function was twice as large as that of income in most countries. Results from SEM highlight an indirect effect of education on cognitive functioning via income. The magnitude of this indirect effect was about a quarter of the direct effect of education.

Our findings are in line with previous studies, which have shown that higher education is associated with better cognitive functioning, an effect that can be attributed to better functional brain connectivity[12] as well as higher cognitive reserve.[32] Moreover, higher education also comes with life competencies such as self-esteem and self-efficacy, productive efficiency, resilience to stressful and risky environments, and health behavior.[33] Individuals with stronger life competencies are, on one hand, more capable of avoiding risk factors that could impair cognitive functioning and, on the other hand, engage in more cognitive demanding activities that additionally help to keep up cognitive functioning in old age.[34] Furthermore, education strengthens socioeconomic competencies that give access to other resources such as higher income. Our findings confirm that. Higher income (and other resources) could then additionally improve cognitive functioning—the results of our SEM support that notion. The extent to which education can provide those effects depends on the content and quality of education as well as the structural setting and function of education in the society. This might explain cross-country differences.

To better understand why the effects differ between countries, we investigated the role of GDP. GDP per capita was associated with cognitive functioning with an effect size twice as large as that of individual income. Further, our results suggest that GDP has a strong influence on the effect of education on cognitive functioning, which could explain the very small effect size of education in Ghana, which has a low GDP, and the strong effect size of education in the United States and Ireland, both having a high GDP. However, the small effect sizes in countries like Switzerland, Denmark, and Germany—other high GDP-countries—remain puzzling. It is conceivable that these countries give individuals from low income/education groups other resources that protect cognitive functioning. More research is necessary to identify those resources (e.g., social welfare system).

Our findings emphasize that, in addition to the effect of formal education, the individual's health status is strongly associated with cognitive functioning. We tested whether government health expenditures might play a role in improving the situation of low education and low income groups, but our results cannot confirm this idea. Accessibility, acceptability, and quality of the health care system as well as health behaviors and exposure to susceptibility are factors that influence health[35] and those cannot be directly moderated by government health expenditure. Factors on an individual level, such as health-related knowledge and behaviors (e.g., smoking, nutrition), working conditions, perceived control, and discrimination[36] might be more crucial.

Our study is not without limitations. First, we used cross-sectional data. Longitudinal observations are necessary to

TABLE 3 Effect estimates of the association of education and income on cognitive functioning (immediate and delayed recall), analyzed via linear regression modeling for each country separately adjusted for covariates and with sampling weights (2006/2007)

