International Institute for
Applied Systems Analysis
Schlossplatz 1
A-2361 Laxenburg, Austria

Tel: +43 2236 807 342
Fax: +43 2236 71313
E-mail: publications@iiasa.ac.at
Web: www.iiasa.ac.at

Interim Report **IR-14-015**

Is Population Ageing Decelerating in Terms of Cognition?

Authors (in alphabetical order)

Valeria Bordone (bordone@iiasa.ac.at)
Sergei Scherbov (scherbov@iiasa.ac.at)
Nadia Steiber (steiber@iiasa.ac.at)

Approved by

Wolfgang Lutz
Program Director, World Population Program

October 1, 2014

Contents

Abstract

Higher chronological age tends to be associated with lower cognitive functioning in all cohorts. However, in light of increasing healthy life expectancy, people of a certain age today may perform better in terms of cognition than people of the same age in the past. To test this contention, we use tests of cognitive functioning collected in the German Socio-Economic Panel (SOEP) and the English Longitudinal Study of Ageing (ELSA) in two points in time with a 6-year interval. Focusing on the population aged 50 and above, we investigate change over time in cognitive functioning along three dimensions (memory, verbal fluency, and speed of processing). Results based on a repeat cross-sectional design that overcomes potential bias from retest effects suggest that cognitive functioning has improved across survey waves on all of these dimensions. This indicates an extension of significant Flynn effects (which have mainly been studied in children, adolescents, and young adults) to older populations. We find significant secular improvements in cognitive functioning for both women and men, across age groups and educational strata. Several explanations are proposed that go beyond the role of education as the initial driver of the cohort cognitive improvements.

Acknowledgments

We would like to thank the participants of the BSPS 2014 annual conference for their constructive comments on a previous version of this paper. The authors acknowledge funding from the European Research Council Grant no ERC2013-AdG 323947-Re-Ageing.

The data on England were made available through the UK Data Archive. ELSA was developed by a team of researchers based at the University College of London, the National Centre for Social Research and the Institute for Fiscal Studies. The data were collected by the National Centre for Social Research. The funding is provided by the National Institute of Aging in the USA, and a consortium of UK Government departments co-ordinated by the Office for National Statistics. The developers and funders of ELSA and the Archive do not bear any responsibility for the analyses or interpretations presented here. The data for Germany used in this publication were made available to us by the German Socio-Economic Panel Study (SOEP) at the German Institute for Economic Research (DIW), Berlin.

About the Authors

Valeria Bordone is a Research Scholar with the World Population Program at the Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), International Institute for Applied Systems Analysis.

Sergei Scherbov is Deputy Program Director and Project Director of the Reassessing Aging from a Population Perspective Project (Re-Aging) at the World Population Program at IIASA, and Leader of the Population Dynamics and Forecasting Group at the Vienna Institute of Demography (VID) of the Austrian Academy of Sciences, Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU).

Nadia Steiber is a Research Scholar with the World Population Program at the Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), International Institute for Applied Systems Analysis, and Assistant Professor at the Department of Economic Sociology, University of Vienna.

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Valeria Bordone (bordone@iiasa.ac.at)
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1 Introduction

Life expectancy is increasing and there is evidence that the onset of degenerative aging processes has been delayed to higher ages (Vaupel, 2010). Some parts of the population start aging earlier than others, however, education being a central factor in this regard. Evidence suggests that the lower educated start aging earlier than those with higher levels of education, both in terms of physical health and fitness (e.g., Christensen et al., 2009; Mäki et al., 2013; Sanderson and Scherbov, 2014) and in terms of mental health and cognitive functioning (e.g., Lièvre et al., 2008). When populations are increasingly composed of higher educated individuals, we may expect to observe a deceleration of population aging processes.

Higher educated individuals tend to participate in more cognitively stimulating activities during their lifetime and therefore remain cognitively fit until a higher age (Wilson et al., 2003). Moreover, rising educational attainment – even if it is restricted to some parts of the population – has been argued to have peer effects in the sense that it increases the frequency of interaction with more highly educated members of society and results in cognitively more stimulating social interactions for all ("social multiplier effect" as proposed by Dickens and Flynn, 2001). Respective to the older population, intergenerational relationships with highly educated children and grandchildren may act as a cognitive stimulant.

In addition to rising formal education levels, human aging in modern societies may also be delayed due to rising demands for life-long learning. Our societies and everyday environments are increasingly complex and cognitively demanding (computerization of activities, shorter cycles of technological innovation, use of information technology in everyday life, cf., Greenfield, 1998; Charness et al., 2011). This may have improved abilities to solve novel and abstract problems. Particularly the older parts of the population that used to withdraw from cognitively demanding tasks and environments at relatively young ages (mental retirement, cf. Rohwedder and Willis, 2010) are increasingly exposed to cognitive challenges in everyday life (Schaie and Charness, 2003).

The present study aims to ascertain if a deceleration of population aging processes can be observed. We focus on cognitive functioning as a characteristic of individuals that is associated with but not determined by chronological age. The maintenance of good cognitive functioning is one of the central components of successful aging (Rowe and Kahn, 1987; WHO 2002). Decline in cognitive functioning correlates with a wide range of factors that are themselves associated with higher chronological ages such as hypertension and diabetes (McCrimmon et al., 2012; Slomski, 2014) and is thus a good predictor of future morbidity and mortality (Negash et al., 2011). This makes cognitive function a useful measure of differential aging across cohorts and population groups. In order to ascertain if people of a certain age today perform better in terms of cognition than comparable people of the same age did in the past, we investigate change over time in the cognitive functioning of the population aged 50+ along three dimensions. We use a speed constrained measure of the mechanics of cognition (Symbol-Digit Task) that is available from the German Socio-Economic Panel (SOEP), two measures of memory function (immediate and delayed verbal recall) and one of verbal fluency (Animal Naming Task) that are available from the English Longitudinal Survey of Ageing (ELSA). These measures vary in the degree to which they are based on fluid intelligence (Cattell, 1987) and therefore in the degree to which they are considered central dimensions of cognitive decline in old age (Schaie, 2005).

