

# Book-Oriented Environment in Childhood and Current Cognitive Performance among Old-Aged Europeans

Galit Weinstein<sup>a</sup> Ella Cohn-Schwartz<sup>b</sup> Noam Damri<sup>c</sup>

<sup>a</sup>School of Public Health, Faculty of Social Welfare and Health Sciences, University of Haifa, Haifa, Israel;

<sup>b</sup>Department of Public Health, Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel;

<sup>c</sup>Israel Gerontological Data Center, Paul Baerwald School of Social Work and Social Welfare, The Hebrew University of Jerusalem, Jerusalem, Israel

## Keywords

Cognitive function · Early-life factors · Epidemiology · Longitudinal study

## Abstract

**Introduction:** Identifying early-life factors that protect against compromised late-life cognition is of great public health interest. We aimed to explore the associations between book-oriented environment in childhood and late-life cognitive performance in the Survey of Health, Ageing and Retirement in Europe (SHARE). **Methods:** The sample included 8,239 individuals aged  $\geq 65$  years ( $N = 8,239$ ) free of stroke, Parkinson's disease, or Alzheimer's disease, who participated in both waves 4 (2011) and 5 (2013) of SHARE. Book-oriented environment was assessed by the self-reported home library size during childhood. Cognitive performance was assessed using tests of memory and verbal fluency. Covariates included education and measures of current health, lifestyle, and financial status. Additionally, interactions with age and education were assessed. **Results:** After controlling for potential confounders, having large home libraries was related to better performance on the immediate and delayed memory ( $\beta = 0.11 \pm 0.02, p < 0.001$ ;  $\beta = 0.13 \pm 0.02, p < 0.001$ ) and

the verbal fluency tests ( $\beta = 0.14 \pm 0.06, p < 0.001$ ) and to a lesser decline in these domains ( $\beta = 0.08 \pm 0.01, p < 0.001$ ;  $\beta = 0.09 \pm 0.02, p < 0.001$ ; and  $\beta = 0.09 \pm 0.06, p < 0.001$ , respectively). Significant interactions were observed between library size and age such that larger home library was more strongly associated with improved immediate memory ( $p = 0.016$ ), delayed memory ( $p < 0.001$ ), and verbal fluency ( $p = 0.003$ ) and with less cognitive decline ( $p = 0.013, p < 0.001$ , and  $p = 0.095$ , respectively) among the younger-old ( $< 80$  years) compared to the oldest-old ( $\geq 80$  years) participants. No effect modification by education was observed. **Conclusions:** These findings suggest that early-life book-oriented environment may be important in shaping cognitive aging.

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## Introduction

Cognitive decline is a prominent condition that can occur with aging [1] and may encompass various cognitive domains including processing speed, reasoning, memory, and executive function [2]. Life-time experiences, such as education attainment or engagement in social

and occupational activities, have been linked with risk reduction of cognitive decline [3]. These factors are thought to increase cognitive reserve [4], which in turn enables a larger burden of brain pathologies before deficits begin to be apparent [5]. Although cognitive reserve is seen as a dynamic entity, which can be modified through cognitive stimulation throughout the life course, evidence suggests that the most influential period is during the first years of life, when key processes in brain development take place [6, 7]. Indeed, indicators of early-life environment such as birth weight [8] and adulthood height [9, 10] have been linked with late-life cognitive performance. These morphometric measures reflect nutritional and health status during development in addition to genetic propensity [11]. Moreover, direct measures of early-life conditions such as childhood socioeconomic status, education, and perhaps most pronouncedly literacy [12, 13] are thought to delay the manifestation of cognitive impairment. Recent findings further suggest that cognitive enrichment in early life may be linked with better late-life cognitive health, which could partially be explained through changes in pathological processes in the brain [14].

