Variation in cognitive functioning as a refined approach to comparing aging across countries

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Comparing the burden of aging across countries hinges on the availability of valid and comparable indicators. The Old Age Dependency Ratio allows only a limited assessment of the challenges of aging, because it does not include information on any individual characteristics except age itself. Existing alternative indicators based on health or economic activity suffer from measurement and comparability problems. We propose an indicator based on age variation in cognitive functioning. We use newly released data from standardized tests of seniors' cognitive abilities for countries from different world regions. In the wake of long-term advances in countries' industrial composition, and technological advances, the ability to handle new job procedures is now of high and growing importance, which increases the importance of cognition for work performance over time. In several countries with older populations, we find better cognitive performance on the part of populations aged 50+ than in countries with chronologically younger populations. This variation in cognitive functioning levels may be explained by the fact that seniors in some regions of the world experienced better conditions during childhood and adult life, including nutrition, duration and quality of schooling, lower exposure to disease, and physical and social activity patterns. Because of the slow process of cohort replacement, those countries whose seniors already have higher cognitive levels today are likely to continue to be at an advantage for several decades to come.

The world population is growing older (1, 2). Comparisons of the burden of aging across countries hinge on the availability of valid and comparable indicators. Demographic indicators like the old-age dependency ratio and median age are widely used to characterize and rank how old countries are. Based on these measures, the populations of Germany, the United States, and Japan are much older than those of India, China, or Mexico. However, the fact that these indicators are exclusively based on chronological age distributions limits their usefulness in terms of drawing conclusions about the consequences of and possible responses to population aging. Alternative approaches to comparing the extent of aging across countries are based on subjective health, life expectancy, and economic activity (3–5). These studies show that different countries can be considered to be the oldest in the world depending on how aging indicators are defined. Such measures, however, can be influenced by culture- and nation-specific interpretations of health level and disability and by business cycle fluctuations.

In contrast to existing studies, we here compare the extent of aging across nations according to age variation in cognitive abilities. Recently released surveys allow us to compare country-level variation in seniors' cognitive functioning across populations with younger and older age distributions.

Studies have found that cognitive ability levels predict individual productivity better than any other observable individual characteristics and that they are increasingly relevant for labor market performance (6–10). This finding applies to a variety of countries and settings, including poorer countries and rural settings (11, 12). In the wake of long-term advances in countries' industrial composition and technological advances, the ability to handle new job procedures is now of high and growing importance, which increases the importance of cognition over time (7, 13).

The growing importance of seniors for the labor market and the fact that certain cognitive abilities decline considerably during late adult ages are the reasons why we focus our study on the population that is 50 y and older (14–18). The length of time for which individuals can retain high cognitive performance will influence the age until which they can potentially stay active in the labor market. We use standardized questions based on representative surveys from different world regions. These international comparable surveys of seniors include English Longitudinal Study of Aging (ELSA), Health and Retirement Study (HRS), World Health Organization (WHO) Study on global AGEing and adult health (SAGE), and Survey of Health, Aging and Retirement in Europe (SHARE), which together allow us to cover almost one-half (45.5%) of the world population (see *SI Materials and Methods* for more details). These surveys include a measure of cognitive ability that is operationalized comparably across all surveys, namely, immediate recall of a certain number of given words, which is a measure of short-term memory (19). Other variables that measure cognitive abilities, like delayed word recall or fluency, are either not included in every survey or not measured in a comparable way. Analysis for countries where these measures can be compared corroborates the results we get for immediate word recall (see Figs. S1 and S2, Tables S1 and S2, and *SI Results* for more details). This study compares seniors' age variation in cognitive abilities across countries from both developed and emerging economies by using results from standardized testing procedures. The inclusion of seniors from world regions with chronologically younger populations has become possible only recently with the release of SAGE.

Immediate recall has been shown to be important for a variety of outcomes, ranging from financial decisionmaking to the risk of developing dementia (20–23). Moreover, technological advances and changes in working procedures imply that the importance of the ability to learn and remember is increasing (24). Employers are particularly concerned that their employees are able to learn new work procedures and process new information (25), which also suggests that employers view the ability to immediately recall information as advantageous to labor market performance.

