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Retirement and cognitive abilities

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Non-technical summary

Within a context in which extending working life is prioritised in the UK policy agenda, this paper investigates how retirement influences the cognitive abilities of older British workers.

According to the "use it or lose it" hypothesis, retirement worsens the natural, ageing related process of cognitive decline. Entering retirement provides a less stimulating cognitive environment than working. Being less utilised, some cognitive functions deteriorate over time. The decline in cognitive abilities could potentially begin while still working if the approaching retirement does not justify further investment in cognitive skills.

Our findings support the theoretical predictions and suggest that retirement induces a decline in cognitive skills for both males and females. Exploring whether the effect of retirement differs across socio-economic groups, we show not only that respondents employed in routine occupations underperform in the cognitive tests compared to the rest of the population, but also that the negative influence of retirement on cognitive skills is weaker for women who had routine jobs. Finally, we do not find evidence in support of heterogeneous effects of retirement with respect to levels of education. Although the cognitive test scores of low qualified individuals are lower, we find that an extra year in retirement affects the cognitive skills of low educated individuals as much as it affects the rest of the population.

Therefore, disregarding the potentially offsetting effects on other dimensions of health, our findings indicate that the cognitive functions of older workers potentially benefit from postponing retirement. Within the “use it or lose it” hypothesis, our results support the importance of maintaining a healthy and cognitively engaging lifestyle after retirement from work as a way to maintain healthy cognitive functions.

Retirement and Cognitive Abilities

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Abstract

This paper investigates how retirement influences the cognitive abilities of British older workers. The analysis employs data from Understanding Society and relies on an instrumental variable approach to address endogeneity bias. Consistent with the "use it or lose it" hypothesis, we show that retirement induces cognitive decline, although the relationship is weaker for women employed in routine occupations. Disregarding potentially offsetting effects on other dimensions of health, we conclude that extending the working life has a beneficial effect on the cognitive capital of older workers and that maintaining a mentally engaging and stimulating life-style during retirement contributes to the cognitive health of the mature population.

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Introduction

In a context within which extending working life is a priority in the UK policy agenda, with the state pension age (SPA) gradually rising to 67 and potentially 68 for men and women (Department for Work and Pension 2013), a study of the consequences of retirement on cognitive capital is relevant for at least three reasons. First, there is an association between the process of accumulation and deterioration of human capital with that of cognitive capital (Rohwedder and Willis, 2010). Studying the extent to which retirement affects the deterioration of cognitive capital is therefore important in order to understand and potentially contrast human capital depreciation during various phases of old age (Mazzonna and Peracchi, 2012). Second, there is evidence that cognitive abilities, in particular numeracy, are strongly related to financial literacy. Although causation is still under debate, the relevance of this relationship is enhanced by a context in which social provisions shrink and private pensions and savings become increasingly important sources of income for the elderly (Banks et al., 2007). Third, cognitive measures are shown to be significantly correlated with health outcomes. Reviewing previous studies, Deary (2012) reports that cognitive capital is inversely associated with different causes of mortality such us cardiovascular disease, suicide, homicide and accidents, while Salthouse (2012) highlights a significant association between cognitive functioning and the ability of elderly people to live independently, experiencing a lower risk of depression and facing better general health.

In this paper we analyse the extent to which retirement influences the cognitive performances of older workers in Britain, and explore the existence of heterogeneous effects across gender, education level and job type. The analysis makes use of data from wave 3 of Understanding Society and, following the approach proposed by Mazzonna and Peracchi (2012), estimates the relationship between time spent in retirement and cognitive decline using an Instrumental Variable (IV) approach. The contribution of this paper to the limited UK-based literature is twofold. First, we employ a novel dataset in an area of research which mainly uses data from the English Longitudinal Study of Ageing (ELSA). Second, we add to existing UK evidence by analysing men and women separately and exploring the heterogeneity of the retirement-induced cognitive decline across various levels of education and type of work performed.

We find that retirement worsens cognitive decline for both men and women, although the estimated coefficients indicate smaller effects among females. In particular, depending on the cognitive measure analysed, an extra year in retirement is predicted to generate a decline of between 0.035 and 0.089 of a standard deviation for men and between 0.015 and 0.048 for women. We also find that, among the latter, those employed in routine occupations face a lower retirement-induced cognitive decline and could potentially benefit from it.

Given that postponing retirement is predicted to be potentially beneficial for the cognitive capital of older workers, our results advocate the importance of keeping an active and mentally stimulating lifestyle following retirement.

This paper is organised as follows. Section 1 discusses the theoretical background and reviews a number of relevant studies on the relationship between retirement and cognitive decline. Section 2 briefly introduces the UK system of public support for older people. Data and methodology are described in Section 3. In Section 4 we report the results of our analysis and carry out robustness checks. Conclusions follow.

I. Background and review of the literature

According to the model proposed by Cattell and Horn (1966), what is commonly known as general intelligence can be considered to be the result of the interaction of different factors. Among these factors, fluid intelligence and crystallised intelligence are the main ones. Fluid intelligence is the ability to deal logically with new and/or unfamiliar situations. It usually involves processes of abstraction, categorization and placing objects/events in relation to one another. Fluid intelligence is assumed to work independently from previously held knowledge. Crystallised intelligence is the ability to employ previously acquired knowledge and experiences and it is relevant for tasks such as those involving vocabulary (Gustafsson, 1984; Salthouse, 2010; Cattell and Horn, 1966).