Growing up with large home libraries reflects the parents' commitment to a book-oriented environment. Accumulating evidence suggests that home library size is positively associated with educational attainment [15], educational achievement [16, 17] and occupational success [18], which in turn have been linked with better cognitive function in late life [19]. A recent study among adults aged 25–65 years from 31 societies demonstrated a link between growing up with home libraries and improved cognitive skills (i.e., literacy, numeracy, and technological problem solving), independently of one's own or parental education or occupational attainment [20]. In the current study, we sought to assess the relationship between book-oriented environment as indicated by home library size in childhood and cognitive performance and decline in old individuals (aged  $\geq 65$  years) who participated in the Survey of Health, Ageing and Retirement in Europe (SHARE) [21] and examined potential effect modification by age and education.

## Methods

### *Study Sample*

SHARE is a multidisciplinary cross-national, longitudinal survey which collects information on nationally representative samples of the community-dwelling population from 27 European countries and Israel. The target population of this survey was non-institutionalized individuals aged 50 years and older and their

spouses of any age. To date, data have been collected biennially during 6 waves, beginning in 2004 [22], using a computer-assisted personal interviewing program, supplemented by a self-completed paper-and-pencil questionnaire. The current analysis focused exclusively on participants aged 65 years and above who participated in the latest 2 waves of the survey for which data have been publicly released: wave 4 (2011) and wave 5 (2013). Wave 4 collected a wide range of data on health, socioeconomic status, and social and family networks from 16 European countries (Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, The Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, and Switzerland) [23]. Wave 5 additionally included information on childhood conditions.

The current analytical sample was limited to age relevant participants who participated in both waves 4 and 5 ( $N = 19,314$ ). We excluded 1,839 participants who reported being diagnosed with a stroke, Parkinson's disease, or Alzheimer's disease in wave 5, resulting in an initial sample of 17,475. We then retained only individuals who answered the retrospective questions on childhood conditions. In wave 5, this retrospective information was gathered only from participants who did not participate in SHARE prior to wave 4, and thus our sample narrowed to 9,991 individuals. We further excluded 1,752 individuals who had missing information on the study's variables, and thus the main analytical sample for the current analysis included 8,239 participants. Informed consent was obtained from all participants prior to the interview [23].

### *Measurements*

#### *Cognitive Performance*

The cognitive evaluation included 4 cognitive tests. Immediate and delayed episodic memory was assessed using the modified version of Rey's Auditory Verbal Learning Test – RAVLT [24], which evaluates short-term verbal learning and memory and information retention. In the modified version used in SHARE, the interviewer reads out a list of 10 words, after which the respondent is asked to recall as many of them as s/he can. The test is then repeated after 5–10 min. In the verbal fluency test, the participants were required to state the names of as many animals as they could, without repetitions or proper nouns, in a 1-min period. Due to outliers in a small number of cases, scores above 45 were re-coded as 45. This test measures executive functioning and language ability [25].

#### *Childhood Conditions*

Information on home library size in childhood was first collected in wave 5 of SHARE (2008/9), which focused on gathering retrospective information during the life course. This variable was assessed using the 5-scale item "How many books, approximately, were in your residence when you were 10 years or younger? (very few or none [0–10 books], 1 shelf [11–25 books], 1 bookcase [26–100 books], 2 bookcases [101–200 books], or >2 bookcases [200 books])."

#### *Covariates*

Education level was based on participants' highest educational degree using the International Standard Classification of Education (ISCED-97) [26]. These classifications were then regrouped into 3 categories of low, medium, and high educational attainment as has been previously done [27]. Height and weight were assessed by self-report, and BMI was defined as weight (kg)