	Education (high school completed)		Education (completed college or higher)		Income (2nd quintile)		Income (3rd quintile)		Income (4th quintile)		Income (5th quintile)	
Country	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
Immediate recall												
Austria	0.65 (0.38–0.92)	<0.001	0.94 (0.64–1.25)	<0.001	0.88 (0.50–1.26)	<0.001	0.79 (0.44–1.13)	<0.001	1.00 (0.66–1.35)	<0.001	1.26 (0.91–1.60)	<0.001
Belgium	0.64 (0.49–0.78)	<0.001	1.05 (0.90–1.20)	<0.001	0.20 (0.01–0.39)	0.043	0.43 (0.24–0.62)	<0.001	0.53 (0.33–0.73)	<0.001	0.65 (0.45–0.85)	<0.001
China	0.69 (0.59–0.79)	<0.001	1.06 (0.91–1.20)	<0.001	0.15 (0.05–0.26)	0.005	0.40 (0.29–0.51)	<0.001	0.69 (0.58–0.79)	<0.001	0.73 (0.62–0.84)	<0.001
Czech Republic	0.61 (0.44–0.78)	<0.001	1.12 (0.88–1.36)	<0.001	−0.18 (−0.49–0.14)	0.280	0.01 (−0.21–0.23)	0.931	0.13 (−0.09–0.35)	0.271	0.18 (−0.08–0.44)	0.185
Denmark	0.66 (0.47–0.84)	<0.001	0.83 (0.64–1.02)	<0.001	0.24 (0.03–0.45)	0.023	0.46 (0.25–0.67)	<0.001	0.60 (0.39–0.81)	<0.001	0.49 (0.28–0.72)	<0.001
France	0.67 (0.52–0.82)	<0.001	1.11 (0.93–1.28)	<0.001	−0.01 (−0.21–0.19)	0.929	0.18 (−0.03–0.39)	0.090	0.55 (0.35–0.75)	<0.001	0.58 (0.38–0.79)	<0.001
Germany	0.42 (0.19–0.65)	<0.001	0.91 (0.66–1.16)	<0.001	0.11 (−0.12–0.34)	0.345	0.23 (−0.00–0.47)	0.055	0.29 (0.07–0.52)	0.010	0.38 (0.16–0.61)	0.001
Ghana	0.08 (−0.07–0.22)	0.299	0.07 (−0.24–0.37)	0.655	−0.07 (−0.24–0.09)	0.387	−0.01 (−0.17–0.15)	0.919	0.05 (−0.10–0.21)	0.504	−0.11 (−0.27–0.05)	0.166
Greece	0.42 (0.28–0.57)	<0.001	0.64 (0.48–0.79)	<0.001			−0.18 (−0.45–0.08)	0.175	0.18 (0.04–0.32)	0.010	0.27 (0.12–0.41)	<0.001
India	0.51 (0.30–0.71)	<0.001	0.88 (0.65–1.11)	<0.001	0.13 (−0.04–0.29)	0.128	0.18 (0.01–0.36)	0.040	0.33 (0.15–0.52)	<0.001	0.66 (0.49–0.83)	<0.001
Ireland	0.98 (0.55–1.40)	<0.001	0.91 (0.67–1.16)	<0.001	0.32 (−0.03–0.67)	0.070	0.57 (0.19–0.95)	0.003	0.46 (0.09–0.82)	0.013	0.64 (0.25–1.04)	0.001