Although ageing is correlated with cognitive decline, a consensus exists in the psychology literature on different cognitive functions evolving heterogeneously with age. In particular, Salthouse (2010) shows that the decline of cognitive functions related to fluid intelligence starts in early adulthood, while crystallised intelligence tends to increase well into adulthood and begins to decline after the age of 60.

Rohwedder and Willis (2010) develop a parallelism between the process of the development of human capital as modelled by Ben-Porath (1966) and the development of fluid and crystallised intelligence over time. In particular, the authors argue that the main inputs of the human capital production function, which are ability, current stock of human capital, and other purchased inputs, can be seen, respectively, as fluid intelligence, crystallised intelligence, and involvement in activities which facilitate human capital formation such as schooling and on-the-job training. In this context, the stock of human capital evolves according to the rates of investment and depreciation of human capital, where the latter can be interpreted as losing crystallised knowledge. Investments in human capital formation and involvement in activities that stimulate cognitive processes are therefore expected to counterbalance the ageing related human capital depreciation. [1]

Within this framework, Rohwedder and Willis (2010) predict that retirement may negatively influence the process of depreciation of cognitive capital for two reasons. First, according to the "unengaged lifestyle" or "use it or lose it" hypothesis, retirement might provide a less cognitively stimulating environment than working, with the consequent worsening of the cognitive capital ageing profile. Second, if returns to work-related cognitive capital fall as retirement age approaches, it is also possible for workers to start reducing investments in cognitive capital while still working. The authors call this hypothesis "on the job retirement".

From an empirical point of view, the endogeneity of retirement decisions with respect to cognitive performances represents the main challenge for the identification of the causal effect of retirement on cognitive abilities. The issue is often solved using retirement eligibility rules as instruments for the retirement decision. A number of papers have applied this strategy to pooled cross-country data, relying on cross-country variations in early and standard retirement age to address the endogeneity. The results are mixed, with evidence in favour of both negative and non-significant effects of retirement on cognitive performance (Rohwedder and Willis, 2010; Mazzonna and Peracchi, 2012; Mazzonna and Peracchi, 2014; Coe and Zamarro, 2011).

Rohwedder and Willis (2010) pool 2004 data from the Survey of Health, Ageing and Retirement in Europe (SHARE) which contains data from 11 EU countries[2]; the US Health and Retirement

[1] See also Mazzonna and Peracchi (2012) for a formalised model of the formation of cognitive capital.
[2] Austria, Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Spain, Sweden and Switzerland.

Survey (HRS); and the English Longitudinal Study of Ageing (ELSA). They find evidence that retirement negatively impacts cognitive abilities measured as the combined result of an immediate and delayed word recall test. Using the same SHARE data, Mazzonna and Peracchi (2012) employ a similar identification strategy although retirement is now allowed to change the slope of the cognitive capital age profile rather than shifting it. While in Rohwedder and Willis (2010) retirement enters the analysis as a binary indicator variable, which implies that retirement generates a shift in the age profile of cognitive decline, in Mazzonna and Peracchi (2012) a continuous measure of time since retirement is used as an endogenous regressor and time elapsed since eligibility for early and standard pensions as instrumental variables. Moreover, the study conducts separated analysis by gender and uses five different measures of cognitive abilities. The authors show evidence that retirement worsens the rate of decline of cognitive capital, although the effects are heterogeneous across gender. The authors also find that the level of education influences cognitive performances at older ages and that low educated women tend to experience a stronger decline in cognitive performance after retirement than more highly educated women. Mazzonna and Peracchi (2014) extend their previous analysis by modelling the effect of retirement both as a binary treatment and as a slope effect and, exploiting the longitudinal dimension of SHARE, by estimating a first difference instrumental variable model. The results confirm the existence of a negative effect of retirement on cognitive decline, while a beneficial immediate effect of retirement is identified only for manual workers. By contrast, using 2004 SHARE data, and focusing on men only, Coe and Zamarro (2011) find evidence of retirement improving general health but not cognitive measures, measured by immediate and delayed recall tests and a verbal fluency test.

However, as reported in Bonsang et al. (2012), country specific cultural and institutional characteristics are likely to influence both the age profile of cognitive abilities and the settings governing retirement rules. The authors report that citizens from northern countries tend to perform better than their southern counterparts in various health outcomes and that they face higher retirement ages. If differences in the eligibility ages for retirement failed to explain such patterns across countries then the exclusion restrictions would be invalid and the effects of retirement on cognitive abilities over-estimated. In this sense, although the use of country-fixed effects is likely to mitigate the problem, single country studies are likely to be more suitable than cross-country ones for this kind of analysis.