divided by the square of height (m). The number of chronic conditions was assessed by asking the respondents if a doctor ever told them that they had any of the conditions listed on a card, namely, cardiovascular disease, high blood pressure, high blood cholesterol, stroke or cerebrovascular disease, diabetes, chronic lung disease, asthma, arthritis or rheumatism, osteoporosis, cancer or malignant tumor, stomach or duodenal or peptic ulcer, Parkinson disease, cataracts, and hip or femoral fracture. Participants could choose from 20 conditions or provide a different condition that was not listed in the questionnaire. Self-perceived health and hearing difficulties were assessed on a range from 1 to 5, in which higher score indicated poorer status, and were included as covariates in the analyses. A participant was considered as physically inactive if he/she reported not doing moderate or vigorous physical activity at least once per week. Current financial status was assessed using 2 measures: (1) self-reported household wealth, which was imputed in SHARE, as the monetary variables were affected by nonnegligible amounts of missing data ([http://share.cerge-ei.cz/documentation/Wave2004/SHARE\\_w1\\_Imputation\\_of\\_Missing\\_Data\\_in\\_Waves\\_1\\_and\\_2\\_of\\_SHARE.pdf](http://share.cerge-ei.cz/documentation/Wave2004/SHARE_w1_Imputation_of_Missing_Data_in_Waves_1_and_2_of_SHARE.pdf)). In addition, household wealth was adjusted for purchasing power parity and split into quintiles, calculating the quintile limits for each country separately. (2) Self-perceived financial status was measured by asking the participants about the extent to which they experienced difficulty in making ends meet. The scale ranged between 1 (difficult) and 4 (easy). This measure has been found to work effectively as a relative income indicator that can be compared across countries in which incomes have differing purchasing power [28]. In addition, respondents were asked whether they currently smoke cigarettes and whether or not they had a partner (spouse or registered partnership). Last, depressive symptoms (0–12) were measured using the Euro-D depression scale [29].

#### Statistical Analyses

Data analysis was conducted using STATA (version 13) [30]. Linear regression models were used to evaluate the associations of the number of books with cognitive performance on the immediate and delayed word list recall and the fluency tests. We also assessed the relationship of the number of books with change in cognitive performance between waves 4 and 5. For this purpose, we subtracted the test score in wave 5 from the score in wave 4 and ran linear regression models with the change as the outcome, while controlling for the variable at baseline. In addition, we tested whether current age and education modify the associations between number of books and cognitive function by including interaction terms for these variables in the linear regression model. If a significant interaction was found, we ran a stratified model. *p* value cutoff for interaction was set to be 0.10 due to low power of statistical interaction tests. For age stratification, we chose the cutoff of 80 years. Models were adjusted first for age, sex, education, and country. Subsequent models were additionally adjusted for BMI, number of chronic conditions, perceived health, perceived financial status, household wealth, hearing difficulties, having a partner, physical inactivity, and smoking status. Of note, although financial status in childhood was considered a potential confounder, we did not adjust for it because it was not associated with cognitive function and decline in our sample and was highly correlated with other covariates (data not shown).

**Table 1.** Characteristics of study population (wave 5)

Subjects, <i>N</i>	8,239
Age, years	73±6.3
Women	4,531 (55)
Education	
Less than high school	2,966 (36)
High school	2,966 (36)
Higher education	2,307 (28)
Has a partner	5,190 (63)
BMI	27±4.4
Chronic conditions (0–20), <i>n</i>	1.9±1.5
Perceived health (1–5)	2.7±1.0
Physical inactivity	906 (11)
Current smoking	1,071 (13)
Perceived financial adequacy (1–4)	2.9±0.9
Quintiles of current household wealth, Euros	
1 quintile (lowest)	11,586
2 quintile	77,615
3 quintile	161,016
4 quintile	272,947
5 quintile (highest)	749,242
Hearing difficulties (1–5)	2.8±1.0
Depression (Euro-D; 0–12)	2.3±2.1
Word list recall, immediate (0–10)	5.3±1.7
Word list recall, delayed (0–10)	3.8±2.1
Verbal fluency (0–45)	20.7±6.8
Serial sevens test (% all correct answers)	5,685 (69)
Books in childhood (1–5), <i>n</i>	2.2±1.2

Values are *n* (%) or mean ± SD.

## Results

The characteristics of the study participants in wave 5 are described in Table 1. Mean age of the responders was 73.0 ± 6.3 years and 4,531 (55%) were women. Most participants reported having books that were “Enough to fill one shelf (11–25 books)” in their childhood.