Results

Fig. 1 shows the age variation in immediate recall across countries and country regions. It depicts the proportion of words (out of 10 read out nouns) which the respondents are able to recall within 1 min (18 countries) and 2 min (UK and the US; 95% of

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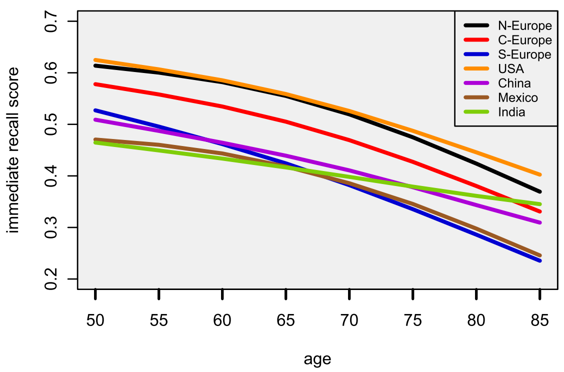

Fig. 1. Mean age-group–specific immediate recall scores (values between 0 and 1, where a score of 0.4 means being able to recall 40% of the given words). Curves are smoothed by using spline interpolations. Logistic regression to test for significant age-related decline, significance levels $P < 0.001$. Analysis of variance to test for differences between countries, significance levels $P < 0.01$.

the US participants completed the task within 1 min. See *SI Materials and Methods* for more details). In Table 1 summary statistics for all used variables of our dataset are provided.

The findings highlight a statistically significant age-related decline in all countries within the 50–85 age interval. Immediate recall age trajectories for northern and continental European countries and the United States run parallel to those of southern Europe, Mexico, and China, whereas the decline in India proceeds at a much slower pace. Our findings show statistically significant differences in the levels of cognitive performance between countries. Thus, seniors in the United States and northern and continental European countries have the highest immediate recall ability, whereas their peers in China, India, Mexico, and southern Europe perform worse.

To take the observed differences in cognitive functioning of seniors into account when comparing aging across countries, we propose an additional indicator that focuses on cognition and demographic change: cognition-adjusted dependency ratio (CADR). For this measure, the denominator is composed of everyone who is 15 to 49 y old and the 50+ population (no upper age bound) with good cognitive functioning (approximated by those who are able to recall at least one-half of the words in the test). The numerator consists of the number of persons aged 50+ who recall fewer than one-half the words in the test.

Our aging indicator is presented and compared with the usual old-age dependency ratio (OADR), which is defined as the ratio of the number of persons aged 65+ to the number of persons between the ages of 15 and 64, in Table 2. The rank ordering of the different countries and regions changes as we apply the alternative aging indicator: Mexico, India, and China do less well compared with the rank order based on the OADR, whereas the United States and continental and northern Europe do better.

This result implies that although continental European countries have a larger population share above the age of 65 than China, their lower CADR would suggest that these countries are effectively "younger." That is, they have a lower share of seniors with poor cognitive performance.

Discussion

One potential source of explanation for the international variation in seniors' cognitive functioning levels are life-course differences among the cohorts we consider. Present-day seniors in different countries have varying experiences with respect to a large number of influences, including their average length and quality of schooling, nutrition (prenatal, early life, and adult), exposure to famines, disease, and pollutants, physical and social activity patterns, and whether working conditions have been stimulating or detrimental to cognitive performance (26–37).

An increase in cognitive performance among successive cohorts describes a phenomenon that has been observed in many countries for an extended period (38–40). In the United States, such evidence began with comparisons of test performances of conscripts from World War I and World War II, with continued cognitive improvements having been documented for most of the 20th century. Successive cohorts in western countries have been shown to generally perform better at cognitive tests for long periods, whereas in other countries, cohort improvements have only been documented for recent cohorts. The likely later onset of cognitive improvement would follow the observed delayed onset of drivers of cognitive improvements, including mortality decline, universal education, improved nutrition, and better economic conditions (40–44).