2 State of Knowledge

Steadily increasing average scores on cognitive tests over cohorts are a well-documented phenomenon that has been observed in many parts of the world. The "sustained upward drift in mean cognitive abilities" (Hiscock, 2007: 514) is referred to as the Flynn effect (Flynn, 1984, 1987, 2000, 2009) in the neuropsychological literature. Such an increase over time has been found using a wide range of different tests. A review of the literature suggests that it is most marked in terms of abilities that are based on abstract problem solving (fluid intelligence), while it tends to be less pronounced in terms of abilities that are based on culturally shared knowledge, education, or experience (crystallized intelligence, cf. Lynn 1990, Wechsler, 1999; Hiscock, 2007, Baxendale, 2010). In other words, the Flynn effect has been found to be most pronounced in terms of the cognitive functions that are most sensitive to the biological aging processes of the brain (Hiscock 2007).

The majority of available studies on the Flynn effect have focused on children, adolescents, and prime-age adults, while much less is known about older adults. The scant evidence to date suggests that cognitive functioning has also increased in older populations. Significant Flynn effects on the older population have for example been found using data for Britain (Baxendale, 2010; Skirbekk et al. 2013), France (De Rotrou et al. 2013), Sweden (Rönnlund and Nilsson 2008), and the United States (Gerstorf et al. 2011). Moreover, there is evidence that Flynn effects extend to very old populations: using the mini-mental state examination, Christensen et al. (2013) report significantly higher cognitive test scores of Danish nonagenarians from the 1915-cohort compared to the 1905-cohort.

Our contribution to this literature is three-fold. First, while most of the previous studies carried out simple T-tests for the significance of change in mean cognitive test scores over time[1], in this study we additionally control for changes in the composition of the sample in terms of education. Second, while most of the existing literature on cognitive functioning in later life is based on small samples[2], we examine secular changes in average cognitive function of the population aged 50+ using large scale representative survey data that involve a much greater number of observations. Third, in contrast to prior work that has put very little attention to subgroup differences (Ang et al., 2010), we investigate whether the Flynn effect in older populations varies across educational groups.

Based on the existing body of evidence, we expect cognitive function to show a negative association with chronological age (Schaie, 2005) and a positive one with education (Le Carret et al., 2003; Mazzonna and Peracchi, 2010), while we expect to observe a significant improvement of average test scores comparing the earlier with the later period of observation, the so-called Flynn effect. The expectation of an improvement of average scores

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[1] This is the case for Baxendale (2010), Christensen et al. (2013), and Rotrou et al. (2013).

[2] Rotrou et al. (2013) test about 200 individuals in 1991 and 2008. Baxendale (2010) bases the study on even fewer older individuals. Rönnlund and Nilsson (2008) tested 700 individuals aged 50+ in 1989 and 350 in 2004.

on cognitive performance tests in older populations is also supported by the observation that the incidence of cognitive impairment at older ages has declined over time in a number of countries (Matthews et al., 2013) and that younger generations tend to develop dementia at higher ages (Dening, 2013).

3 Data and Method

We use data from the German Socio-Economic Panel (SOEP) and from the English Longitudinal Study of Ageing (ELSA). SOEP is a survey of private households that provides representative, longitudinal micro-data that has been collected on an annual basis since 1984. To date, cognitive testing has been carried out in two waves of SOEP. In 2006, a subsample of 7,440 participants was randomly selected to participate in the cognitive tests. Many of these individuals were again tested in 2012. Additionally, a large refresher sample was tested for the first time in 2012. For this analysis we focus on the sample of individuals tested for the first time either in 2006 or 2012 (to avoid re-test biases we do not use the longitudinal sample, see method section for detail). To attain comparability with ELSA, we focus on individuals aged 50 and older (see Table 1a for a description of the sample). ELSA provides longitudinal data for a representative sample of the English population aged 50 and older. Data have been collected on a biannual basis starting in 2002/03. In wave 4 (2008/09), additional respondents aged 50-74 and their co-residing partners were sampled to rejuvenate the sample and to top up the general sample that has shrunk due to panel attrition (for more details about the refreshment sample see Hussey et al., 2010 and Cheshire et al., 2012). For this analysis we focus on individuals participating in the cognitive testing for the first time in 2002/03 or 2008/09. Because the refreshment sample in ELSA wave 4 does not contain respondents aged 75 or older, our sample for repeat cross-sectional analysis on the English data are respondents aged 50-74 (see Table 1b for a description of the sample). Statistical significance tests suggest that the educational composition of the SOEP sample remained constant across time. In ELSA, we observe a significantly rising average level of education across the observation period. This is likely to correspond to the education reforms that took place in England in the mid and late 1940s, which have extended the duration of compulsory schooling (see Banks and Mazzonna, 2012 for a discussion of the 1944 Education Act that entered into force on 1st April 1947). In both surveys the average age of the samples has increased slightly across survey waves.

3.1 Measures of Cognitive Functioning

The surveys used for the analysis administered three types of cognitive performance tasks that are designed to assess respondents' general intellectual ability (Lang et al., 2007). The Symbol-Digit Test (SDT), administered in the SOEP, is designed to tap abilities based on the mechanics of cognition – the hard-wired capacities of information processing that are best captured by measures of perceptual speed and accuracy (Lindenberger, 2002; Schaie, 2005). Using the terminology proposed by Cattell (1987), SDT is conceptually related to fluid intelligence (Heineck and Anger, 2010). SDT is based on the Symbol-Digit-Modality-Test (Smith 1982) that was developed to identify key neurocognitive functions and neurological impairment. Before the test starts, respondents are presented with a screen image that shows a series of nine graphical symbols, each of which is assigned a number between 1 and 9. The test starts with the appearance of one of the nine symbols on the screen, asking respondents to match it with the correct digit as quickly as possible. The test ends automatically after 90 seconds. The software calculates the number of correct responses after 30 seconds, 60 seconds, and 90 seconds. Importantly, the test does not require the respondents to recall the match – the full band of nine symbols with the digits remains visible on top of the screen. In our pooled sample of the 2006 and 2012 waves of SOEP, the measures range from 0 to 28 after 30 seconds, to 38 after 60 seconds, and to 54 after 90 seconds. The mean scores in 2012 are 25.4 in the case of men and 24.8 in the case of women on the 90 second measure (SDT90). Statistical significance tests suggest that average scores have increased over the six-year observation period for both women and men (Table 1a). The number of correctly assigned numbers in SDT provides a measure of "respondents' perceptual information-processing speed" (Lang et al., 2007: 185). It captures the speed with which respondents are able to solve novel tasks. The vast majority of respondents complete the test on a laptop. In exceptional cases, the interviewer retained control over the laptop and entered the digits suggested by the participant. As test scores for this group are not directly comparable, individuals using interviewer assistance are excluded from the analysis.[3] Further information on the SDT can be found in Lang, Weiss, Stocker and von Rosenbladt (2007), and in Schupp, Herrmann, Jaensch and Lang (2008).

