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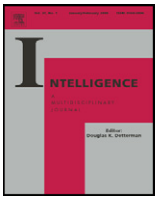

The Flynn effect and population aging[☆]

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ABSTRACT

Although lifespan changes in cognitive performance and Flynn effects have both been well documented, there has been little scientific focus to date on the net effect of these forces on cognition at the population level. Two major questions moving beyond this finding guided this study: (1) Does the Flynn effect indeed continue in the 2000s for older adults in a UK dataset (considering immediate recall, delayed recall, and verbal fluency)? (2) What are the net effects of population aging and cohort replacement on average cognitive level in the population for the abilities under consideration?

First, in line with the Flynn effect, we demonstrated continued cognitive improvements among successive cohorts of older adults. Second, projections based on different scenarios for cognitive cohort changes as well as demographic trends show that if the Flynn effect observed in recent years continues, it would offset the corresponding age-related cognitive decline for the cognitive abilities studied. In fact, if observed cohort effects should continue, our projections show improvements in cognitive functioning on a population level until 2042—in spite of population aging.

1. Introduction

There is a clear longitudinal evidence that fluid intelligence declines over the adult life span, starting in people's mid-twenties and becoming more prominent during later midlife (e.g., Park, Nisbett, & Hedden, 1999; Schaie & Hofer, 2001; Verhaegen & Salthouse, 1997). However, fluid intelligence has a high and growing importance for individuals' social, professional, and health-related functioning, and adults aged 50+ are particularly at risk of decline (Maitland, Intrieri, Schaie, & Willis, 2000; OECD, 2006; Schmidt & Hunter, 2004; Verhaegen & Salthouse, 1997).

Based on a lifespan perspective on aging, levels and trajectories of cognitive aging are not considered as predetermined but rather as an outcome of continuous interactions between genetic predispositions, contextual influences, and individual decisions, which very likely are different for each successive birth cohort (cf. Baltes, Lindenberger, & Staudinger, 2006). In this respect, numerous individual-level studies have documented tremendous cognitive plasticity in the sense that cognitive performance has been improved using training interventions of different kinds (e.g., Hertzog, Kramer, Wilson, & Lindenberger, 2008; Mårtensson et al., 2012). Also, there is evidence supporting performance differences at age 70 and less steep cognitive declines between 50 and 80 years of age favoring younger cohorts (e.g., Gerstorf, Ram, Hoppmann, Willis, & Schaie, 2011). Later-born cohorts have also been found to develop higher levels of fluid intelligence in youth and early adulthood: the so-called Flynn effect (Colom, Ma Lluis-Font, & Andrés-Pueyo, 2005; Flynn, 1987, 2012; Lynn, 2009; Neisser,

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1997; te Nijenhuis, Cho, Murphy, & Lee, 2012; te Nijenhuis, Murphy, & van Eeden, 2011;Teasdale & Owen, 2000; Tuddenham, 1948). For instance, based on evidence from the Wechsler Intelligence Scale for Children (WISC) tests (Flynn & Weiss, 2007), young Americans have gained about 22 IQ points over the 70 years between 1932 and 2002 (where 15 IQ points represent a standard deviation). This is also relevant for older ages, as cognitive abilities at younger ages strongly influence cognitive functioning in prime-age and senior adulthood (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Richards, Shipley, Fuhrer, & Wadsworth, 2004; Snowdon et al., 1996; Whalley et al., 2000).

We need to consider, however, that lifespan trajectories of specific cognitive abilities (as compared to general cognitive ability g) may differ (Flynn & Weiss, 2007; Sundet, Barlaug, & Torjussen, 2004; te Nijenhuis, in press). In the present study, we will focus on the two indicators of memory functioning (immediate and delayed recall) and one of executive functioning (verbal fluency). For memory tests, which are not part of usual IQ tests, higher performance levels have been found for later born cohorts by Rönnlund and Nilsson (2009) who used cohort-sequential analyses to compare measures of recall and recognition memory as well as fluency over 15 years. Baxendale (2010) also demonstrated positive cohort effects in terms of learning and recall of both verbal and nonverbal materials over a 22-year period in the UK.

very rarely, however, is this individual-level perspective combined with a population-level approach. This is the gap that the present paper aims to fill. Demographers predict that much of global population growth will occur among the 50+ age group, and that this growth will occur first in richer countries (UN, 2011). This in turn calls into question whether aging societies will be able to maintain economic productivity levels, or even increase them (OECD, 2006). Fortunately, there is also evidence that we are living not only longer but also healthier lives. According to one study, current 70-year-olds are as healthy as the 60-year-olds were when comparing the middle with the end of the 20th century (Vaupel, 2010). The present study addresses how such demographic trends affect cognition in the 50+ population, taking into account cohort effects in cognitive aging.