In some countries, particularly in India, the cohorts presently 50 y and older have grown up during periods of widespread poverty and deprivation and where mortality levels were high, which could lower the overall levels of cognition among the cohorts presently old (41, 45). At the same time, large socioeconomic mortality differentials within a population could imply that the population is positively selected at a more advanced age. Given that those with higher cognitive performance live longer,

Table 1. Summary statistics of the survey subsets

	HRS	SAGE			SHARE (Northern Europe)	SHARE (Continental Europe)	SHARE (Southern Europe)
Measurements	United States	China	India	Mexico	Denmark, England, Ireland, Sweden	Austria, Belgium, Czech Republic, France, Germany, Netherlands, Poland, Switzerland	Greece, Italy, Spain
Year	2006/07	2007–2009	2007–2009	2007–2009	2006/07	2006/07	2006/07
Sample size	17,995	13,367	7,150	2,306	4,736	14,948	6,153
Females, %	58.3	53.1	49.4	60.5	53.4	55.2	54.6
Birth cohorts	1901–1956	1910–1959	1909–1957	1904–1959	1907–1957	1903–1957	1905–1957
None of the words recalled, %	0.7	1.3	1.0	2.8	0.4	1.9	2.9
All words immediately recalled, %	0.7	0.4	0	0	0.9	0.4	0.5

Table 2. Different measures for the burden of aging

Country/group	Rank (ratio) CADR	Rank (ratio) OADR
United States of America	1 (0.10)	4 (0.19)
Northern Europe (Denmark, England, Ireland, Sweden)	2 (0.12)	5 (0.24)
India	3 (0.14)	1 (0.07)
Mexico	3 (0.14)	2 (0.09)
China	5 (0.15)	3 (0.12)
Continental Europe (Austria, Belgium, Czech Republic, France, Germany, Netherlands, Poland, Switzerland)	6 (0.18)	6 (0.25)
Southern Europe (Greece, Italy, Spain)	7 (0.32)	7 (0.27)

Source: Population data for the year 2005 from UN (2009) and for England for the year 2005 from the Office for National Statistics (2010); survey data from HRS, SAGE, and SHARE.

this could entail a "flatter" age-cognition curve (46, 47), such as for India (48–50).

A few studies suggest that there has been a leveling off and reversal in cognitive increases among recent generations of younger men in some countries; however, it will take several decades until these cohorts attain senior age (51, 52).

Education has been identified as significantly raising levels of cognitive functioning, including memory (16, 53, 54). The countries in our study with better cognitive functioning levels are also the countries with higher educational attainment. Northern Europeans and Americans have globally the highest educational attainment among their 50+ population, whereas education levels are much lower in the Chinese and Mexican senior populations. Epidemiological research has identified low educational attainment as an important risk factor for low cognitive functioning and Alzheimer's disease (55, 56). Education is related to better cognitive performance in late life, and researchers relate the effect to occupational complexity and the acquisition of a lifelong ability to sustain attention and conceptualize problems. Although it is uncertain whether education affects the rate of decline (57), it can affect the cognitive level for all age groups (53, 54). Being mentally active, through courses and cognitive training, has been shown to improve cognitive functioning among older people (33, 58–60). Education may increase the synaptic density in the neocortical association cortex and, therefore, delay cognitive decline and dementia by several years (61). At the same time, lower childhood intelligence in early life appears to be a reliable proxy for lower cognitive ability later in life (62–64).

Later born cohorts with higher cognitive functioning will eventually replace older cohorts with poorer cognitive performance. If this trend continues, cognitive performance is likely to improve along cohort lines at senior adult ages (65). In Mexico, where time series data allow comparison of successive cohorts, we find that individuals of the 1941–45 cohorts at age 60 were able to remember on average 4.2 words, whereas those born 1946–50 were able to recall 5.1 words at the same age. The same holds for England's 60-y-olds: Here, we find an increase from 6.0 to 6.3 recalled words for the 1941–45 relative to the 1946–50 cohorts. Overall, these developments suggest that there will be a universal increase in cognitive functioning among seniors in the coming decades. However, as cohort replacement is a slow process, the countries whose seniors have higher cognitive levels today are likely to continue to have an advantage for several decades ahead.

Age-related norms (such as at which age a person is regarded as being "old") can vary by countries and cultures (66, 67). They may be influenced by age-related laws and regulations, including official retirement ages, which vary significantly between countries (68). Retiring at older ages can imply that one stays mentally active until higher ages, which could improve the level of cognitive functioning until higher ages (69).