Table 2 demonstrates the associations of library size in childhood with cognitive performance and rate of cognitive decline in late life. A larger library in childhood was related to better performance on the immediate and delayed memory test ( $\beta = 0.12 \pm 0.02$ ,  $p < 0.001$ ; and  $\beta = 0.14 \pm 0.02$ ,  $p < 0.001$ , respectively), as well as on the fluency test ( $\beta = 0.15 \pm 0.06$ ,  $p < 0.001$ ) in wave 5 independently of age, sex, education, and country of residence. These associations remained similar after additional adjustment for health, lifestyle, and financial factors ( $\beta = 0.11 \pm 0.02$ ,  $p < 0.001$ ;  $\beta = 0.13 \pm 0.02$ ,  $p < 0.001$ ; and  $\beta = 0.14 \pm 0.06$  for immediate memory, delayed memory, and fluency, respectively). On average, change in cognitive performance between waves 4 and 5 was 0.17, 0.06, and –0.08

**Table 2.** Cross-sectional and longitudinal associations between childhood library size and cognitive function ( $N = 8,239$ )

	Memory – immediate recall		Memory – delayed recall		Fluency	
	$\beta \pm SE$	$p$ value	$\beta \pm SE$	$p$ value	$\beta \pm SE$	$p$ value
Cross-sectional in wave 5						
Model 1	<b>0.12±0.02</b>	<0.001	<b>0.14±0.02</b>	<0.001	<b>0.15±0.06</b>	<0.001
Model 2	<b>0.11±0.02</b>	<0.001	<b>0.13±0.02</b>	<0.001	<b>0.14±0.06</b>	<0.001
Change between waves 4 and 5						
Model 1*	<b>0.08±0.02</b>	<0.001	<b>0.09±0.02</b>	<0.001	<b>0.10±0.06</b>	<0.001
Model 2	<b>0.08±0.01</b>	<0.001	<b>0.09±0.02</b>	<0.001	<b>0.09±0.06</b>	<0.001

Model 1: adjusted for age, sex, education, and country. Model 2: model 1 + number of chronic conditions, perceived health, perceived financial status, household wealth, hearing difficulties, partner, physical inactivity, smoking status, and depression. Values in bold indicate  $p$  value  $\leq 0.05$ . \* Additionally adjusted for cognitive score at baseline.

on the immediate, delayed recall, and fluency tests, respectively (not statistically significant). A large library at home during childhood was associated with slower cognitive decline in immediate recall, delayed recall, and fluency ( $\beta = 0.08 \pm 0.02$ ,  $p < 0.001$ ;  $\beta = 0.09 \pm 0.02$ ,  $p < 0.001$ ; and  $\beta = 0.10 \pm 0.06$ ,  $p < 0.001$ , respectively), after adjusting for age, sex, education, and country of residence. Similar trends were observed in models adjusting for additional health, lifestyle, and financial factors ( $\beta = 0.08 \pm 0.01$ ,  $p < 0.001$ ;  $\beta = 0.09 \pm 0.02$ ,  $p < 0.001$ ; and  $\beta = 0.09 \pm 0.06$ ,  $p < 0.001$ , respectively; Table 2).

We found statistically significant interactions between library size and current age in relation to cognitive performance in immediate recall ( $p$  for interaction = 0.016), delayed recall ( $p$  for interaction <0.001), and fluency test ( $p$  for interaction = 0.003) in wave 5. Similar interactions were found between age and number of books in relation to changes in immediate recall ( $p$  for interaction = 0.013), delayed recall ( $p$  for interaction <0.001), and fluency, although it was borderline for the latter ( $p$  for interaction = 0.095) (Table 3; Fig. 1). For both the cross-sectional and longitudinal associations between library size and cognition, a stratified analysis revealed that the associations were stronger among those younger than 80 years of age (Table 3). At the current age below 80 years, a larger home library was associated with an increase of  $0.11 \pm 0.02$  ( $p < 0.001$ ),  $0.13 \pm 0.02$  ( $p < 0.001$ ), and  $0.14 \pm 0.07$  ( $p < 0.001$ ) in immediate and delayed memory and in fluency, respectively, and with a slower cognitive decline in these domains ( $0.09 \pm 0.02$ ,  $p < 0.001$ ;  $0.09 \pm 0.02$ ,  $p < 0.001$ ; and  $0.10 \pm 0.06$ ,  $p < 0.001$ , respectively) after adjustment for health, lifestyle, and financial factors (Table 3; Fig. 1).