The Animal-Naming Task (ANT) administered in ELSA[4] is a test of knowledge-based verbal fluency (Lindenberger and Baltes, 1997). Participants in ANT are requested to name as many different animals as possible. Respondents have 1 minute to name the animals. Interviewers count the number of different animals that are named. This test is generally thought to be more strongly based on the pragmatics of cognition – the experience-related competencies that are developed through education and training (Lindenberger, 2002). It is commonly used as a measure of crystallized intelligence that involves a speed dimension (Heineck and Anger, 2010). In our pooled sample of wave 1 and the refresher of wave 4, this measure ranges between 0 and 55, with an average of about 21 animals named by men and 20 by women. For both men and women the ANT score was higher in the later wave and this difference is statistically significant (Table 1b). ELSA further contains two tests of memory function, in which the respondent is asked to recall as many words as possible out of ten words that are read by the interviewer. The first test requires a recall immediately after having heard the words (immediate recall); the second test is performed after a few minutes (delayed recall). In both cases, the respondent has up to 2 minutes for recalling. On average in our pooled sample of wave 1 and the refresher of wave 4, men recall almost 6 words immediately and about 4 delayed; while women recall on average 6 and 5 words, respectively. In all cases the mean number of words recalled is higher in the later wave than in the earlier one and this difference is statistically significant (Table 1b). The two tests of immediate recall (IR) and delayed recall (DR) are conceptually based on a compound of fluid and crystallized intelligence (Jaeggi et al. 2008). Although the test is time-constrained, its speed component is less relevant than in ANT.

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[3] In 2006, 17% of participants used interview assistance (Schupp et al., 2008), while in 2012 the possibility of interviewer assistance was not foreseen anymore. Those seeking interviewer assistance tend to be older and less educated. Yet, they tend to have higher test scores as the interviewer is trained using SDT. Excluding them, we obtain conservative estimates of secular improvements in cognitive function.

[4] The SOEP also includes ANT, but this test was not carried out with a refresher sample in 2012. Therefore, we can unfortunately not compare this measure with ELSA.

Table 1a. Descriptives of the SOEP Sample.

	Men						Women					
	2006 (N=980)			2012 (N=1,388)			2006 (N=1,033)			2012 (N=1,490)		
	min	max	mean (s.d.)	min	max	mean (s.d.)	min	max	mean (s.d.)	min	max	mean (s.d.)
Age	50	90	63.4 (8.8)	50	90	65.2 (9.5)	50	89	62.7 (9.1)	50	90	64.4 (9.5)
Years of education	7	18	12.5 (2.8)	7	18	12.3 (2.8)	7	18	11.6 (2.5)	7	18	11.7 (2.6)
SDT 30	0	18	7.2 (3.4)	0	23	7.5 (3.1)	0	23	7.1 (3.4)	0	24	7.4 (3.2)
SDT 60	0	33	15.4 (6.4)	0	38	16.3 (6.1)	0	31	15.0 (6.6)	0	36	16.0 (6.0)
SDT 90	0	50	23.5 (8.9)	0	54	25.2 (8.2)	0	48	22.9 (9.0)	0	49	24.7 (8.1)

Notes: The change in averages between 2006 and 2012 is significant at $p<0.05$ for all measures and for both men and women, with the exception of the average number of years of education, which have not changed over time. *Source*: Authors' calculation on German Socio-Economic Panel, 2006 and 2012.

Table 1b. Descriptives of the ELSA Sample.

	Men						Women					
	2002 (N = 4,068)			2008 (N = 780)			2002 (N = 4,976)			2008 (N = 881)		
	min	max	mean (s.d.)	min	max	mean (s.d.)	min	max	mean (s.d.)	min	max	mean (s.d.)
Age	50	74	61.4 (6.9)	50	74	62.4 (6.6)	50	74	61.1 (7.1)	50	74	62.0 (6.6)
ANT	0	48	20.6 (6.4)	0	43	21.7 (6.6)	0	50	19.9 (6.1)	0	55	21.3 (6.4)
IR	0	10	5.6 (1.7)	0	10	5.9 (1.7)	0	10	5.9 (1.6)	0	10	6.1 (1.6)
DR	0	10	4.2 (2.0)	0	10	4.5 (2.0)	0	10	4.5 (2.0)	0	10	5.0 (1.9)
Educational level	N	%		N	%		N	%		N	%	
No qualification	1,309	32.2		185	23.7		1,973	41.1		265	30.1	
NVQ1/CSE	304	7.5		43	5.5		107	2.2		19	2.2	
NVQ2/GCE O-level	657	16.2		141	18.1		954	19.9		198	22.5	
NVQ3/GCE A-level	341	8.4		83	10.6		265	5.5		74	8.4	
Higher ed below degree	577	14.2		136	17.4		501	10.5		128	14.5	
NVQ4/NVQ5/Degree	676	16.6		171	21.9		438	9.1		137	15.6	
Foreign/other	204	5.0		21	2.7		558	11.6		60	6.8	

Note: All differences between 2002 and 2008 are significantly different (at 0.1%). *Source*: Authors' calculation on ELSA, wave 1 and refresher sample of wave 4.