Israel	0.49 (0.28–0.69)	<0.001	0.97 (0.76–1.18)	<0.001	0.35 (−0.07–0.78)	0.105	0.27 (0.01–0.53)	0.041	0.42 (0.18–0.67)	0.001	0.82 (0.57–1.06)	<0.001
Italy	0.96 (0.68–1.23)	<0.001	1.36 (1.11–1.59)	<0.001	0.44 (0.15–0.73)	0.003	0.27 (0.04–0.51)	0.022	0.56 (0.33–0.79)	<0.001	0.77 (0.56–0.99)	<0.001
Mexico					0.28 (−0.04–0.61)	0.090	−0.02 (−0.43–0.39)	0.939	0.56 (0.18–0.93)	0.004	1.11 (0.77–1.45)	<0.001
Netherlands	0.67 (0.49–0.85)	<0.001	0.89 (0.71–1.08)	<0.001	0.49 (0.25–0.72)	<0.001	0.54 (0.29–0.78)	<0.001	0.67 (0.42–0.91)	<0.001	0.66 (0.41–0.90)	<0.001
Poland	0.47 (0.31–0.64)	<0.001	0.75 (0.52–0.97)	<0.001			−0.16 (−0.62–0.31)	0.509	0.17 (−0.00–0.34)	0.054	0.23 (0.04–0.41)	0.019
Russia	0.47 (0.18–0.76)	0.002	0.59 (0.28–0.89)	<0.001	0.37 (0.11–0.63)	0.005	0.34 (0.09–0.59)	0.008	0.84 (0.29–1.39)	0.003	0.57 (0.21–0.93)	0.002
South Africa	0.62 (0.30–0.94)	<0.001	0.71 (0.31–1.10)	<0.001	−0.09 (−0.35–0.15)	0.437	−0.27 (−0.52–−0.03)	0.025	−0.15 (−0.41–0.10)	0.245	0.39 (0.12–0.66)	0.004
Spain	0.71 (0.41–1.02)	<0.001	1.11 (0.81–1.41)	<0.001	0.25 (−0.03–0.54)	0.080	0.20 (−0.07–0.48)	0.151	0.45 (0.18–60.73)	0.001	0.64 (0.35–0.94)	<0.001
Sweden	0.16 (−0.06–0.39)	0.147	0.55 (0.38–0.72)	<0.001	0.19 (−0.05–0.44)	0.113	0.37 (0.11–0.62)	0.004	0.37 (0.12–0.62)	0.004	0.49 (0.22–0.76)	<0.001
Switzerland	0.31 (0.11–0.51)	0.003	0.71 (0.49–0.93)	<0.001	0.18 (−0.10–0.47)	0.213	0.24 (−0.04–0.53)	0.095	0.70 (0.41–0.99)	<0.001	0.63 (0.35–0.91)	<0.001
United States	0.81 (0.73–0.88)	<0.001	1.36 (1.27–1.45)	<0.001	0.36 (0.26–0.45)	<0.001	0.63 (0.54–0.73)	<0.001	0.79 (0.69–0.88)	<0.001	0.97 (0.87–1.07)	<0.001
Delayed recall												
Austria	0.57 (0.28–0.86)	<0.001	0.93 (0.58–1.28)	<0.001	0.98 (0.59–1.37)	<0.001	0.91 (0.54–1.28)	<0.001	1.14 (0.76–1.51)	<0.001	1.42 (1.05–1.79)	<0.001
Belgium	0.61 (0.45–0.78)	<0.001	1.12 (0.94–1.29)	<0.001	0.36 (0.14–0.57)	0.001	0.60 (0.38–0.81)	<0.001	0.65 (0.43–0.88)	<0.001	0.71 (0.48–0.93)	<0.001