Estimating the size of inter-cohort cognitive performance change of older adults gains particular relevance as the 50+ share of the total UK population is scheduled to increase from 33% in 2000 to 40% in 2040 (UN, 2011, medium variant scenario). Further, the prevalence of poor cognitive health is concentrated among seniors; raising the potential health implications of improvements for these age groups (Williams, Plassman, Burke, & Benjamin, 2010).

The first question we studied was whether or not the Flynn effect would continue to be seen in the older part of the population (in the UK) in tests of immediate and delayed recall as well as verbal fluency. The second aim was to identify the net effect of demographic change (both population aging and cohort replacement) on the average level of cognition at the population level by using projections.

To understand whether levels of cognitive performance on a population level are increasing or decreasing over historical time, we need to assess (i) the impact of older age structures (with increasing population shares ofolder age groups) and (ii) cohort replacement (as cohorts die out, they are replaced by later-born cohorts with potentially different characteristics). To do this, we need to run population-based projections of cognitive performance, using a model that is calibrated with assumptions on the input factors (cohort variation over the life cycle, lifespan trajectories of cognitive performance, population aging and cohort replacement)— in one joint projection model.

1.1. The Flynn effect for cohorts currently aged 50+

The evidence for the Flynn effect is based predominantly on the performance of younger individuals, usually children and students. There is much less evidence for cognitive change among individuals over the age of 50, although some studies do focus on older adults. Substantial improvements in four cognitive measures of Swedes aged 62 to78 have been identified for tests of verbal, memory, speed, and fluency. Cohorts born from 1926 to 1948 have been found to perform considerably better on all cognitive measures than those born from 1900 to 1925 (Finkel, Reynolds, McArdle, & Pedersen, 2007). Further evidence in support of a Flynn effect from the Betula project in Northern Sweden has been provided by Rönnlund and Nilsson (2008). Evidence from the Seattle Longitudinal Study corroborates and extends earlier findings by documenting differences in the level of cognitive aging of up to 0.50 SD at age 70. Comparing cohorts born from 1914 to1948 with those born from1886 to1913, less steep rates of cognitive aging for most abilities between 50 and 80 years were found, favoring the later-born cohorts (Gerstorf et al., 2011). Zelinski and Kennison (2007) studied reasoning, memory, spatial and verbal abilities in two cohorts from the Long Beach Longitudinal Survey in California born 16 years apart. Individuals were assessed at ages 55 to 87, and comparisons were made between those born in 1893–1923 and those born in 1908–1940. An increase in levels of cognitive functioning between cohorts was found, with those born later performing considerably better on all measures tested. The effect was considerable. The level of cognitive performance of younger cohorts was at the level of those 15 years younger in the previous cohort. Cohort improvements and stronger cohort effects were found particularly for fluid abilities (including memory) rather than crystallized abilities (see also studies by Horn & Cattell, 1966; Raven, 2000). Evidence suggests further that from 1993 to 1998 there was a decrease in the share of cognitively disabled among older Americans (Freedman, Aykan, & Martin, 2001).

Some studies have, however, identified a cognitive stagnation or even a reversal of the Flynn effect among the young. These include analyses from Denmark and Norway (for example, Sundet et al., 2004; Teasdale & Owen, 2007), where later-born cohorts' test performances have only been as good as or slightly worse than those of their predecessors. In Australia, teenagers aged 13–14 have been found to display a small but statistically significant fall in numeracy over the period 1964–2003, and in both literacy and numeracy over the period 1975–1998 (Leigh & Ryan, 2011). Further, analysis of results on two Piagetian tests of formal operations in England (school grades 8 and 9) showed that school performance worsened from 1976 to 2004 for both girls and boys (Shayer, Ginsburg, & Coe, 2007).