3.2 Methodological Approach

We adopt a repeat cross-sectional approach to analyse secular trends in the cognitive functioning of the population aged 50 and above. That is, we focus on first-time participants of the cognitive tests. In this way, we can avoid upward bias from potential retest effects that arise as the result of repeated exposure of individuals to cognitive tests (see Schaie and Hofer, 2001 and Schaie, 2005 for a discussion of this drawback of longitudinal studies of cognition) and selective attrition, which is a serious issue in panel surveys on the elderly (Zamarro et al., 2008). Our aim is to estimate the degree of change in the cognitive tests performance over a 6-year period. The empirical analysis is carried out in three steps.

First, we estimate the difference in mean scores across two survey waves using regression analysis in the frame of a repeat cross-sectional design. Since cognition scores in both surveys vary to a significant degree between women and men (as discussed in Weber et al., 2014 and as shown in our data, results available on request), we run separate analyses for our male and female samples. A time dummy indicating cognitive testing in the earlier (= 0) or the later wave (= 1) enters as the main predictor of interest. The estimated difference between survey waves is a compound of period and cohort effects that represents the Flynn effect in the literature (denoted FE in the following). We control for age and education. While in the SOEP we use information about the number of years that respondents spent in education, ELSA has information on respondents' educational qualifications (no qualification; NVQ1/CSE; NVQ2/GCE O-level equivalent; NVQ3/GCE A-level equivalent; higher education below degree; NVQ4/NVQ5/Degree; foreign or other).

Second, we test whether secular trends in cognitive function vary by age or education, estimating full interactions between age, education, and the time dummy (separately for women and men). In particular, we test if any of the following is significant: age squared to test for a curvilinear effect of age, age*FE to test if the FE is larger at some ages than in others, education*FE to test if the FE is different for more and less highly educated parts of the population, and age*education to test if the age-skill profile varies with the educational attainment of participants.

Third, following the procedure proposed by Sanderson and Scherbov (2014), we use our estimates to illustrate how subgroups of test participants differ in terms of their "constant characteristics ages" (CCA). Based on the regression-based prediction of scores in the later wave (2012 in the SOEP and 2008 in the ELSA), we calculate the age at which the same score (i.e., constant characteristic) would have been obtained in the earlier wave (2006 in the SOEP and 2002 in the ELSA). Subsequently, we calculate the difference between the age at interview in the earlier wave and the estimated CCA for the later wave. In this way we can illustrate how much "younger" participants in the later wave are compared to participants in the earlier wave, despite the fact that they are of the same chronological age.

4 Findings

Tables 2a[5] and 2b report the results of our regression models based on data from SOEP and ELSA, respectively, first controlling only for age and then adding education as a control. As expected, both for men and women, the older the person, the lower the cognitive test score. The squared term of age, even where significant (i.e., for IR and DR in the female sample), hardly improved the goodness of fit (results available on request). We have therefore preferred to use linear regressions in order to keep the models simple.

The better educated have higher scores in all cognitive tests at each age. In particular, for both men and women, one year more of education corresponds to about 0.2 symbols more matched with the correct digit in the SDT30, 0.4 in the SDT60, and 0.6 in the SDT90. A person with BA degree (i.e., about 16 years in education), for example, attains on average 1.2 more matches within 30 seconds than a person who only completed compulsory education (i.e., about 10 years). Both among men and women, the (positive) effect of having a BA degree as compared to not having a qualification corresponds to recalling on average 1.4 words more immediately. Concerning delayed recall, the difference between a man with a BA degree and a man with no qualification is 1.6 words; while for women it is 1.5 words. On average, a man with a BA degree names 4.8 more animals than a man with no qualification within 2 minutes. The same figure for women is 5.7.

[5] We have carried out robustness checks on the SOEP data in order to consider the same age group as in the ELSA (i.e. sample aged 50-74). The results (not shown, available on request) remain very similar to those shown in Table 2a.

Table 2a. Coefficients from Main Models with and without Control for Education, Separately for Women and Men (SE in parenthesis), SOEP.

	Men						Women					
	SDT30		SDT60		SDT90		SDT30		SDT60		SDT90	
Age	-0.108***	-0.104***	-0.222***	-0.214***	-0.313***	-0.301***	-0.109***	-0.099***	-0.231***	-0.209***	-0.322***	-0.290***
	(0.007)	(0.007)	(0.013)	(0.013)	(0.018)	(0.017)	(0.007)	(0.007)	(0.012)	(0.013)	(0.017)	(0.017)
Years of education		0.208***		0.447***		0.638***		0.166***		0.373***		0.568***
		(0.023)		(0.042)		(0.057)		(0.025)		(0.046)		(0.062)
FE	0.506***	0.539***	1.320***	1.390***	2.369***	2.470***	0.491***	0.458***	1.373***	1.297***	2.336***	2.221***
	(0.134)	(0.132)	(0.246)	(0.241)	(0.335)	(0.327)	(0.129)	(0.128)	(0.238)	(0.235)	(0.322)	(0.317)
Constant	14.011***	11.176***	29.459***	23.354***	43.297***	34.585***	13.886***	11.367***	29.493***	23.824***	43.099***	34.483***
	(0.464)	(0.555)	(0.855)	(1.014)	(1.162)	(1.376)	(0.434)	(0.574)	(0.801)	(1.057)	(1.085)	(1.426)
N	2,368	2,368	2,368	2,368	2,368	2,368	2,523	2,523	2,523	2,523	2,523	2,523
R2	0.090	0.120	0.112	0.152	0.124	0.168	0.096	0.111	0.125	0.147	0.136	0.163

Note: ***p<0.001, ** p<0.01, * p<0.05. FE is a dummy variable = 1 if 2012 wave; = 0 if 2006 wave.
Source: Authors' calculation on German Socio-Economic Panel, pooled data for 2006 and 2012.