(Continues)

TABLE 3 (Continued)

Country	Education (high school completed)		Education (completed college or higher)		Income (2nd quintile)		Income (3rd quintile)		Income (4th quintile)		Income (5th quintile)	
	b	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*	*b*	*p*
China	0.83 (0.71–0.95)	<0.001	1.21 (1.01–-1.40)	<0.001	0.17 (0.03–0.31)	0.015	0.43 (0.29–0.57)	<0.001	0.79 (0.66–0.94)	<0.001	1.05 (0.90–1.19)	<0.001
Czech Republic	0.72 (0.52–0.91)	<0.001	1.23 (0.97–1.49)	<0.001	0.02 (−0.35–0.39)	0.919	−0.05 (−0.30–0.21)	0.722	0.28 (0.01–0.55)	0.040	0.15 (−0.13–0.42)	0.297
Denmark	0.58 (0.36–0.79)	<0.001	0.76 (0.54–0.99)	<0.001	0.21 (−0.03–0.44)	0.081	0.28 (0.05–0.52)	0.019	0.44 (0.19–0.69)	0.001	0.31 (0.05–0.58)	0.019
France	0.57 (0.39–0.74)	<0.001	1.19 (0.99–1.37)	<0.001	−0.10 (−0.31–0.11)	0.349	0.06 (−0.18–0.30)	0.618	0.47 (0.26–0.69)	<0.001	0.50 (0.27–0.73)	<0.001
Germany	0.39 (0.14–0.65)	0.002	0.92 (0.64–1.20)	<0.001	0.04 (−0.20–0.29)	0.726	0.13 (−0.12–0.39)	0.302	0.22 (−0.03–0.47)	0.087	0.44 (0.18–0.69)	0.001
Ghana	−0.05 (−0.25–0.16)	0.649	0.28 (−0.11–0.67)	0.161	−0.09 (−0.32–0.13)	0.412	−0.39 (−0.62– −0.17)	0.001	−0.13 (−0.36–0.09)	0.251	−0.12 (−0.35–0.10)	0.284
Greece	0.49 (0.33–0.66)	<0.001	0.67 (0.48–0.86)	<0.001			−0.23 (−0.59–0.13)	0.219	0.18 (0.02–0.35)	0.032	0.18 (0.00–0.35)	0.047
India	0.62 (0.20–1.03)	0.004	1.15 (0.87–1.43)	<0.001	0.09 (−0.16–0.34)	0.466	0.41 (0.17–0.64)	0.001	0.51 (0.29–-0.72)	<0.001	1.05 (0.85–1.25)	<0.001
Ireland	1.22 (0.75–1.69)	<0.001	1.32 (1.03–1.61)	<0.001	0.41 (−0.01–0.83)	0.054	0.62 (0.17–1.07)	0.006	0.33 (−0.09–0.76)	0.123	0.48 (0.01–0.95)	0.044
Israel	0.52 (0.28–0.75)	<0.001	0.91 (0.66–1.16)	<0.001	0.52 (−0.14–1.18)	0.125	0.08 (−0.22–0.38)	0.591	0.38 (0.09–0.68)	0.010	0.66 (0.36–0.95)	<0.001
Italy	0.84 (0.54–1.14)	<0.001	1.29 (0.99–1.59)	<0.001	0.24 (−0.11–0.58)	0.173	0.05 (−0.19–0.29)	0.659	0.33 (0.05–0.60)	0.020	0.47 (0.22–0.73)	<0.001
Mexico					0.08 (−0.42–0.59)	0.747	1.21 (0.48–1.94)	0.001	0.84 (0.31–1.37)	0.002	1.39 (0.78–1.99)	<0.001
Netherlands	0.76 (0.54–0.97)	<0.001	0.98 (0.76–1.21)	<0.001	0.57 (0.29–0.86)	<0.001	0.49 (0.21–0.79)	0.001	0.70 (0.43–0.97)	<0.001	0.81 (0.53–1.08)	<0.001
Poland	0.51 (0.33–0.69)	<0.001	0.75 (0.48–1.02)	<0.001			0.11 (−0.40–0.63)	0.671	0.06 (−0.13–0.26)	0.520	0.17 (−0.03–0.37)	0.095
Russia	0.53 (0.14–0.93)	0.008	0.68 (0.21–1.15)	0.004	−0.16 (−0.53–0.22)	0.418	−0.12 (−0.59–0.35)	0.615	0.59 (0.13–1.04)	0.011	0.65 (0.08–1.22)	0.026
South Africa	1.13 (0.69–1.57)	<0.001	0.86 (0.42–1.31)	<0.001	−0.09 (−0.40–0.21)	0.549	−0.14 (−0.46–0.18)	0.387	0.09 (−0.24–0.42)	0.599	0.57 (0.21–0.94)	0.002
Spain	0.52 (0.20–0.83)	0.001	0.98 (0.62–1.33)	<0.001	−0.09 (−0.34–0.16)	0.488	−0.08 (−0.35–0.18)	0.536	0.26 (0.00–0.52)	0.048	0.54 (0.28–0.81)	<0.001
Sweden	0.27 (0.02–0.52)	0.032	0.59 (0.40–0.79)	<0.001	0.15 (−0.12–0.43)	0.281	0.21 (−0.08–0.49)	0.165	0.30 (0.04–0.57)	0.026	0.46 (0.19–0.72)	0.001
Switzerland	0.28 (0.05–0.51)	0.019	0.61 (0.33–0.89)	<0.001	0.04 (−0.27–0.35)	0.812	0.31 (−0.03–0.66)	0.071	0.46 (0.14–0.79)	0.005	0.43 (0.09–0.76)	0.011
United States	0.79 (0.70–0.88)	<0.001	1.41 (1.29–1.51)	<0.001	0.39 (0.28–0.51)	<0.001	0.68 (0.56–0.79)	<0.001	0.88 (0.77–0.99)	<0.001	1.11 (0.99–1.23)	<0.001