The stalled or reversed Flynn effect could reflect worsening cognition levels among successive cohorts in some countries, which might subsequently decrease cognitive functioning among seniors. However, the finding of a stagnation/decline in cognitive performance among seniors could also be due to increasingly biased samples. For instance, some studies depend on the intelligence tests conducted when entering the military service. Mandatory military service, however, has ended in recent years in a number of countries and those who now volunteer to enter military service could be more negatively selected and less representative of the general population than when military service was compulsory — which could imply that observed negative cognitive trends based on such data represent increasing sample selection rather than changes in the population's cognitive performance levels. Furthermore, the inflow of many migrants that may have had poor education, weak language skills, and lack of familiarity with testing procedures may result in lower cognitive performance — on the other hand, factors such as possible improvements in terms of the integration of migrants (we only consider the 50+ population — most migrants arrive at younger ages and will have a long duration of stay) might mitigate such effects (te Nijenhuis, de Jong, Evers, & van der Flier, 2004). Consequently, a lower average score does not necessarily need to imply that the Flynn effect has stalled or reversed but may be due to differences in population composition. Moreover, even if the Flynn effect is exhausted among the young, it most likely still continues to be present, from a population perspective, in midlife and later for many years ahead, echoing historical gains from earlier periods in life. Adult schooling, on-the-job training and tertiary educational courses could further increase cognitive performance (level and/or slope) among adults, even when children's levels have stalled (Flynn, 2012). Further, more cognitively stimulating work and healthier lifestyles, as discussed below, may additionally improve newer generations' cognitive development over the life cycle (Staudinger & Kocka, 2010).

1.2. Causes of changes in cognition along cohort lines

Assuming that the Flynn effect persists or is at least present among currently middle-aged adults in modern industrialized societies, the question arises as to what this means for cognitive performance levels at the population level. In the following, we describe some factors that are important in determining cognitive performance and the extent to which they change along cohort lines, although an in-depth discussion is outside the scope of the present study.

Cohort differences in cognitive outcomes at an older age may follow from changes in factors that determine cognitive functioning and its ontogenesis. This includes schooling, changes in infectious disease prevalence, familiarity with cognitive performance tests, different degrees of cognitively stimulating work environments, better hygiene, smaller families, and other factors that may affect cognitive performance across birth cohorts (Neisser, 1997; Williams et al., 2010). Further, most of the previous discussion around the causes of the Flynn effect relate to changes in the performance of the younger population. The mechanisms that determine performance at older ages can be very different, as they relate to experiences during adulthood. This includes influences that have cumulatively impact as individuals grow older, such as work conditions, lifestyles, nutrition, exercise patterns, social network, and support biography, as well as alcohol and tobacco use.

Several factors that could affect the ontogenesis of cognitive functioning can be projected with relatively low degrees of uncertainty. One such example is the improvement of the educational composition of the population, which inevitably implies a growth in the educational attainment of older adults in the years to come. Education has grown considerably in recent years: for instance, the proportion of tertiary educated in the United Kingdom (UK) for 60–64 year olds is estimated to have grown from approximately 7% in 1970 to 23% in 2010, while the share of secondary-educated grew from 11% to 36%, see Fig. 1 (KC, Barakat, Goujon, Skirbekk, & Lutz, 2008). This is important as schooling has been found to have a causal positive effect on cognitive development, both at younger (Ceci, 1991) and older ages (Glymour, Kawachi, Jencks, & Berkman, 2008). A study of the effects of changes in school requirements in European countries found that longer compulsory schooling causally improved cognitive performance at older ages (Schneeweis, Skirbekk, & Winter-Ebmer, 2012). A Swedish study identified that education and training are related to improved cognitive performance as well as neurological changes (Mårtensson et al., 2012).

The strong rise in labor force participation and economic activity among later-born female cohorts, has also been related to a rise in cognitive performance and improved relative female performance (Bonsang, Adam, & Perelman, 2012; Flynn, 2012; OECD, 2006). Following shifts in the industrial composition of the UK, a larger proportion of the older cohorts worked in agriculture or manufacturing, while services and information processing have increased over time (accounting for 70% of GDP by 2005; World Bank, 2008). Potentially this process would raise the number of cognitively stimulating functions for later-born cohorts in our study, with less physical and routine work and more non-routine and cognitively stimulating tasks (Autor, Katz, & Kearney, 2006; Schooler, Mulatu, & Oates, 1999). Rohwedder and Willis (2010), Mazzonna and Peracchi (2012), and Bonsang et al. (2012) find that a later retirement has a positive causal effect on cognitive functioning at older ages. The increase in retirement age over the last decade in UK (OECD, 2011) may benefit cognitive functioning among older individuals.