Table 2b. Coefficients from Main Models with and without Control for Education, Separately for Women and Men (SE in parenthesis), ELSA.

	Men						Women					
	IR		DR		ANT		IR		DR		ANT	
Age	-0.059***	-0.044***	-0.077***	-0.060***	-0.206***	-0.154***	-0.054***	-0.037***	-0.068***	-0.050***	-0.193***	-0.125***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.013)	(0.013)	(0.003)	(0.003)	(0.004)	(0.004)	(0.011)	(0.011)
Education (ref. no qualification)												
NVQ1/CSE		0.126		0.406***		1.220***		0.171		0.217		1.122*
		(0.092)		(0.109)		(0.360)		(0.139)		(0.167)		(0.522)
NVQ2/GCE O-level		0.737***		0.936***		2.438***		0.823***		0.932***		2.827***
		(0.068)		(0.081)		(0.267)		(0.056)		(0.067)		(0.210)
NVQ3/GCE A-level		0.877***		1.065***		2.766***		0.962***		1.085***		3.871***
		(0.086)		(0.101)		(0.336)		(0.090)		(0.108)		(0.336)
Higher ed below degree		0.897***		1.049***		3.262***		0.995***		1.017***		4.292***
		(0.071)		(0.084)		(0.278)		(0.069)		(0.083)		(0.259)
NVQ4/NVQ5/Degree		1.375***		1.600***		4.790***		1.364***		1.497***		5.664***
		(0.067)		(0.080)		(0.264)		(0.073)		(0.087)		(0.272)
Foreign/other		0.464***		0.702***		1.424***		0.460***		0.594***		1.485***
		(0.110)		(0.130)		(0.432)		(0.069)		(0.083)		(0.258)
FE	0.337***	0.199**	0.440***	0.286***	1.301***	0.838***	0.307***	0.137*	0.503***	0.322***	1.521***	0.810***
	(0.063)	(0.061)	(0.075)	(0.072)	(0.245)	(0.238)	(0.058)	(0.056)	(0.069)	(0.067)	(0.220)	(0.211)
Constant	9.252***	7.698***	8.916***	7.097***	33.206***	27.977***	9.140***	7.592***	8.673***	6.976***	31.672***	25.630***
	(0.211)	(0.214)	(0.248)	(0.253)	(0.815)	(0.839)	(0.186)	(0.191)	(0.221)	(0.229)	(0.699)	(0.714)
N	4,848						5,677					
R2	0.063	0.149	0.076	0.157	0.052	0.120	0.056	0.139	0.066	0.135	0.054	0.150

Note: ***p<0.001, ** p<0.01, * p<0.05. FE is a dummy variable = 1 if 2008 wave; = 0 if 2002 wave.
Source: Authors' calculation on ELSA wave 1 and refreshment sample of wave 4.

For all the cognitive tests, we observe a significant FE effect, which is positive and statistically significant also after controlling for age and education. The FE has no significant interaction with either age or education, that is, the FE effect is constant over age and educational attainment. This allows us to simply calculate the number of years “gained” between the two points in time considered (t_0 being 2006 for Germany and 2002 for England; t_1 being 2012 for Germany and 2008 for England, with $\Delta t = 6$ in both cases). Table 3 shows the positive gains in years for both men and women in all cognitive dimensions tested.

In order to have comparable samples of German and English respondents, we have additionally calculated such age gains on the SOEP sub-sample aged 50-74 and the results are very similar to those calculated on the sample aged 50-90, hinting to a positive age-gain between the two waves.

Table 3. Calculation of Age-gains for the Different Measures, 2006-2012 SOEP and 2002-2008 ELSA.

	Men		**Women**	
SOEP	No control for education	Control for education	No control for education	Control for education
SDT30	4.7	5.2	4.5	4.6
SDT60	5.9	6.5	5.9	6.2
SDT90	7.6	8.2	7.3	7.7
ELSA				
IR	5.7	4.5	5.7	3.7
DR	5.7	4.8	7.4	6.4
ANT	6.3	5.4	7.9	6.5

Note: In the calculation of the above age-gains, SOEP education = 12 years and ELSA education = NVQ2/GCE O-level.
Source: Authors’ calculation on German Socio-Economic Panel 2006 and 2012 and on ELSA wave 1 and refreshment sample of wave 4.

Graphically (see Figures 1a and 1b), we show the predicted value of the cognitive scores by survey wave and gender over age. The performances in all the cognitive tests considered increase over time for both genders and in both England and Germany. In other words, we find parallel lines, meaning that the “age-gain” is the same at all ages and the interaction between age and period is not statistically significant. People interviewed more recently have higher scores in all cognitive tests than people interviewed in a previous year at the same age. This result holds for each level of education. Although the higher the education the more upward the line is shifted in the graph, the difference between the line referring to the previous wave considered and the line of the later wave considered is the same.

Figure 1a. Predicted Value of SDT30, SDT60, and SDT90 by Survey Wave and Gender over Age, SOEP