US-based evidence provides mixed results. On the one hand, using HRS data, Coe et al. (2012) show a limited impact of retirement on cognitive outcomes, and highlight the heterogeneity of such effects between typologies of workers. In particular, the authors show that the cognitive performances of white collars are not significantly affected by retirement once the endogeneity of retirement decision is accounted for, while retirement emerges to be positive for blue collar workers. Within the "use it or lose it" hypothesis, the authors interpret the finding as blue collar workers being able to access more cognitively stimulating activities during retirement than whilst still working, while white collars do not experience a significant reduction in the exposure to such activities. On the other hand, basing their analysis on a panel dataset of American respondents to the HRS, Bonsang et al. (2012) estimate a fixed effect model with instrumental variables, where the issue of endogeneity of retirement decisions is accounted for by using two indicator variables for having reached the age of 62 and of 65 as instruments. The authors account for a delayed effect of retirement on cognitive abilities by defining the endogenous independent variable as being retired for at least one year, and in different specifications also use time since retirement as endogenous variable, and time since the age 62/65 thresholds as instruments. The analysis shows evidence in favour of a worsening of the age profile of cognitive measures after retirement.

UK-based studies suggest the presence of negative effects of retirement on cognitive measures, although the evidence is quite limited. Adam et al. (2007) apply a stochastic frontier approach for 2004 data from ELSA for the UK, HRS for the US and SHARE, separately. The results indicate a worsening in cognitive efficiency with time spent in retirement. Behncke (2012) applies non parametrical IV and matching techniques to ELSA data in order to analyse the health effects of retirement. Modelling retirement effects as discrete shifts, the author finds evidence that retirement increases the probability of experiencing a cognitive functioning problem measured through the word recall test and awareness of current date.[3]

Using data from Understanding Society, this paper analyses the role of retirement in influencing the cognitive performances of older workers in Britain. Additionally, we explore the existence of heterogeneous effects across gender, education level and job type. Following Mazzonna and

[3]Focusing on different health outcomes, Johnston and Lee (2009) apply a regression discontinuity analysis around age 65 to a pooled data of the 1997-2005 Health Survey for England (HSE). The authors find evidence that retirement has a beneficial effect on mental health, measured by the GHQ-12 questionnaire.

Peracchi (2012), we adopt an IV approach and use time elapsed since state pension age as instrumental variable for the time spent in retirement. The next section briefly describes the functioning and evolution of the system of public support for older people in the UK.

II. Retirement age and state pension age in the UK

State pension age is the age at which the basic state pension and a number of other benefits become available for older people. Introduced in 1946 and effective from 1948, the UK basic state pension has been designed as a flat rate benefit aimed at providing a basic level of resources to pensioners. Eligibility is based on both age and contribution history, with female state pension age (SPA) originally set at 60 and male SPA at 65. Earnings-related pensions, flat rate non-contributory benefits and a number of means-tested benefits complete the public system of support for pensioners.

A process of reform of the system of public support of elderly people is ongoing. Over the years, budgetary considerations have not only prevented the full development of earnings related pensions, but also eroded the capacity of the basic state pension to guarantee minimum subsistence levels to all pensioners, with the consequent increase of the relevance of means-tested benefits aimed at older people. Current reforms, such as the phasing in of the New State Pension in April 2016, aim at re-establishing the Beveridgean nature of the state pension system (see Bozio et al. (2010) for further details on the development of the public system of support for pensioners).

The process of reform has also involved an increase in the state pension age. In particular, under the provisions of the 1995 Pension Act, female state pension age is currently increasing from 60 to 63 years of age. Women born between 6th April and 5th May 1950 have been the first to be affected by the reform, reaching eligibility on the 6th May 2010, with the state pension age spanning from 60 years and a day to 60 years and a month. Women born on each following month have faced a further one month increase in the state pension age, until a state pension age of 63 is reached by women born between 6th March and 5th April 1953 who gained eligibility on 6th March 2016. Under the provision of the 2011 Pension Act, female state pension age will increase faster for those born after the 6th April 1953, until catching-up with male state pension age of 65. The state pension age for men and women is then due to reach 66 for those born between 6th October 1954 and 5th April 1950, and to further increase to 67 under the Pension Act 2014, and to the age of 68 under the 2007 Pension Act (Department for Work and Pension 2013). Figure 1 shows the evolution of state pension ages over time.

It should be noted that no compulsory retirement is attached to the state pension age. Although until 2006 employers had the possibility to set retirement ages for their employees, the adoption of a Framework Directive of the European Commission led to the 2006 Employment Equality (Age) Regulations, which prohibited any unjustified direct and indirect age discrimination. As a consequence, employers lost their ability to set retirement ages for their employees below a default retirement age of 65, except if objectively justified. Different from a compulsory retirement age, workers could work past the default retirement age if in agreement with the employer. The default retirement age was abolished in 2011, prohibiting employers from forcing employees into retirement on the ground of age, although this included the provision of objectively justified exceptions (Pyper, 2013).

State pension age is, hence, the age at which state retirement benefits become available and traditionally represents the age at which an important part of the labour force enters retirement (Bound and Waidmann, 2007). In our analysis we use state pension age as an instrumental variable for retirement decisions, and its relevance is further discussed in Section 3.3.