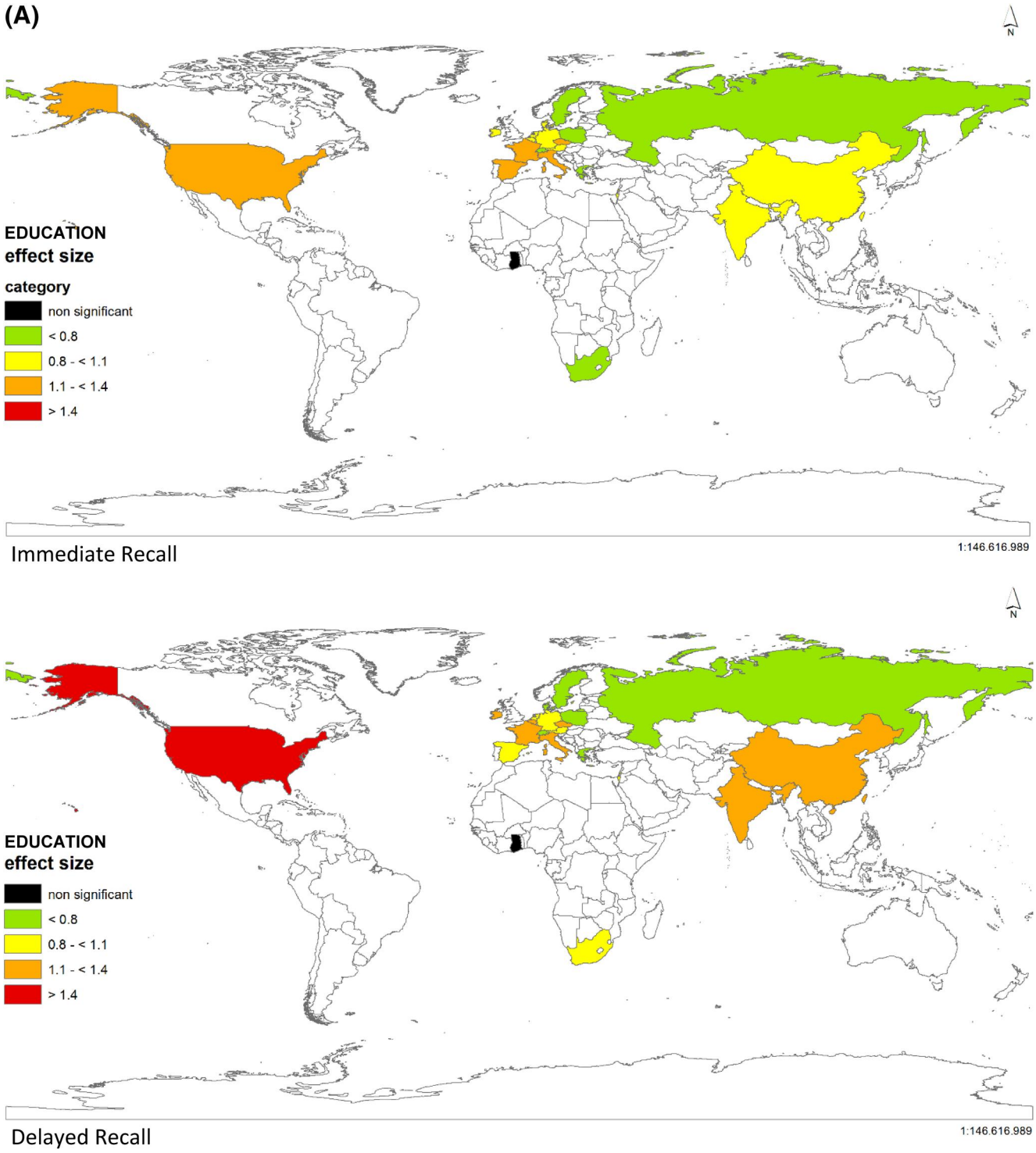

FIGURE 1 Coefficients on cognitive performance estimated via linear regression analysis adjusted for marital status, age, gender, health status, and depression (2006/2007). (A) Effects of education; (B) Effects of income [Colour figure can be viewed at wileyonlinelibrary.com]

estimate the effect sizes of education and income on the risk of developing dementia in old age. Second, we cannot exclude that the effects are moderated by innate predispositions like intelligence. Yet, as even a few years of education seem to make a substantial difference in cognitive functioning in our sample, effects may be more than innate predisposition. Third, cognitive functioning was measured via the word list test, which is a good indicator for Alzheimer-related cognitive impairment but not sensitive for small variations in cognitive abilities. Fourth, we used formal education for our analyses. However, education can take several forms across life-course and across cultures. They all can potentially impact cognitive functioning. Fifth, the data do not provide information on