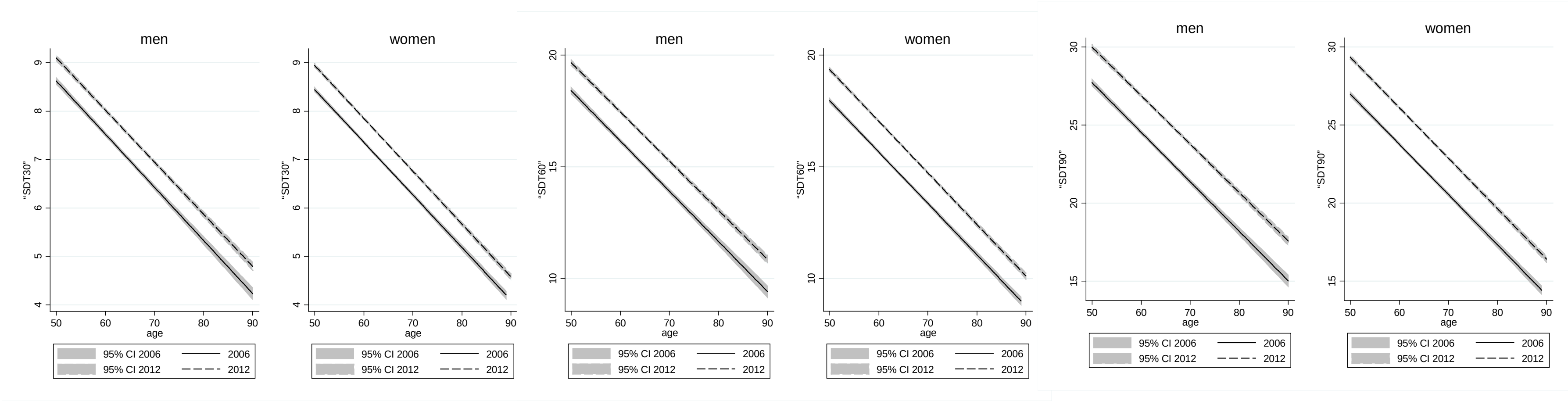
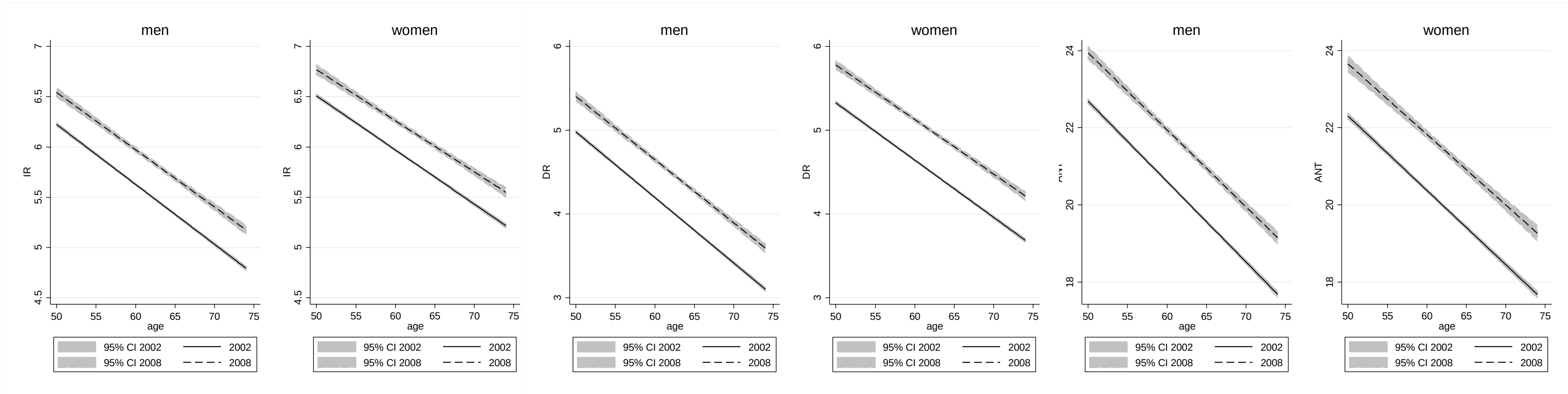


Figure 1b. Predicted Value of IR, DR, and ANT by Survey Wave and Gender over Age, ELSA



Note: Linear fit of the predicted cognitive test on age, by sample and controlling for education; confidence interval of the predicted mean. *Source:* Authors' calculation on German Socio-Economic Panel 2006 and 2012 and on ELSA wave 1 and refreshment sample of wave 4.

5 Discussion

Our results confirm the literature discussed in the introduction, which found steadily increasing average scores in cognitive functioning over successive cohorts for different dimensions of cognitive functioning and in various countries. In line with previous research, we find a significant improvement at all ages for younger cohorts compared to previous cohorts for both men and women and in both Germany and England. This so-called Flynn effect holds for all cognitive dimensions considered (i.e., memory, verbal fluency, and speed of processing). We add to previous literature on the topic by showing that the Flynn effect on 50+ year olds remains even after controlling for education and holds constant for every level of education.

Indeed, education or improvement in education has been the most favored explanation of improvements in cognitive functioning over cohorts in the literature (Flynn 1984; Weede and Kampf 2002; Meisenberg, Lawless, Lambert and Newton 2006). In earlier decades, educational expansion may have driven a good part of the observed FE and this is also observed in our English sample where controlling for education reduces the FE to about 50 to 70% of its original value, depending on the gender and cognitive measure considered. However, the expansion of education within our German sample has basically halted during the observation period. We may therefore speculate that part of the observed increase in cognition scores in more recent years is driven by other, more informal forms of learning in everyday life which we cannot control for in our analysis. As suggested by Flynn (2006), educational expansion within younger cohorts may have a trans-generational impact on older parts of the population through a social multiplier effect. In other words, those aged 50 or above in 2012 may not be more highly educated on average than their counterparts of the same age in 2006. Yet, the first may be surrounded by increasingly educated children and grandchildren or colleagues.

We also believe that part of the FE we find may be the result of the increasing exposure of the population to digital innovation and to the spread of gadgets used in everyday life that challenge users with ever changing visual interfaces (Greenfield, 1998). Since the FE has been first observed long before touch screens and interactive media started to affect our everyday experience, technological innovation and exposure is unlikely to fully account for it (Baxendale, 2010). However, over the time considered in our study, increasing complexity of the environment with more television, media, and computer games has led to greater cognitive stimulation (Sundet et al. 2004). In our data, the increase in the use of PCs and mobiles is statistically significant for both women and men over the 6-year period considered (see Tables A1a and A1b in the Appendix).