Nutrition affects brain development, and improvements in nutrition could potentially play a role in improving cognition of successive cohorts in the UK— a balanced intake of for instance B12- and E-vitamins, folate and essential fatty acids could

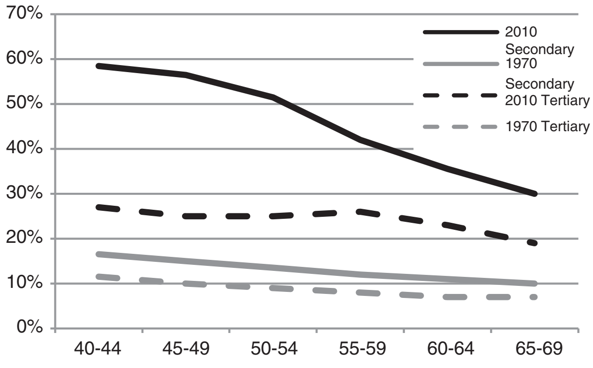

Fig. 1. Education by age (both sexes), UK, 1970 and 2010.

increase performance (Coppedè, Bosco, Fuso, & Troen, 2012; Flynn, 2009; van de Rest et al., 2012). Conversely, obesity has been found to be related to worsened cognitive outcomes (Elias, Elias, Sullivan, Wolf, & D'Agostino, 2003). Obesity is rising in the UK, the share of adults with a normal BMI having fallen to 31% among men and 40% among women in 2010, down from 40% and 49% respectively in 1993 (NHS, 2006). The trend towards increasing obesity levels may affect cognition directly or indirectly (and negatively).

1.3. The present study

A useful longitudinal dataset that has been used before to estimate the Flynn effect as well as to describe cognitive aging is the English Longitudinal Study of Ageing (ELSA). One study suggests that there has been an improvement in cognitive performance among older English adults: Llewellyn and Matthews (2009) compare independent population-based samples, MRC-CFAS (Medical Research Council — The Cognitive Functioning and Ageing Studies) and ELSA, as well as two smaller samples to investigate recent trends in semantic verbal fluency among those aged 65+. They find that the verbal fluency scores (based on the animals naming test) increased by 1.1 extra words between 1991 and 2002 (95% CI 0.9, 1.3).

At younger ages, improvements in cognition among the British cohorts we studied have been identified using standardized measures of cognitive performance since the first half of the 20th century (Flynn, 1987; Raven, 1981, 2000). Flynn (2009) showed, based on Raven's progressive matrices tests, that British pupils (ages 5–15) gained 14 IQ points from 1942 to 2008; or 0.216 per year.

In the present study, we estimated age and cohort patterns in cognitive function using cohort-sequential data from British nationally representative surveys (cf. Gerstorf et al., 2011; Rönnlund & Nilsson, 2009). Through simulations we estimated the net effect of those cohort improvements relative to age-related cognitive changes among people aged 50+. In the Figures below, solid lines display what is actually observed. The dashed lines show our assumptions (within each of the scenarios) based on past observations. In this stylized example, the complete lifespan changes in cognition can be observed for the 1920 cohort, while for later-born cohorts we can only observe an incomplete section of these lifespan changes in cognition. Projections can then be carried out based on demography-based projections that incorporate empirically estimated trends in age and cohort changes in cognition using multi-state projection methodology (Philipov & Rodgers, 1981; Skirbekk, Goujon, & Kaufmann, 2010).

2. Method

2.1. Sample

This analysis used data from the first and fourth waves of the English Longitudinal Survey on Ageing (ELSA). ELSA is a survey that provides a representative sample of the English population aged 50+, and covers the time period 2002–2008 in four waves. It contains detailed information about socioeconomic factors and health, and includes a module for measuring cognitive ability. Our analysis focused on the first wave which is based on interviews of 9166 individuals.

In addition, we used the refreshment sample from Wave 4 that accounts for about 2254 individuals aged between 50 and 74. This refreshment sample includes new people from HSE 2006 and their younger/older partners, and benefits from the fact that those individuals do not suffer from retest effects (including test familiarity, shorter warm-up phase and recognition) that may affect our results (Hoffman, Hofer, & Sliwinski, 2011). We further found that the refreshment sample is representative of the 2008 sample as a whole for socioeconomic status-related characteristics—there are no differences between the “refresher” and “non-refresher” regarding average level of income and wealth.

2.2. Measures

We focused on three indicators of cognitive performance based on measures using short and simple tests of immediate word recall, delayed word recall, and verbal fluency. The rationale underlying this choice is twofold: from a psychometric point of view, we selected sensitive cognitive scores that are not affected by ceiling or floor effects. From a more theoretical point of view, it is widely recognized that episodic memory (measured by the immediate and delayed word recall tests) and executive functioning (measured by the verbal fluency test) are two cognitive domains that are particularly sensitive to cognitive aging—executive functions and episodic memory can be among the first cognitive abilities to decline with age.

2.2.1. Immediate and delayed recall

The episodic memory task integrated in the survey was a test of verbal learning and recall, where the participants were required to learn a list of ten common words. At encoding, the words were presented automatically on a computer, and respondents were asked to read each word out loud. Then, immediate and delayed recall tasks were carried out. Immediate recall directly followed the encoding phase, while a short waiting period was inserted before the delayed recall. During immediate and delayed recall, participants were asked to recall the ten words in any order.