III. Data and Methods

III.1 Data and Descriptive Statistics

In this paper we analyse the extent to which retirement influences cognitive decline in the UK. The analysis makes use of wave 3 data from Understanding Society, the UK Household Longitudinal Study (UKHLS)[4]. Starting in January 2009, Understanding Society is a large household panel survey which annually re-interviews adult (16 and older) and young (10-15) household members, collecting information on a great variety of household and individual circumstances and on their evolution over time. The General Population Sample (GPS) used in this analysis is based on a proportionally stratified clustered sample of addresses for England, Scotland and Wales and on a systematic, unclustered, random sample of addresses for Northern

[4] University of Essex. Institute for Social and Economic Research,NatCen Social Research. (2014). *Understanding Society: Waves 1-4, 2009-2013: Special Licence Access*. [data collection]. *4th Edition.* UK Data Service. SN: 6931

Ireland. The GPS sample contained just over 26 thousand households in wave 1, with above 43 thousand individuals giving full or proxy interviews. Wave 3 fieldwork spanned from January 2011 to July 2013, with a household response rate of 75.3 percent in Great Britain and 79.1 percent in Northern Ireland and more than 33 thousand adult individuals with a full or a proxy interviews (see Knies, 2014 for further details).

In our estimation sample we include fully respondent individuals aged between 50 and 70 (both included) reporting to have ever worked and to be either active in the labour market or retired.[5] We exclude unusually early retired individuals by dropping those whose retirement started before the age of 50. Labour market status is defined by combining the information on whether the respondent was in work or temporarily out of work in the week before the interview and that on the self-reported current labour market status. Any respondent with a contradictory status was excluded from the estimation sample. We also exclude from our sample individuals whose retirement date is either missing or inconsistent with the information on labour market status provided in previous waves, or those who have missing values on any of the variables used in the analysis.

Panel A of Table 1 summarises the characteristics of the resulting sample. The average age is close to 60, with retired averaging 66-years-old and non-retired 57-years-old, respectively. Males account for 47 percent of our estimation sample, while just above one third of our respondents are retired. The proportion of retired respondents is slightly higher among females than males, arguably because females are subject to a lower state pension age. Years since retirement and years since the state pension age measure the number of years elapsed since retirement occurred or the state pension age was reached. Both variables are originally measured in months and divided by 12. The variables take value of 0 if respondents are respectively non retired or younger than the state pension age. Data from annual history questions in waves 1 to 3 are used to retrieve information on the retirement age.[6]

[5] As a robustness check we extended the sample by including people up to the age of 80, see Section 4.3.

[6] The date on which the respondent left their last job is used to measure retirement for respondents who were interviewed for the first time in wave 2 or wave 3 of Understanding Society. Also, being day of birth not available and day of retirement either not available if someone retired before wave 1 or often missing if someone retired after that we choose to measure both variables in months. Finally, as explained in section 2, reforms in state pension age are implemented according to the date of birth, with cut-off points set on the 6th day of each month. Being the day of birth not available we apply state pension age rules relative to those born between, say, 6th April and 6th May of

One quarter of our sample is low qualified, measured as having no-qualifications or other qualification as opposed to highly qualified respondents, defined as those with GCSEs or above. Such proportions are similar across genders but not across retirement statuses, with 36 percent of retired people reporting to be low qualified as opposed to 23 percent of non-retired respondents. Controlling for heterogeneity in cognitive decline with respect to education might be important as Mazzonna and Peracchi (2012) show evidence of less educated women experiencing a stronger decline than the rest of their sample.

The proportion of individuals performing, or who performed in the last job, a routine task is 11 percent. The Job National Statistics Socio-economic Classification (NS-SEC) is used to classify a job as "routine" as opposite to non-routine. While the proportion of people employed in routine jobs is constant across retirement statuses, a higher proportion of males enter in this category compared to females – 14 percent versus 9 percent, respectively. Occupation type is shown to affect retirement induced cognitive decline, with Coe et al. (2012) reporting evidence of heterogeneity between blue collar and white collar workers in the US, and Mazzonna and Peracchi (2014) showing that cognitive decline affect workers from manual occupations differently.[7]

Three quarters of our sample live with a partner, with a higher prevalence among males than females (81 percent versus 71 percent). Living with a partner is expected to mitigate cognitive decline as it could arguably encourage individuals to maintain active cognitive functioning (Mazzuco et al. 2013). 81 percent of our sample reports to be in good general health although the prevalence is higher among non-retired than retired individuals (83 percent versus 77 percent). If, on the one hand, general health is likely to suffer endogeneity issues, its introduction might help in disentangling the role of age related health decline. Finally, Table 1 also contains the

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a given year to all those born in April of that year, while those born between 1st and 5th May of that year will follow state pension age rules related to those born between 6th May and 5th June. Consequently, if rules state that respondents become eligible on the 6th day of a given month, we apply that month as the one in which state pension age is reached. These assumptions, which are entirely data driven, are equivalent to implying that all women born in April 1950 will reach state pension age at the age of 60 and one month; those born in May 1950 will reach state pension age at the age of 60 and two months, and so on. Being the misclassification driven by the day of birth in a given month, we can assume this to be random and hence not biasing our estimates. Moreover, the consequences of misclassification should not be relevant in size, as the differences in state pension age for people born in consecutive months are usually contained to one or two months.

[7] Including the workers employed in semi-routine occupations in the routine category does not significantly affect the results of the paper. Results are available on demand from the author.

proportion of respondents living in each of the countries of the UK. Specifically, 83 percent of the respondents live in England, 8 percent in Scotland, while the rests are equally split between Wales and Northern Ireland.