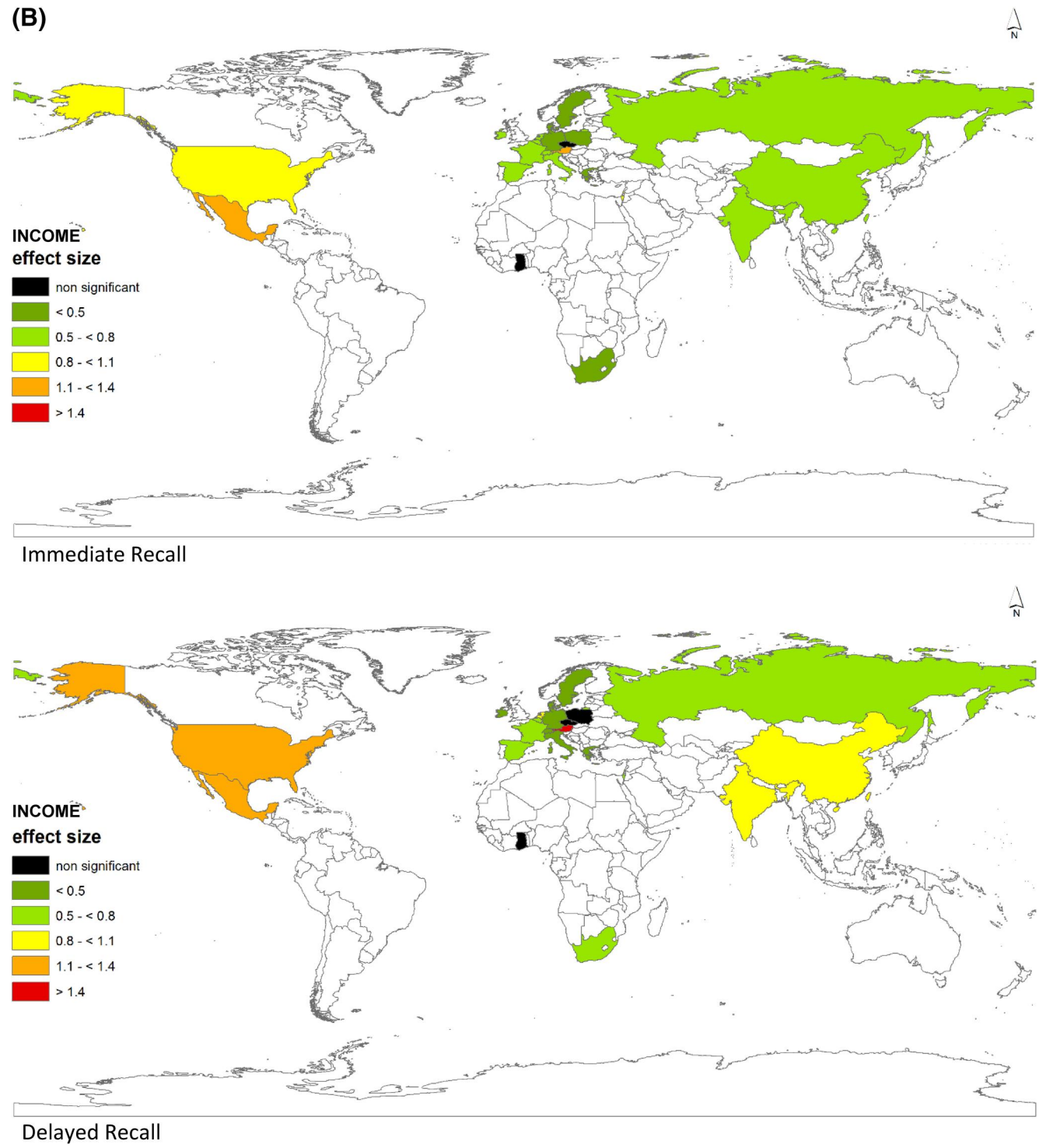

FIGURE 1 (Continued)

the presence of brain pathology. Due to the financial and technical constraints of conducting research studies in countries with lower income, the availability of such parameters is heavily limited. Realizing studies that include brain parameters would give more detailed insight in the mechanisms. Finally, despite of great efforts of harmonizing datasets, there always remain discrepancies between the studies. For instance, in SHARE, income was defined mainly by financial assets not including all valuables in the household. Even though money is the necessary means of living in Europe in contrast to many other countries, it might have influenced the cross-country comparison by accentuating the wealth effects in other countries. Another example is the assessment of depression which comprised