The immediate recall test was as follows: “I'm going to read you a list of words. Listen carefully. When I finish reading them, you should repeat all the words that you can. It does not matter in which order you repeat them.” (a list of X words out of Y possible lists, afterwards this procedure was repeated twice [reading and recalling]). We used only the results of the first trial. The question for delayed recall was: “Remember the long list of words that I read before? Please tell me as many of the words on the list that you can recall, in whatever order you wish.” (Approximately 7 min after reading the list for the first time).

Another indicator of fluid cognition was a *verbal fluency task*, which is a test of how quickly participants can think of words from a particular category; in this case, they had to name as many different animals as possible in 1 min. The timing of this test was controlled by computer. Performance was defined as the total number of different animal names given by the participant. Repetitions and redundancies (e.g., *white cow*, *brown cow*) were not counted, nor were proper nouns (e.g., *Spot*, *Bambi*). However, different breeds (e.g., *dog*, *terrier*, *poodle*) and different gender- or generation-specific names (e.g., *bull*, *cow*, *steer*, *heifer*, *calf*) were counted as correct.

3. Results

3.1. Descriptive findings

In terms of age variation by sex for the three cognitive measures there is a linear decline with age for all measures (see Fig. 2). In terms of loss from ages 50 to 90+, the slowest decline is for verbal fluency (decreasing from 22.5 to 12.7 words for males — by 1.6 standard deviation (SD), and 21.5 to 11.9 for females — 1.62 SD), followed by immediate recall (6.1 to 3.2 for males — 1.77 SD, and 6.2 to 3 for females — 1.98 SD) and delayed recall (decreasing from 4.9 to 1.3 for males — 1.9 SD, and 5 to 1.3 for females — 1.9 SD). Further, women outperform men on both memory tests in almost all age groups (except among the 90+ age group, which may be due to a greater, less selected share of women surviving to these advanced ages). However, men perform better on verbal fluency tasks.

3.2. Cohort trend findings

As described above, in order to identify cohort effects, we analyzed men and women aged 50 to 74 using ELSA data from 2002 to 2008 (Banks et al., 2010; Marmot, Banks, Blundell, Lessof, & Nazroo, 2003). Individuals over the age of 74 were not considered because of the low sample size. In particular, we analyzed the differences at every age for those born from 1936 to 1955 compared with those born from 1930 to 1949. We found historical increases for all three measures, for both sexes, and for most age groups.

The cohort trend results are portrayed in Table 1, where the cohorts are compared by sex and cognitive ability for every five-year age group. Results show that all differences between the cohorts are positive and statistically significant, except for both sexes aged 50–54 for both immediate and delayed recall, for men aged 50–54 for verbal fluency, and for men aged 70–74 for immediate recall. One (of several) potential reasons for this non-significant effect among those in their early 50s could be a slowing down – or stalling – of the Flynn effect.

The average five-year cohort effects are given in Fig. 3. On average, for all age groups, immediate word recall increased by 0.17 words for men (0.11 SD) and 0.19 for women (0.12 SD), delayed word recall increased by 0.29 words for men (0.15 SD) and 0.30 for women (0.16 SD). Verbal fluency increased by 0.69 words for men (0.11 SD) and 1.03 for women (0.17 SD).

3.3. Projection scenarios

The projections conducted aim to demonstrate what cohort differences in cognitive abilities at different ages might imply for the population level for each of the three abilities using three scenarios (*A*, *B* and *C*) for the future of the Flynn effect. For all scenarios, cognitive age effects are assumed to follow the observed cross-sectional life cycle trajectory of the base year. Further, each projection was carried out twice to take into account alternative population scenarios developed by the UK Office of National Statistics: *rapid aging*— low mortality, low fertility, and low immigration; and *slow aging*— high mortality, high fertility, and high immigration (cf. ONS (2011)):

A) This scenario shows projections if there should be no cohort variation in cognitive performance. This shows the implications of a population with a rising share of older adults, without the Flynn effect. This could for instance be the case if there should be an end to educational increases, where schooling levels would meet a saturation point and cease to rise.
B) This scenario shows projections *with* the Flynn effect. We justify our assumption of continued cohort effects based on: a) a continuation of the trends observed among older adults in recent years; b) the fact that the cohorts currently getting older have experienced a rise in cognitive scores when they were young; and c) a continued increase in the determinants that can increase cognitive performance levels.
C) This scenario was carried out to identify how strong cohort effects need to be to allow the average cognitive level of the 50+ population in 2042 to be the same as in 2002, in spite of population aging.