Conclusion

The current study's shift in focus from chronological age distributions to actual cognitive functioning at older ages leads to a relevant additional possibility to compare aging across countries. This shift in perspective is crucial because it changes focus from predictable changes in the demographic age structure toward the importance of improving and maintaining cognitive abilities. Because the adjustment for aging requires long-term investments and changes in training policies and lifestyles, it is essential to implement policies and efforts that prepare societies for an older population by maintaining cognitive abilities throughout the life cycle (70, 71).

The degree to which demographic aging translates into societal challenges depends to a considerable extent on the age at which mental functioning becomes significantly impaired. Technological improvements increasingly allow seniors to participate longer in the working life (72, 73). Normal aging, however, also tends to involve a decline in certain cognitive abilities, where technological innovations are less likely to be able to compensate to a significant extent for cognitive decline. At the same time, the need for cognitive fitness seems to continue to increase. Nations that are truly challenged by aging may be those where the cognitive performance among their seniors is poor; not those who have chronologically older age structures.

Materials and Methods

A growing number of surveys are focusing on the elderly (for an overview of selected cross-national and single-country databases, see ref. 1). However,

Table 3. Overview of all used datasets

Dataset	Country/region	Year	Sample size
ELSA (English Longitudinal Study of Aging)	England	2006/07	9,771
HRS (Health and Retirement Study)	United States	2006/07	18,469
MHAS (Mexican Health and Aging Study)	Mexico	2003	13,704
SAGE (WHO Study on global Aging and adult health)	China, India, Mexico	2007/09	32,696
SHARE (Survey of Health, Aging and Retirement in Europe)	Europe	2006/07	26,515

the number of surveys that contain the information we need for our analysis is limited (Table 3). The main reasons for excluding data sources are (*i*) The survey only includes people above 60 or 65, which is higher than our lower age bound of 50 y and (*ii*) the measure for cognitive ability is not included in the survey or not comparable to our measure of word recall.

Data Sources and Variables. ELSA, representative for the population aged 50+ of England, consists of four waves (2002–2009) (74). HRS is representative for the 50+ population of the United States. It started 1992 and was conducted every year until 1996. Thereafter it was done only every other year. So far, 11 waves are available. For our purpose we took the RAND HRS dataset, a user-friendly subset of HRS (75). SHARE is a European survey that is representative of the participating countries' population aged 50+. The first survey was conducted in 11 countries in 2004/2005. Three more countries were added for the second wave in 2006/07. We divided the individual country files of SHARE into three regional datasets: continental (Austria, Belgium, the Czech Republic, France, Germany, the Netherlands, Poland, and Switzerland), southern (Greece, Italy, and Spain) and northern Europe (Denmark, Sweden, and Ireland) (76). Mexican Health and Aging Study (MHAS) consists of two waves. The baseline survey was conducted in 2001, the follow-up in 2003. The survey population is representative of Mexicans aged 50+ (77). SAGE was initiated by WHO to collect longitudinal information on health and well-being of adults (18+ with an emphasis on 50+). We use this data for China, India, and Mexico (78).

ELSA is part of the Northern European country group. All "don't know" and "refused" answers are coded as missing in all surveys. For cross-country comparison we use the 2006/07 waves to compare cognitive performance by age and country/region for a similar period. MHAS was only used for obtaining cohort differences in cognitive functioning. All provided results are gained by including the provided cross-sectional individual sample weights or individual sample weights for longitudinal investigations.

CADR. As described above, we introduce CADR, which is formally defined by the following equation.

$$CADR = \frac{|\{x \in P | (m_x < 0.5) \wedge (age_x \geq 50)\}|}{|\{x \in P | (15 \leq age_x < 50\} \cup \{m_x \geq 0.5) \wedge (age_x \geq 50)\}|},$$

where m_x represents the memory score of person x, age_x represents the age of person x, and P is the population.

Trends in Cognitive Abilities. We use all four waves of ELSA and calculate the mean immediate recall score at age 60 for the cohorts born between 1941 and 1945 and the cohorts born between 1946 and 1950. MHAS data for 2001 and 2003 are combined with SAGE data for 2007/09, because both surveys are representative for the 50+ population in Mexico. The cohorts born between 1941 and 1945 and the cohorts born between 1946 and 1950 are analyzed in an analogous manner to ELSA.

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