The internet has become an external source of memory that we can access at any time. With search engines available, people are less required to encode the information internally because when information is needed, it can be looked up in the internet. It is however necessary to remember where we can find it. One can therefore think that such accessibility to a huge transitory memory would result in flawed recall abilities. However, relying on computers for memory depends on several of the same memory processes that underlie social information-sharing in general (Sparrow et al., 2011). People tend to forget items that they think will be available externally but they remember items they know will not be available. Processes of human memory seem therefore to be adapting to the advent of new computing and communication technology. Therefore, the increased use of computers and smartphones, among perhaps other factors, likely accounts for a large portion of this age-gain. In additional analyses where we aimed to “explain” the FE, measures that tap changes in the use of PCs and mobiles in the population help to explain part of the observed FE (see Tables A2a and

A2b in the Appendix). For men, the coefficient for the FE effect on SDT tests, once education and use of computer and mobile phone are added as controls, is reduced up to about 84% of its original size. Such reduction is larger (up to about 67%) if only older people are considered, i.e. aged 65+. For women, the coefficient for the FE effect on SDT tests, once education and use of computer and mobile are added as controls, is reduced up to about 68% of its original size. Such reduction is larger (up to about 55%) if only younger people are considered, i.e. aged 50-64. In the analyses of ELSA data, education already reduces significantly the coefficients for FE up to 46% of their original value (in IR women). A large further reduction is then associated to the control for use of computer and mobile.

The literature has proposed several other potential factors that refer to the particular focus on children, but we believe they are not directly applicable to older populations. Rather, employment until higher ages, changes in the kinds of work that people do, engagement in cognitively maintaining leisure activities, greater levels of physical activity, and improved health (for a review, see Neisser, 1998) may all further explain the positive gain in cognitive functioning over cohorts. Further studies may deepen the investigation on the other possible factors driving the FE once longer panels of data are available.

In this paper, we have presented a simple procedure for using measures of cognitive functioning to produce a comparative measure of aging across population subgroups. Our measure is a characteristic-based age (Sanderson and Scherbov, 2013). Therefore, it is easy to interpret and communicate to policy-makers.

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7 Appendix

Table A1a. Descriptives of Developments (%), SOEP.

	Men						Women					
	W1 = 2006		W2 = 2012				W1 = 2006		W2 = 2012			
	Age 50-64	Age 65-90	Age 50-64		Age 65-90		Age 50-64	Age 65-90	Age 50-64		Age 65-90	
R with PC in HH	77.8	42.5	86.5	+++	59.1	+++	70.1	29.5	80.4	+++	47.7	+++
R with mobile in H	88.4	74.6	93.7	+++	86.1	+++	86.9	60.0	93.6	+++	76.2	+++

Note: +++ increase at p<0.001, ++ increase at p<0.01, + increase at p<0.05, – decrease at p<0.05.
Source: Authors' calculations on German Socio-Economic Panel, 2006 and 2012.

Table A1b. Descriptives of Developments (%), ELSA.

	Men						Women					
	W1 = 2002			W2 = 2008			W1 = 2002			W2 = 2008		
	All	<age 65	Age 65+	All	<age 65	Age 65+	All	<age 65	Age 65+	All	<age 65	Age 65+
R uses PC	41.28	50.10	25.62	65.85+++	75.48+++	51.26+++	31.61	39.95	15.62	58.82+++	70.93+++	38.00+++
R has mobile	65.48	72.19	53.58	82.93+++	86.19+++	77.98+++	64.50	71.65	50.81	89.09+++	92.25+++	83.67+++

Note: +++ increase at p<0.001, ++ increase at p<0.01, + increase at p<0.05, -- decrease at p<0.01, – decrease at p<0.05. Statistics are derived from the following questions in the main self-completion questionnaire of ELSA: "Which of these statements apply to you? i) I use the internet and/or e-mail (Yes/No); ii) I own a mobile phone (Yes/No).
Source: Authors' calculations on ELSA, wave 1 and refresher sample of wave 4.

Table A2a. Explaining Away the FE, Men Age 50-90, SOEP. Coefficients and standard errors in parenthesis.

	SDT30			SDT60			SDT90		
Age	-0.108***	-0.104***	-0.092***	-0.222***	-0.214***	-0.182***	-0.314***	-0.302***	-0.254***
	(0.007)	(0.007)	(0.008)	(0.013)	(0.013)	(0.014)	(0.018)	(0.017)	(0.019)
FE	0.518***	0.550***	0.433**	1.343***	1.411***	1.116***	2.398***	2.496***	2.058***
	(0.134)	(0.132)	(0.134)	(0.246)	(0.241)	(0.244)	(0.334)	(0.326)	(0.330)
Years of education		0.206***	0.171***		0.444***	0.354***		0.633***	0.497***
		(0.023)	(0.024)		(0.042)	(0.045)		(0.057)	(0.060)
PC in HH			0.514**			1.406***			2.157***
			(0.166)			(0.302)			(0.409)
Mobile in HH			0.425*			0.890*			1.205*
			(0.206)			(0.375)			(0.507)
Constant	14.004***	11.193***	10.179***	29.455***	23.396***	20.904***	43.344***	34.707***	31.048***
	(0.465)	(0.555)	(0.603)	(0.856)	(1.015)	(1.098)	(1.162)	(1.375)	(1.485)
N					2,362				
R2	0.09	0.12	0.127	0.112	0.152	0.165	0.125	0.169	0.184

Note: ***p<0.001, ** p<0.01, * p<0.05. FE is a dummy variable = 1 if 2012 wave; = 0 if 2006 wave.
Source: Authors' calculations on German Socio-Economic Panel, 2006 and 2012.

Table A2b. Explaining Away the FE, Women Age 50-90, SOEP. Coefficients and standard errors in parenthesis.