No significant interactions were observed between library size and education in relation for cognitive function both cross-sectionally and longitudinally. While  $p$  for interaction suggested a possible modifying effect for immediate memory performance and change in it ( $p$  for interaction 0.092 and 0.037, respectively, comparing higher education to elementary and 0.012 and 0.006 comparing high school to elementary), stratified analyses revealed no meaningful differences in effect sizes between levels of education (Tables 2, 3).

## Discussion

Our findings stress the possible contribution of home libraries to improved cognitive health and to slower brain aging decades later. Prior research shows that growing up in homes with larger libraries has benefits beyond that of education attainment. It is thought that children who are encouraged to read and enjoy books acquire cognitive skills that help them succeed [31]. Indeed, a recent study showed that exposure to books in early life fosters long-term cognitive competencies spanning literacy, numeracy, and technological problem solving at adulthood [20]. Thus, the association between library size and cognitive performance in old age shown in our study may be mediated through acquisition of cognitive skills. Literacy, in particular, has been related to late-life cognitive function as well as with neuropathological measures of brain aging in the Nun study [32]. Because linguistic abilities appeared to moderate the relationship between neuropathology and late-life cognition (i.e., for

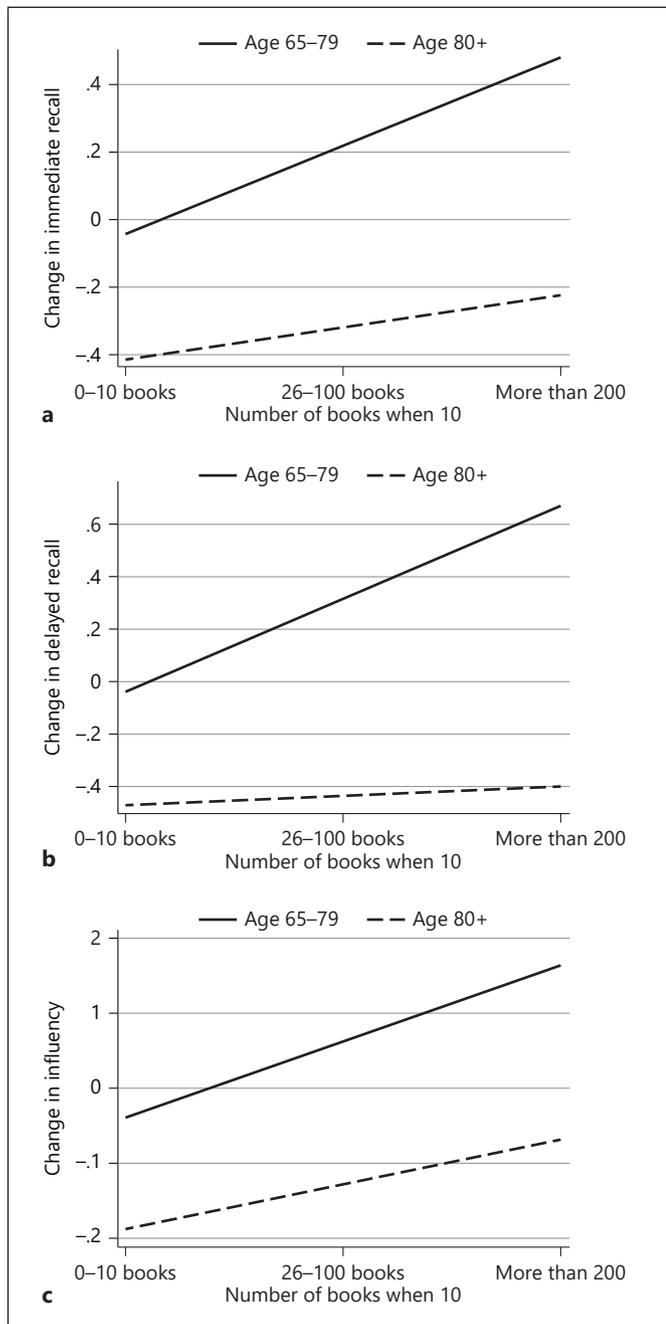
**Table 3.** Cross-sectional and longitudinal associations between childhood library size and cognitive function by age and level of education