The results concerning the three scenarios are now presented in turn.

Our projection findings from *scenario A* show that population aging (with no cohort trends) will lead to an overall cognitive decrease (see Fig. 4). This scenario investigates the case where there is no continuation of the Flynn effect. As can be seen, the change in the age structure implies that average cognition declines as the population grows older. The demographic changes in the period 2002–2042 imply that the average immediate recall score falls from 5.34 to 5.02 for men and from 5.39 to 5.11 for women in the rapid aging scenario; in

Fig. 2. Cognition by age and sex: average cognitive score in population aged 50+.

Table 1
Average changes in cognitive scores by age and cohort.

Age	Men						Women					
	Born 1927–52		Born 1933–58		(ii)–(i)	Effect size	Born 1927–52		Born 1933–58		(iv)–(iii)	Effect size
	(i)		(ii)				(iii)		(iv)			
Immediate recall												
50–54	6.12	(1.63)	6.02	(1.77)	−0.103	−0.06	6.22	(1.59)	6.41	(1.66)	0.192	0.12
55–59	5.88	(1.54)	6.25	(1.8)	0.362***	0.23	6.1	(1.61)	6.34	(1.65)	0.230**	0.15
60–64	5.53	(1.62)	5.91	(1.58)	0.380***	0.24	5.92	(1.52)	6.18	(1.64)	0.263**	0.17
65–69	5.17	(1.6)	5.49	(1.66)	0.320**	0.20	5.5	(1.61)	5.79	(1.59)	0.290**	0.18
70–74	4.97	(1.69)	5.16	(1.65)	0.195	0.11	5.11	(1.64)	5.51	(1.58)	0.394***	0.25
Delayed recall												
50–54	4.86	(1.82)	4.81	(1.98)	−0.049	−0.03	5.04	(1.85)	5.23	(1.98)	0.194	0.10
55–59	4.47	(1.87)	5.12	(1.91)	0.651***	0.35	4.82	(1.92)	5.16	(1.86)	0.336***	0.18
60–64	4.11	(1.99)	4.56	(1.84)	0.445***	0.23	4.49	(1.81)	5.14	(1.8)	0.653***	0.36
65–69	3.63	(1.93)	3.92	(1.88)	0.289*	0.15	4.11	(1.9)	4.57	(2.07)	0.468***	0.24
70–74	3.29	(1.96)	3.75	(1.88)	0.462***	0.24	3.61	(2.03)	4.05	(1.91)	0.441***	0.22
Verbal fluency												
50–54	22.47	(6.48)	22.57	(6.96)	0.1	0.02	21.5	(6.35)	22.44	(6.87)	0.944*	0.15
55–59	21.46	(6.33)	21.91	(7.22)	0.452	0.07	20.59	(6.11)	22.32	(6)	1.730***	0.28
60–64	19.98	(6.18)	21.81	(6.32)	1.829***	0.29	19.8	(5.91)	21.3	(6.7)	1.503***	0.25
65–69	19.34	(6.24)	20.53	(6.35)	1.187**	0.19	18.98	(5.69)	19.78	(6)	0.806*	0.14
70–74	18.37	(5.76)	19.18	(6.09)	0.811	0.14	17.34	(5.42)	18.91	(5.93)	1.573***	0.28

Note: (***), (**), (*) means that the difference is significant at the 1%, 5%, and 10% levels, respectively.
Standard deviations given in brackets.
Cohen's *d* effect size (Cohen, 1992).

the slow aging scenario it decreases to 5.14 among men and 5.21 among women; delayed recall decreases from 3.87 to 3.46 for men and from 3.92 to 3.60 for women in the rapid aging scenario (in the slow aging scenario it changes to 3.61 among men and 3.71 among women); and for verbal fluency it decreases from 19.86 to 18.76 for men and from 18.55 to 17.70 for women in the rapid aging scenario (in the slow aging scenario it changes to 19.15 among men and 18.00 among women). This provides evidence that in the absence of a continuation of the Flynn effect demographic shifts will have relatively strong implications for the distributions of cognitive performance at the population level. The stronger the degree of population aging (cf. rapid aging versus slow aging), the stronger the overall decline in cognition will be.