Following Mazzonna and Peracchi (2012), we use four measures of cognitive ability throughout our analysis. (i) Immediate recall and (ii) delayed recall tests measure the number of correct answers to a test consisting of a computer reading a list of 10 words and the respondent having to remember as many of them as possible. While in the immediate recall test the respondent is asked to lists the words immediately after hearing them, in the delayed recall test the respondent is asked to do so after other cognitive tests have been performed. Both immediate and delayed recall tests are expected to assess episodic memory. (iii) Numeric ability is assessed by a test requiring the respondent to perform some simple numerical operations related to the use of numbers in everyday life. In particular, a set of three questions is submitted to all respondents. In the event that the respondent makes one or more mistakes in answering these three questions, an extra question is asked in a second round. If the respondent gives three correct answers, a fourth and eventually a fifth question are asked. We use the number of correct answers to measure numeric ability. This measure is expected to be related to wealth and financial literacy. (iv) Verbal fluency is measured by the number of correct answers in a test consisting of respondents naming as many animals as possible in one minute. Verbal fluency measures aspects of executive functioning, and it requires mental flexibility, organization and abstract abilities (see McFall, 2013 and papers cited therein).

Panel B of Table 1 shows that male respondents perform better than females in numeric ability (3.99 versus 3.54 in raw scores) and, to a lesser extent, in verbal fluency (22.50 versus 22.18 in raw scores). By contrast, females outperform males in both immediate and delayed recall, with a raw score of 6.40 versus 6.10, and 5.32 versus 4.90, respectively. Important differences also emerge when we compare cognitive performances of retired and non-retired respondents, with the latter outperforming retired people in all the cognitive tests considered.

Figure 2 shows the presence of a negative age profile in cognitive measures, with gender differences holding across the age distribution. A negative relationship also emerges by plotting cognitive performances against years spent in retirement (Figure 3).

Since years in retirement is positively correlated with age, this evidence is expected. Similarly to Mazzonna and Peracchi (2012), we therefore further investigate the relationship between age, retirement, and cognitive performance by differentiating the age-profile of the cognitive tests between retired and non-retired individuals. For both males (Figure 4) and females (Figure 5), we observe that at later ages retired individuals tend to perform worse than non-retired ones, whilst the opposite is true at earlier ages. In particular, whilst for men the cut-off point is close to the age of 65, for women this happens at approximately 60 years of age, with the exception of numeric ability. This evidence suggests that people who are already retired at ages below the state pension age outperform those of a similar age who are active in the labour market, whilst the opposite applies to people who are above the SPA. Figure 6, where we plot the age profile of cognitive performances by retirement status and duration of retirement, confirms this finding.

The graphical evidence reveals that retired individuals experience a sharper decline in their cognitive scores over time than similarly aged people who are active in the labour market. This evidence is, however, partly in contrast with Mazzonna and Peracchi (2012) who show that retired people perform worse than working people across the age distribution. A positive selection into early retirement in the UK might entail better performances of early retired individuals compared with active individuals of a similar age. Supportive evidence is provided in Table 2 where we summarise individual characteristics and test performances by gender, retirement status, and whether the respondent is above or below the state pension age. For both males and females it emerges that individuals who are retired and below the SPA perform better than any other group in all the cognitive measures, showing also the lowest prevalence of low qualification and routine jobs. In the UK, early-retirement therefore appears to be a status in which better off people tend to select. The finding is consistent with Blundell et al. (2002), who show how the incentives embedded in occupational pensions increase the probability that eligible people retire earlier than the state pension age. The positive selection into early retirement is likely to introduce an attenuation bias in our naïve OLS estimates since intuitively early retirees have a positive number of months in retirement and score highly in cognitive measures.

Although the descriptive evidence is consistent with the existence of a cognitive decline induced by retirement, the phenomenon could also be driven by reverse causality issues – people retire when cognitive abilities decline. Furthermore, another driver could be the correlation between retirement and ageing – retired individuals are, on average, older than non-retired individuals and have therefore experienced a greater cognitive decline. In the remainder of the analysis we employ an instrumental variable approach to mitigate the confounding effect described above and to identify the causal effect of retirement on cognitive performances.

III.2 Identification strategy

In this paper, we study how retirement influences cognitive decline in the UK. The endogeneity of retirement with respect to cognitive decline represents the main identification issue in determining the causal effect of retirement on cognitive capital. Whilst retirement can influence the cognitive decline through "use it or lose it" or "on the job retirement" arguments (Rohwedder and Willis, 2010), it is also possible for people who experience cognitive decline to be pushed into retirement. Consistent with previous literature, we employ eligibility rules for state pension age as an instrument for retirement decisions (e.g., Rohwedder and Willis, 2010; Mazzonna and Peracchi, 2012; Coe and Zamarro, 2011).