	Memory – immediate recall		Memory – delayed recall		Fluency	
	$\beta \pm SE$	<i>p</i> value	$\beta \pm SE$	<i>p</i> value	$\beta \pm SE$	<i>p</i> value
Cross-sectional analysis						
Interaction with age		<b>0.016</b>		<b>&lt;0.001</b>		<b>0.003</b>
Age $\geq 80$ yr ( <i>N</i> = 1,401)						
Model 1	<b>0.07±0.4</b>	<b>0.019</b>	<b>0.07±0.05</b>	<b>0.022</b>	<b>0.12±0.14</b>	<b>&lt;0.001</b>
Model 2	<b>0.06±0.04</b>	<b>0.036</b>	<b>0.07±0.05</b>	<b>0.016</b>	<b>0.11±0.14</b>	<b>&lt;0.001</b>
Age <80 yr ( <i>N</i> = 6,838)						
Model 1	<b>0.13±0.2</b>	<b>&lt;0.001</b>	<b>0.15±0.02</b>	<b>&lt;0.001</b>	<b>0.16±0.07</b>	<b>&lt;0.001</b>
Model 2	<b>0.11±0.02</b>	<b>&lt;0.001</b>	<b>0.13±0.02</b>	<b>&lt;0.001</b>	<b>0.14±0.07</b>	<b>&lt;0.001</b>
Interaction with education (high school vs. elementary)		<b>0.012</b>		0.177		0.868
Interaction with education (higher vs. elementary)		<b>0.092</b>		0.756		0.803
Elementary ( <i>N</i> = 2,984)						
Model 1	<b>0.12±0.3</b>	<b>&lt;0.001</b>	<b>0.11±0.04</b>	<b>&lt;0.001</b>	<b>0.12±0.11</b>	<b>&lt;0.001</b>
Model 2	<b>0.10±0.03</b>	<b>&lt;0.001</b>	<b>0.10±0.04</b>	<b>&lt;0.001</b>	<b>0.11±0.11</b>	<b>&lt;0.001</b>
High school ( <i>N</i> = 2,958)						
Model 1	<b>0.10±0.2</b>	<b>&lt;0.001</b>	<b>0.13±0.03</b>	<b>&lt;0.001</b>	<b>0.16±0.10</b>	<b>&lt;0.001</b>
Model 2	<b>0.08±0.02</b>	<b>&lt;0.001</b>	<b>0.11±0.03</b>	<b>&lt;0.001</b>	<b>0.14±0.10</b>	<b>&lt;0.001</b>
Higher education ( <i>N</i> = 2,297)						
Model 1	0.13±0.02	<b>&lt;0.001</b>	0.15±0.03	<b>&lt;0.001</b>	<b>0.16±0.11</b>	<b>&lt;0.001</b>
Model 2	0.11±0.03	<b>&lt;0.001</b>	0.13±0.03	<b>&lt;0.001</b>	<b>0.14±0.11</b>	<b>&lt;0.001</b>
Longitudinal analysis						
Interaction with age		<b>0.013</b>		<b>&lt;0.001</b>		<b>0.095</b>
Age $\geq 80$ yr ( <i>N</i> = 1,401)						
Model 1*	0.03±0.04	0.172	-0.03±0.04	0.199	<b>0.09±0.12</b>	<b>&lt;0.001</b>
Model 2	-0.03±0.04	0.223	-0.03±0.04	0.202	<b>0.09±0.12</b>	<b>0.001</b>
Age <80 yr ( <i>N</i> = 6,838)						
Model 1*	<b>0.09±0.02</b>	<b>&lt;0.001</b>	<b>0.10±0.02</b>	<b>&lt;0.001</b>	<b>0.10±0.06</b>	<b>&lt;0.001</b>
Model 2	<b>0.09±0.02</b>	<b>&lt;0.001</b>	<b>0.09±0.02</b>	<b>&lt;0.001</b>	<b>0.10±0.06</b>	<b>&lt;0.001</b>
Interaction with education (high school vs. elementary)		<b>0.006</b>		<b>0.026</b>		0.852
Interaction with education (higher vs. elementary)		<b>0.037</b>		0.420		0.325
Elementary ( <i>N</i> = 2,984)						
Model 1	<b>0.09±0.03</b>	<b>&lt;0.001</b>	<b>0.08±0.04</b>	<b>&lt;0.001</b>	<b>0.07±0.10</b>	<b>&lt;0.001</b>
Model 2	<b>0.08±0.03</b>	<b>&lt;0.001</b>	<b>0.07±0.04</b>	<b>&lt;0.001</b>	<b>0.07±0.10</b>	<b>&lt;0.001</b>
High school ( <i>N</i> = 2,958)						
Model 1	<b>0.06±0.02</b>	<b>&lt;0.001</b>	<b>0.07±0.03</b>	<b>&lt;0.001</b>	<b>0.09±0.09</b>	<b>&lt;0.001</b>
Model 2	<b>0.06±0.02</b>	<b>&lt;0.001</b>	<b>0.06±0.03</b>	<b>&lt;0.001</b>	<b>0.09±0.09</b>	<b>&lt;0.001</b>
Higher education ( <i>N</i> = 2,297)						
Model 1	<b>0.08±0.02</b>	<b>&lt;0.001</b>	<b>0.10±0.03</b>	<b>&lt;0.001</b>	<b>0.12±0.10</b>	<b>&lt;0.001</b>
Model 2	<b>0.08±0.02</b>	<b>&lt;0.001</b>	<b>0.10±0.03</b>	<b>&lt;0.001</b>	<b>0.11±0.10</b>	<b>&lt;0.001</b>