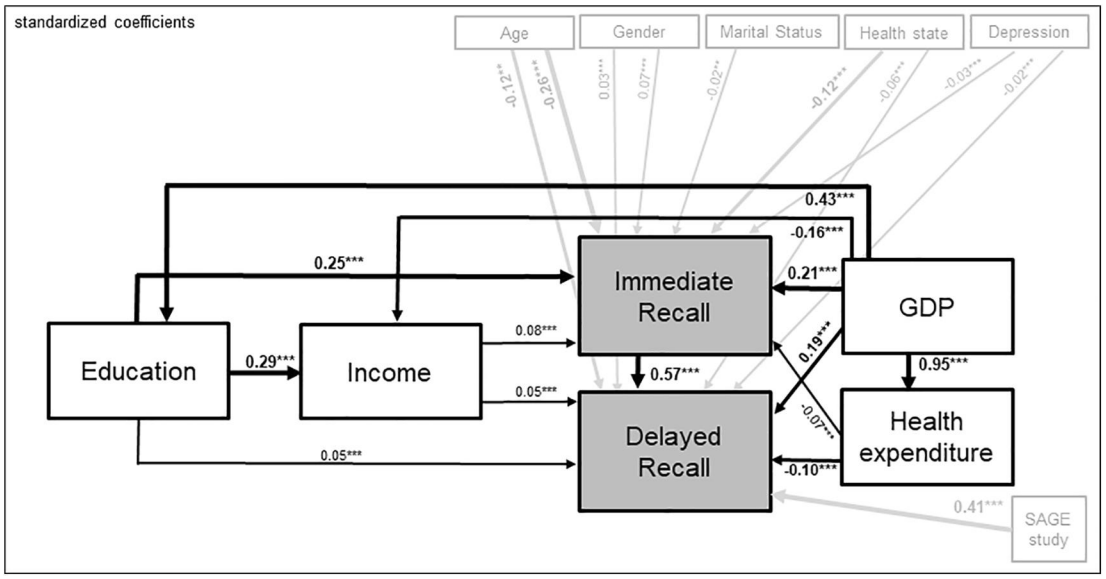

FIGURE 2 Structural equation model of the pathways of income and education on cognitive functioning, 2006/2007. Only path with $p < 0.05$ are shown. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. GDP, gross domestic product; SAGE

a self-reported diagnosis in some studies and subjectively perceived symptoms in other studies. As depressive symptoms are a risk factor for cognitive impairments, adjusting for diagnosis only may not account completely for the variance in cognitive functioning due to depression.

4.1 | Conclusions

A great percentage of the population worldwide is living in poverty, which poses major threats to health.[37] As our findings pointed out, living with low income is a threat to cognitive health. Yet, its predictive value is lower than that of education and education plays a predominate role for late life cognitive functioning. Accordingly, higher education might offset the implications of low income on cognitive functioning and promote good cognitive health for the rest of the life-course. Fostering higher education on a population level can not only help to overcome the adverse effects of low income situations but would also increase economic growth.[38] It has to be noted that between country variation also indicates that the quality of education as well as resources provided for low educated and low income groups might be highly relevant. More research is necessary to identify specific mechanisms.

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CONFLICTS OF INTEREST

Nothing to declare.

ETHICS STATEMENT

All participants in any of the studies provided written informed consent. The studies followed the principles outlined in the Declaration of Helsinki and was approved by the Ethical Review Committees of the local institutions.

AUTHOR CONTRIBUTIONS

Francisca S. Rodriguez: conceptualization, data curation, formal analysis, data interpretation, investigation, methodology, project

administration, supervision, writing original draft, visualization, approved final version, agrees to be accountable for all aspects of the work; Lena M. Hofbauer: literature search, data interpretation, validation, writing review & editing, approved final version, agrees to be accountable for all aspects of the work; Susanne Röhr: conceptualization, investigation, data interpretation, methodology, supervision, validation, writing review & editing, approved final version, agrees to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

All the data used in this analysis are available to others (https://hrs.isr.umich.edu/data-products; https://apps.who.int/healthinfo/systems/surveydata/index.php/catalog; www.share-project.org).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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