Scenario B portrays the case where the cohort trends observed from 2002 to 2008 continue (see Fig. 5). As can be seen, under this scenario there will be an increase in average cognitive performance. Immediate recall score rises from 5.34 to 6.35 for men and 5.36 to 6.56 for women in the rapid aging scenario (in the slow aging scenario it changes to 6.47 for men and 6.66 for women); delayed recall increases from 3.87 to 5.78 for men and 3.90 to 5.97 for women in the rapid aging scenario (in the slow aging scenario, it changes to 5.93 for men and 6.09 for women); and verbal fluency rises from 19.86 to 24.32 for men and 18.38 to 25.83 for women in the rapid aging scenario (in the slow aging scenario it changes to 24.71 for men and 26.12 for women) during the period 2002–2042. Hence, in spite of the fact that populations are aging and cognition declines with age, the effect of a continuation of the Flynn effect is stronger and implies a net improvement in overall cognition.

To identify how strong the cohort improvements need to be to offset the effect of population aging, we ran *Scenario C* (see Fig. 6). We used optimization techniques to identify the size of the five-year cohort change in order to offset the effects of cognitive aging. We found that (slow aging results are in parenthesis) immediate recall must increase by 0.04 words for men and 0.04 words for women (0.03 and 0.02 for slow aging). Delayed recall must increase by 0.05 words for men and 0.04

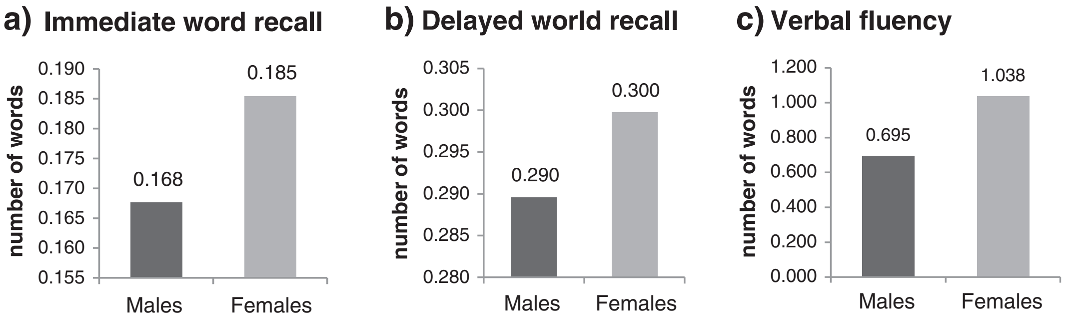

Fig. 3. Observed cognitive improvement by cohorts over a five-year period.

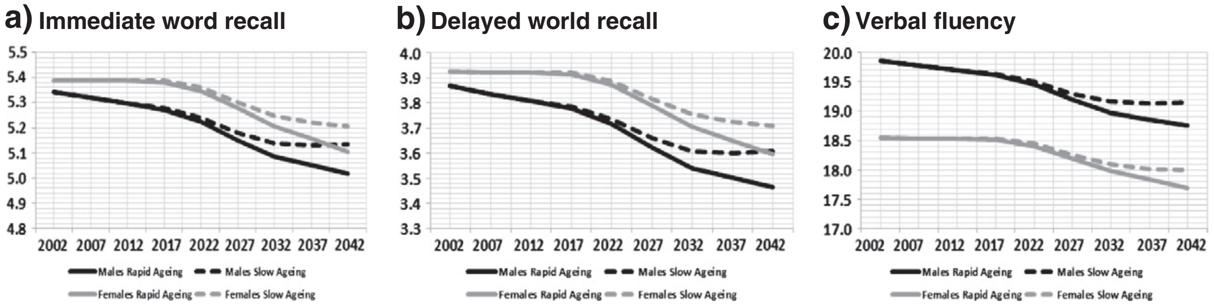

Fig. 4. Scenario A: No cohort effect, Constant age variation. Cognitive score, 2002–2042.

words for women (0.03 for both sexes for slow aging), while verbal fluency must increase from 0.14 words for men and 0.11 words for women (0.09 and 0.07, respectively, for slow aging). Such changes are about a third or less than the observed changes from 2002 to 2008 (cf. Fig. 3) for immediate and delayed recall (see above), and considerably lower for verbal fluency. Consequently, improvements along cohort lines that are only relatively modest and much lower than those that have been observed in the past are needed to offset potential adverse effects of demographic aging.

4. Discussion

This study first of all confirmed a continuation of the Flynn effect for older adults in a UK dataset (considering immediate recall, delayed recall and verbal fluency); even though in recent years some counter evidence had been reported. Furthermore, it used individual-level information on age- and cohort-variation in cognition and combined it with population estimates and projections that include the rate of cohort replacement and the degree of demographic aging. Although lifespan changes in cognitive performance and Flynn effects have both been well documented, there has been little scientific focus to date on the net effect of these forces on cognitive performance at the population level. This study addressed whether projected demographic change is likely to lead to a lower or higher average cognitive level in the population and for the specific abilities under consideration.