Model 1: adjusted for age, sex, education, and country. Model 2: model 1 + BMI, number of chronic conditions, perceived health, perceived financial status, household wealth, hearing difficulties, partner, physical inactivity, smoking status, and depression. Values in bold indicate *p* value  $\leq 0.05$ . \* Additionally adjusted for cognitive score at baseline.

those with high linguistic capabilities, the association between brain pathology and cognitive status proximal to death is weaker), it is thought that early-life linguistic ability may act as a marker for cognitive reserve [33]. More recently, poor linguistic capabilities at young adulthood were associated with greater subsequent decline in

global cognition, semantic memory, episodic memory, and spatial abilities in old age [34]. Thus, availability of books in early life may be an extrinsic factor affecting linguistic abilities [35] which in turn builds-up cognitive reserve [36] and results in improved cognition and slower cognitive decline.



**Fig. 1.** The association between number of books and change in immediate memory (a), delayed memory (b), and fluency (c) by age at baseline (65–79 vs. ≥80 years).

While the association between book-oriented environment and cognition in our study was independent of education per se, it is still possible that those who were exposed to many books at home maintained higher education [37], which resulted in greater mental activity in

occupation and leisure pursuits throughout life [38]. In turn, accumulating evidence suggests that participation in cognitively stimulating activities protects against cognitive impairment and slows cognitive decline [39]. Support for this hypothesis also comes from findings from SHARE, showing that elderly individuals who are engaged in cognitively stimulating leisure activities such as crossword and Sudoku demonstrate better cognitive performance on the same cognitive tests assessed in the present study [40]. Even irrespective of education attainment, larger home libraries lay a foundation for life-long routine activities that enhance literacy and numeracy [20]. Furthermore, children who grew up with large home libraries perform better at school [31, 41] and work [18]. In turn, high childhood school performance is related to lower dementia risk in late life [42], and enriched environment at work has been associated with improved cognitive function in middle and old ages [43] as well as with slower rate of cognitive decline in old adults [44].