First, following Mazzonna and Peracchi (2012) in particular, for each cognitive measure used we estimate an OLS regression of the form described in equation (1):

$$C_i = \beta_0 + \beta_1 \, Age_i + \beta_2 \, RetY_i + \; X_i' \, \gamma + \varepsilon_i \qquad i = 1, \dots, N \qquad (1)$$

where C_i measures the standardised test score for the individual i, Age_i is the age at the time of the interview, $RetY_i$ measures the number of years elapsed since retirement and X_i is a vector of individual characteristics. Years spent in retirement are set to 0 if the respondent is not yet retired, such that $RetY_i = max(0, Age_i - RetAge_i)$. Both age and years since retirement are originally measured in months and divided by 12. We estimate different sets of regressions for men and women.

Second, since the OLS estimates are likely to suffer from the endogeneity of retirement with respect to cognitive decline, we then use the time elapsed since state pension age as an instrumental variable for years spent in retirement. In particular we define the instrument as

$$SpaY_i = max(0, Age_i - SPA_i) \qquad (2)$$

where SPA_i captures the state pension age of the i-th individual. While the coefficient on age (β_1) is expected to capture the age-related cognitive decline in the absence of retirement, the coefficient on years since retirement (β_2) – instrumented by years elapsed since SPA – measures the additional cognitive decline which is imputable to retirement. Given the positive selection into early retirement observed in our data, we expect the OLS estimates to be affected by attenuation bias, and, hence, for the coefficient on years since retirement estimated using OLS to be smaller in size (less negative) than the one estimated using IV. [8]

Following previous literature (Mazzonna and Peracchi, 2014), our identification strategy assumes linearity of age-related cognitive decline. This is a reasonable assumption given the age range in our analysis, 50 to 70 years, and results from previous studies (Coe and Zamarro, 2011). However, we perform robustness checks of the linearity assumption in Section 4.3.

III.3 Instrument validity

As previously mentioned, we deal with the potential endogeneity of retirement using changes in the state pension age as an instrument.

State pension ages are currently being reformed in the UK for both men and women according to the description provided in Section 2. Since the data used in this analysis is collected between 2011 and 2013, no men in our sample actually reached state pension age with the modified rules yet. Only men born since December 1953 are in fact affected by the increase in SPA, with the first cohort reaching SPA in March 2019. Hence, although men who will retire with an increased SPA are part of our sample, our identification strategy for men relies on the changes in retirement probabilities before and after the age of 65, on the grounds that nothing else specifically related to cognitive decline happens at that age (Johnston and Lee, 2009).

[8] Our interest lies in analysing the extent to which retirement determines changes in age-related cognitive decline. A pure regression discontinuity approach which compares individuals who are just above or just below the state pension age threshold is therefore not informative in our setting. A different approach could consist in exploiting the increase in SPA for women and, hence, comparing two women of the same age with different elapsed time periods since SPA. Given the cross sectional nature of our dataset and that the SPA reform maps age, this could only be done by exploiting the fact that wave 3 interviews spanned over two years. Hence, it is possible for some women born in two consecutive years to report the same age at the date of interview and different elapsed time since SPA if affected by the reform. The number of women falling into this category is, however, small and, given the smooth implementation of the SPA increase, the differences in time elapsed since SPA only amounts to a few months. Moreover, all the women affected by the reform in our data are recently retired. We therefore considered the IV approach the most suitable for our analysis.

Among all women, 60 percent are born on or after April 1950 and are therefore affected by the reform. Among those affected by the reform, close to 13 percent - and just below 8 percent of all women in our sample – are over the age of 60 but face a higher state pension age. These women would have already reached the state pension age if the reform was not in place but, instead, they either have not reached it yet or reached it with some delay. Hence, although limited, our analysis includes variations in the state pension age for women.

Figures 7 and 8 graphically assess the validity of our instrument, confirming that the state pension age is a suitable instrument for retirement decisions. In particular, Figure 7 reports the distribution of retirement age for individuals who are retired at the time of the interview. The chart includes both the probability density function (p.d.f.) and the cumulative density function (c.d.f.) for males and females separately. While the former describes the proportion of retired individuals who retired at each point of the age distribution, the latter shows the proportion of retired individuals who retired by a certain age. Both in terms of c.d.f. and p.d.f., the figures show discontinuities at the age of 65 for males, with 20 percent retiring at this age, and at the age of 60 for females, with 25 percent retiring at this age. In both cases there is a strong correspondence between retirement age and state pension age. In Figure 8 we report a local polynomial fit of being retired on age. For both men and women, the fit is performed separately for people who are above and below their state pension age. The chart shows the presence of a discontinuity of between 0.2 and 0.3 in what can be interpreted as the probability of being retired in correspondence to the relevant state pension age. In the next section we report the first-stage estimates to support this evidence.[9]

IV. Results

IV.1 Baseline

In Table 3 we report OLS estimates for our baseline model specification, where the dependent variables are the standardised test scores and the independent variables of interest are (i) age, and (ii) years spent in retirement. We also control for the individual characteristics described in the previous section. The estimates should be treated as naïve because of the endogeneity issues

[9] A graphical inspection reveals similar discontinuities in correspondence of the SPA if we only focus our analysis on people who reached state pension age from 2006 onwards.

discussed in previous sections. Consistent with previous findings and theoretical considerations, estimates show a negative relationship between age and three out of the four cognitive measures analysed.[10] Numeric ability represents the exception, showing a positive association with age for both men and women. Arguably, these positive correlations may be the consequence of a cohort-effect for which we cannot control given the cross-sectional nature of the data (Schaie et al., 2004). In contrast with Mazzonna and Peracchi (2012), after having controlled for age, the naïve OLS results do not show any significant effect of years since retirement on cognitive measures.