We find that without the continuation of the Flynn effect population aging does result in overall cognitive decline. Population aging will, for the UK population aged 50+, imply a substantial decline in average cognitive functioning, given no cohort improvements in cognition. For instance, average immediate recall performance for both sexes will decline from 5.37 to around 5.07 words (depending on the level of population aging) due to demographic aging. Strong negative effects are also found for delayed recall and verbal fluency.

If the Flynn effect observed in recent years continues, however, it would more than offset the corresponding age-related cognitive decline for the cognitive abilities studied. A continuation of the cohort improvements observed between 2002 and 2008 would imply that an increase in chronological age would *not* result in lower level of cognitive ability at the population level. In fact, when cohort effects are taken into account, our projections show *improvements* in cognitive functioning on a population level until 2042—in spite of population aging. Later-born cohorts with higher cognitive functioning will eventually replace older cohorts with poorer cognitive performance, which will improve older adults' cognitive performance. Even cohort effects that are very modest compared to what we observe empirically today, are able to offset the effects of demographic change for some time into the future.

In sum, population aging is not destined to imply lower cognitive ability levels and does not need to result in declining cognitive functioning among the 50+ age group. As age-related levels of cognitive functioning change over time because of cohort replacement, individuals of a given age will experience a different level of cognitive functioning in later periods of their lives. The current cohort effects in cognitive functioning indicate that the 50+ population of the UK could be more cognitively able in 2042 than in 2002 in spite of population aging. To which degree such historical changes effect performance levels or also slopes is a question yet to be clarified. The plasticity of cognitive aging as, for instance, reflected in the Flynn effect implies a great responsibility for society to ensure life-course conditions with regard to education, work, family, and health that make it possible to observe the Flynn effect also in the cohorts to come. Aging research, in fact, has compiled solid evidence that would

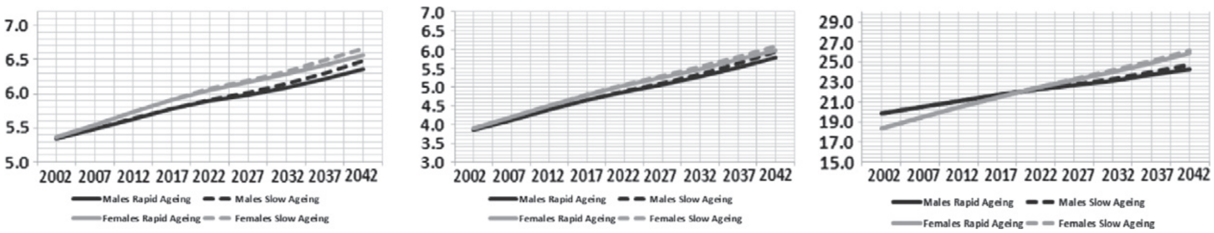

Fig. 5. Scenario B: Continued improvement along cohort lines, constant lifespan trajectories. Projections of cognitive ability, age profile of cognition by cohort.

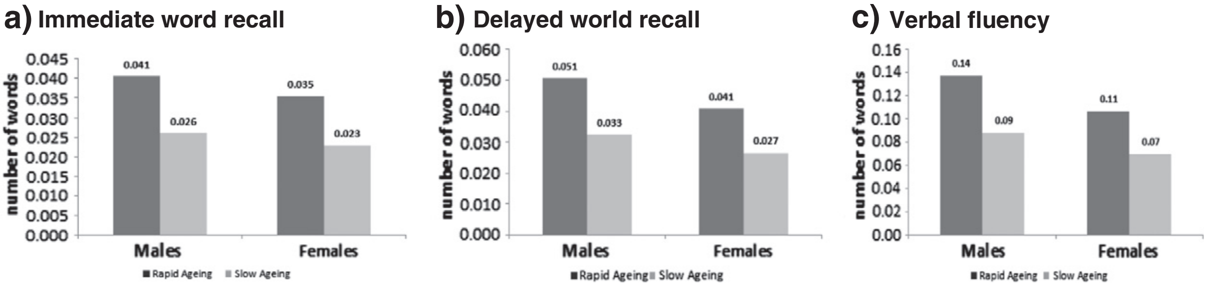

Fig. 6. Scenario C: Five-yearly cohort improvement needed for the same average cognition in 2002 and 2042 in the English population aged 50+, in spite of population aging.

help to construct life courses such that cognitive development is optimized (for example, Staudinger & Kocka, 2010).

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