	SDT30			SDT60			SDT90		
Age	-0.108***	-0.099***	-0.084***	-0.230***	-0.209***	-0.176***	-0.321***	-0.289***	-0.243***
	(0.007)	(0.007)	(0.008)	(0.012)	(0.013)	(0.014)	(0.017)	(0.017)	(0.019)
FE	0.496***	0.462***	0.336**	1.384***	1.307***	1.033***	2.353***	2.235***	1.860***
	(0.129)	(0.128)	(0.130)	(0.238)	(0.235)	(0.239)	(0.322)	(0.317)	(0.322)
Years of education		0.165***	0.134***		0.370***	0.303***		0.563***	0.467***
		(0.025)	(0.026)		(0.046)	(0.048)		(0.062)	(0.065)
PC in HH			0.378*			0.888**			1.354***
			(0.156)			(0.286)			(0.386)
Mobile in HH			0.576**			1.170***			1.432**
			(0.183)			(0.336)			(0.453)
Constant	13.858***	11.364***	10.138***	29.435***	23.823***	21.189***	43.007***	34.477***	30.931***
	(0.435)	(0.575)	(0.628)	(0.803)	(1.057)	(1.153)	(1.087)	(1.427)	(1.557)
N					2,520				
R2	0.095	0.110	0.118	0.124	0.146	0.157	0.135	0.162	0.173

Note: ***p<0.001, ** p<0.01, * p<0.05. FE is a dummy variable = 1 if 2012 wave; = 0 if 2006 wave.
Source: Authors' calculations on German Socio-Economic Panel, 2006 and 2012.

Table A3a. Explaining Away the FE, Men, ELSA. Coefficients and standard errors in parenthesis.

	IR			DR			ANT		
Age	-0.059***	-0.043***	-0.036***	-0.078***	-0.061***	-0.052***	-0.206***	-0.154***	-0.130***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.014)	(0.013)	(0.014)
FE	0.351***	0.222***	0.112	0.482***	0.341***	0.210**	1.400***	0.964***	0.600*
	(0.066)	(0.064)	(0.064)	(0.078)	(0.075)	(0.076)	(0.255)	(0.248)	(0.252)
Education (ref. no qualification)									
NVQ1/CSE		0.054	0.014		0.256*	0.208		1.040**	0.901*
		(0.095)	(0.094)		(0.113)	(0.112)		(0.370)	(0.369)
NVQ2/GCE O-level		0.673***	0.564***		0.849***	0.716***		2.333***	1.981***
		(0.070)	(0.071)		(0.084)	(0.084)		(0.275)	(0.278)
NVQ3/GCE A-level		0.812***	0.642***		0.971***	0.762***		2.618***	2.082***
		(0.089)	(0.090)		(0.106)	(0.107)		(0.348)	(0.353)
Higher ed below degree		0.802***	0.617***		0.916***	0.689***		2.999***	2.412***
		(0.073)	(0.075)		(0.087)	(0.090)		(0.286)	(0.296)
NVQ4/NVQ5/ Degree		1.304***	1.017***		1.493***	1.140***		4.549***	3.651***
		(0.070)	(0.076)		(0.083)	(0.090)		(0.273)	(0.298)
Foreign/other		0.411***	0.309**		0.619***	0.497***		1.226**	0.892*
		(0.113)	(0.113)		(0.134)	(0.134)		(0.441)	(0.441)
Use computer			0.469***			0.590***			1.421***
			(0.055)			(0.065)			(0.216)
Has mobile			0.061			0.036			0.371
			(0.052)			(0.062)			(0.204)
Constant	9.255***	7.761***	7.198***	8.984***	7.259***	6.603***	33.350***	28.251***	26.303***
	(0.216)	(0.222)	(0.233)	(0.256)	(0.264)	(0.277)	(0.836)	(0.868)	(0.915)
N					4,439				
R2	0.064	0.143	0.159	0.079	0.15	0.167	0.054	0.117	0.127

Note: ***p<0.001, ** p<0.01, * p<0.05. FE is a dummy variable = 1 if 2008 wave; = 0 if 2002 wave.
Source: Authors' calculations on ELSA, wave 1 and refresher sample of wave 4.

Table A3b. Explaining away the FE, Women, ELSA. Coefficients and standard errors in parenthesis.

	IR			DR			ANT		
Age	-0.053***	-0.036***	-0.032***	-0.069***	-0.051***	-0.046***	-0.188***	-0.125***	-0.102***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.012)	(0.011)	(0.012)
FE	0.305***	0.140*	0.052	0.498***	0.323***	0.223**	1.498***	0.824***	0.421
	(0.060)	(0.058)	(0.060)	(0.071)	(0.070)	(0.072)	(0.225)	(0.217)	(0.222)
Education (ref. no qualification)									
NVQ1/CSE		0.137	0.107		0.145	0.110		0.846	0.706
		(0.141)	(0.141)		(0.169)	(0.169)		(0.527)	(0.525)
NVQ2/GCE O-level		0.765***	0.690***		0.861***	0.764***		2.532***	2.173***
		(0.058)	(0.059)		(0.069)	(0.071)		(0.215)	(0.219)
NVQ3/GCE A-level		0.936***	0.849***		1.070***	0.950***		3.641***	3.210***
		(0.092)	(0.094)		(0.111)	(0.112)		(0.345)	(0.349)
Higher ed below degree		0.936***	0.839***		0.952***	0.831***		4.011***	3.551***
		(0.071)	(0.073)		(0.085)	(0.087)		(0.265)	(0.271)
NVQ4/NVQ5/ Degree		1.316***	1.179***		1.444***	1.259***		5.291***	4.618***
		(0.075)	(0.079)		(0.090)	(0.095)		(0.280)	(0.295)
Foreign/other		0.402***	0.351***		0.534***	0.470***		1.180***	0.937***
		(0.070)	(0.071)		(0.085)	(0.085)		(0.263)	(0.264)
Use computer			0.195***			0.310***			1.026***
			(0.051)			(0.061)			(0.189)
Has mobile			0.180***			0.119*			0.696***
			(0.048)			(0.058)			(0.179)
Constant	9.106***	7.639***	7.211***	8.767***	7.152***	6.685***	31.504***	25.888***	23.958***
	(0.190)	(0.197)	(0.209)	(0.226)	(0.236)	(0.250)	(0.714)	(0.734)	(0.777)
N					5,283				
R2	0.055	0.132	0.138	0.069	0.132	0.138	0.053	0.139	0.148

Note: ***p<0.001, ** p<0.01, * p<0.05. FE is a dummy variable = 1 if 2008 wave; = 0 if 2002 wave.
Source: Authors' calculations on ELSA, wave 1 and refresher sample of wave 4.