Amongst other regressors, having low academic qualifications and having performed a routine job are associated with a worse performance in the cognitive tests, while having a partner is associated with better outcomes for males at the immediate word recall test and for both males and females at the numeric ability and verbal fluency tests. As expected, good general health is related to a better cognitive performance, although the relationship is possibly endogenous as general health is likely to be correlated with retirement decisions and with cognitive measures. Country dummies are sometimes statistically significant, in particular living in Wales is associated with lower cognitive scores, arguably because of language related issues.

In Table 4 we report the first stage estimate of the IV. The table shows that the number of years elapsed since state pension age is a valid instrument for years spent in retirement. The coefficient on the variable of interest is, in fact, positive and highly statistically significant, indicating that a one extra year since state pension age has been reached is associated with a 9 months increase in time since retirement. For both males and females, the F-statistic is well above the conventional value of 10.

In Table 5 we report the IV estimates of our base model, where years elapsed since state pension age is used as an instrumental variable for years spent in retirement. First, the coefficient on age loses statistical significance in most of the regressions but remains positive and relatively high in the regression for numeric ability for both men and women. Although puzzling, this result can be explained by the fact that the cognitive functions belonging to the broad category of crystallised intelligence tend to improve until adulthood and only start to decline from the age of 60 (Salthouse, 2010).

[10] The variable age has been modified such that a value of 0 indicates age 50, the minimum value in our sample.

The estimates show a negative and statistically significant effect of years since retirement on all the cognitive measures, with the exception of verbal fluency for females, where the effect is negative but insignificant. An increase in time spent in retirement is therefore predicted to negatively affect cognitive development both for males and females. The size of the effect varies across genders and cognitive measures, with an extra year of retirement associated with a decline of between 0.035 and 0.089 of a standard deviation for males, and between 0.015 and 0.048 of a standard deviation for females. These results are consistent with previous findings and with the prediction of the "use it or lose it" argument (Bonsang et al., 2012; Mazzonna and Peracchi, 2012; Rohwedder and Willis, 2010).

With respect to other regressors, the estimated coefficients are in line with the OLS estimates reported in Table 3. The results of the reduced form model are reported in Table 6 and are highly consistent with the IV estimates.

Hence, we find evidence that retirement negatively influences cognitive decline, with the depreciation rate of cognitive capital for retired individuals being higher than for working individuals. In the next subsection we explore the heterogeneity of such a decline with respect to education and type of job performed.

IV.2 Heterogeneity in cognitive decline: the role of education and job type

In this sub-section we extend our baseline analysis by studying whether retirement affects the cognitive decline of various groups of respondents differently from one another. In particular, following Mazzonna and Peracchi (2012) we first study whether retirement related cognitive decline differs between low qualified individuals and the rest of the population. Second, in the spirit of Coe et al. (2012) and Mazzonna and Peracchi (2014), we analyse heterogeneity in retirement-induced cognitive decline between routine and non-routine workers. It should be noted that in our estimation sample the proportion of low qualified individuals is similar across genders (26 percent for men and 28 percent for women), while considerable differences arise with respect to performing routine occupations as 14 percent of men fall into this category as opposed to 9 percent of women.

Table 7 and Table 8 show the results after modifying our baseline specification by adding interaction terms between the low qualifications dummy variable and both age and years since retirement. The first stage regressions are reported in Table 7 and second stage IV estimates are reported in Table 8. Our results do not show evidence of heterogeneity in retirement-induced cognitive decline across levels of education as none of the interaction terms between being lowly qualified and years since retirement are statistically significant.[11] These results are in contrast to Mazzonna and Peracchi (2012) who find evidence that low educated women face a steeper cognitive decline than highly educated ones.

Coe et al. (2012) explore whether heterogeneity in retirement-induced cognitive decline arises between blue and white collar workers in the United States, The authors find no evidence of retirement-induced cognitive decline for white collars workers, while the cognitive abilities of blue collar workers tends to improve following retirement. Consistently, Mazzonna and Peracchi (2014) find evidence of a relevant, immediate positive effect of retirement on the cognitive performances of the workers employed in physically demanding occupations. Our evidence, reported in Tables 9 and 10, shows no significant differences in the effect of retirement on cognitive decline between men with routine jobs and the rest of the male population. However, we find evidence of women who had routine jobs experiencing a less steep cognitive decline after retirement than the rest of the female population. Analysing the size of the interaction coefficient, the cognitive measures of women from routine job could, in fact, benefit from retirement. This result is partly consistent with the findings of Coe et al. (2012) and Mazzonna and Peracchi (2014) and, within the "use it or lose it" interpretation of retirement-induced cognitive decline, it can be explained with routine workers suffering less, or even benefiting, as a result of the changes to cognitive engagement associated with retirement.

IV.3 Robustness checks

In this section we discuss a number of checks to verify the robustness of our results.