Exposure to a large number of books at home in early life may also influence health behaviors and lifestyle choices, which could subsequently result in late-life cognitive performance [12, 45–47]. However, the fact that the link between library size and cognitive function and rate of decline remained similar after adjustment for health and lifestyle factors, together with the association with cognitive change between 2 measurements, implies that early-life exposure to books may be directly associated with brain aging. Further supports for this hypothesis arrive from recent findings showing that part of the association between early-life enrichment activities and cognitive aging is explained by less pathological changes in the brain [14].

Library size may be, at least partly, influenced by genetic variants such as those affecting education attainment [48, 49]. According to large genome-wide association studies, some of these variants overlap with those for cognitive performance and are highly heritable [50]. Thus, our findings can also be explained by genetic propensity affecting both the exposure and outcome of our study through transmission of traits to the offspring generation.

We found that age modifies the association between number of books at home and cognitive performance as well as change in cognition over time, such that stronger associations were apparent in those younger than 80 years. These results may represent cohort effects, as clear trends exist with regard to time spent with leisure reading, and there is a shift toward using other media [51]. Alternatively, cognitive function among the oldest-old is

largely influenced by life-course environmental, lifestyle, and health factors and less by early-life factors. No evidence of effect modification by education level was found in our study, which stands in contrast to others who have shown that early-life leisure time activity has greater benefits to the less educated [40].

The strengths of the current study include its longitudinal design with a relatively large and ethnically diverse sample. In addition, we were able to adjust for multiple potential confounders. The study also has several limitations: first, childhood conditions were self-reported, and thus misclassification within categories of library size may have occurred. Nevertheless, because all responders were free of dementia, such misclassification is likely nondifferential (unrelated to cognitive ability) and therefore results in an underestimation of the real association. Moreover, self-report of childhood living conditions has been shown to be valid [52–54]. Second, the study lacks information on brain imaging, which could add support to our conclusions. Last, residual confounding and possible interactions between covariates could affect our results.

## Conclusion

There is a growing understanding that cognitive health at old ages begins at conception [55]. Thus, identifying early-life factors that influence cognitive function among the growing elderly population is of great importance. Our study shows that availability of books at home during childhood may be related to improved late-life cognitive abilities and to slower cognitive decline, independently of education and life-course factors such as health, lifestyle, and socioeconomic indices. Future research involving neuroimaging is warranted to clarify the possible underlying mechanisms. In addition, the transition from printed to digital material as a proxy for home book-oriented environment should be taken into account.

## Statement of Ethics

The SHARE study is subject to continuous ethics review. Wave 4 and the continuation of the project were reviewed and approved by the Ethics Council of the Max Planck Society. In addition, the country implementations of SHARE were reviewed and approved by the respective ethics committees or institutional review boards whenever this was required. The numerous reviews covered all aspects of the SHARE study, including subprojects, and confirmed the project to be compliant with the relevant legal norms and that the project and its procedures agree with international ethical stan-

dards. Informed consent was obtained from all participants. Overview and summary of the ethics approvals can be found in the following link: [http://www.share-project.org/fileadmin/pdf\\_documentation/SHARE\\_ethics\\_approvals.pdf](http://www.share-project.org/fileadmin/pdf_documentation/SHARE_ethics_approvals.pdf).

## Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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## Author Contributions

G.W., E.C.-S., and N.D. were responsible for the study concept and design. E.C.-S. and N.D. analyzed the data. G.W. and E.C.-S. drafted the manuscript.

## Data Availability Statement

Our study is a secondary analysis of existing data from the Survey of Health, Ageing and Retirement in Europe (SHARE). Data files and documentation are for public use and available at <http://www.share-project.org>.

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