First, we test the fit of different placebo models in which cognitive decline is assumed to start either before or after the official retirement age. We do so with the aim of showing whether the base model presented in the previous section provides the best fit for the data. Since the variable measuring years since retirement is left censored, this means that we cannot observe when the

[11] In different specifications we have modified our model by including GCSE and equivalent in the low qualification category as well as by replacing the low qualification category with being highly qualified, i.e. having a degree or more. In both cases the results are highly consistent with those reported in the paper.

non-retired individuals will actually retire. Thus, we are forced to perform these placebo tests using the reduced form model rather than the full IV specification.

An example may clarify this point. Say that a respondent is observed at age 64 and is not yet retired. For him/her the variable measuring the time elapsed since retirement would take a value of zero in our baseline specification. Suppose now that we want to test whether their retirement-induced cognitive decline starts before actual retirement, say 2 years before. If we knew that the respondent would retire at the age of 65, that is, in one year's time, then we could test whether his or her retirement-induced cognitive decline had started at the age of 63 and therefore assign a value of one year to the variable of interest. However, this would only be possible if we knew when non-retired respondents would actually retire. Since this information is not available to us, we circumvent the problem using the reduced form model, where we can easily modify the variable measuring the years elapsed since state pension age according to the hypothesis that we want to test. In the example above, we would test the fit of a model in which the variable of interests measures the time elapsed from two years prior the state pension age, i.e., since the age of 63 for men.

Table A1 reports the Akaike's information criterion for our baseline specification and for different specifications in which cognitive decline is assumed to start from between 2 to 10 years prior to the state pension age. At each model specification we therefore modify our time "at risk" and assume a 2 year increase in the number of years passed since the start of the retirement-induced cognitive decline. For each cognitive measure used, and for both males and females, the table shows that our baseline specification produces the best Akaike's criterion.[12]

In Table A2 we repeat the exercises by assuming that cognitive decline starts from between 1 to 5 years after retirement (captured by the state pension age). Although it is possible to perform this test using IV, we choose to use the reduced form model for consistency and because it is possible to retrieve goodness of fit statistics using OLS. The results confirm that the baseline model is the one that best fits the data, with the only exception of the one year lead specification for males on the numeric ability and verbal fluency tests.

[12] Used to compare the fit of models on the same data, the Akaike's Information Criterion (AIC) provides an index of the goodness of the fit and of the complexity of the model. Smaller values of AIC identify better models.

In the second robustness check, we repeat our IV estimates excluding from our analysis the individuals who entered retirement before state pension age was reached. In Table 2 we have already shown that individuals who retired early are a positively selected group and, although we already control both for level of education and job type, this might bias our estimates if unobserved characteristics make some individuals both more likely to be retired early, and hence have a positive number of years since retirement, and also to have better cognitive measures. Results reported in Table A3 show that our findings hold if the early retired individuals are excluded from our estimation sample, with the exception of immediate word recall and delayed word recall for males. It should also be noted that coefficients on age gain statistical significance for most of the cognitive measures when the early retired are excluded from the estimation sample.

Third, we follow the modelling strategy of Mazzonna and Peracchi (2014) and estimate a model which controls for both the intercept and slope effects of retirement. The estimated model employs a binary variable for having passed the state pension age and the time elapsed since SPA as instrumental variables for the retirement indicator and the time elapsed since retirement. Table A4 reports the IV estimates for males and females, while in Table A5 we estimate the model separately for routine and non-routine workers but pooling together males and females for issues related to sample size. In both cases the results show no significant evidence of an intercept effect of retirement on cognitive capital. Table A4 confirms the existence of the effect of retirement on cognitive decline, while Table A5 shows that the effect is prevalent among workers employed in non-routine occupations. The pooling of data from men and women is likely to explain the differences between Tables A4 and A5, respectively, and Table 10.

Fourth, we estimate our baseline specification increasing the upper age-limit of our sample to 80. Although being more likely to be influenced by mortality bias, the results reported in Table A6 confirm the main findings of our model. The estimated coefficients of interest for men are, however, smaller than those estimated using our baseline specification.

In Table A7 we also report the estimates of our baseline specification after excluding general health from the list of controls included in the regression. Although the rationale for including it is to control for the effect of health conditions in cognitive decline, general health is likely to cause endogeneity problems in the data. We show that its exclusion does not significantly alter our estimates.

Finally, our identification strategy relies strongly on a linear functional form for the age-related cognitive decline. We therefore check the robustness of our results using different functional forms for age. In this regard, first, we test for a quadratic form and then redefine age as a categorical variable with 3-year bands. Table A8 reports IV estimates for men, while Table A9 reports these estimates for women. The bottom of each column reports the corresponding Akaike's criterion, estimated using the reduced form model. Column (1) reports the baseline estimate. The introduction of a quadratic age term (column 2) results in an increase in the size of the estimated coefficients on years since retirement for men, where both age and quadratic age are statistically significant. Although not statistically significant, the introduction of the quadratic age term leads to a reduction in both the size and significance of the coefficients of interest. It should be noted however that for females both age and age squared are statistically non-significant and that for both males and females the introduction of the quadratic age worsens the model fit according to the Akaike's information criterion.

Controlling for age using 3-year age dummies (column 3) results in an increase in the size of most of the coefficients of interest, while the Akaike's criterion based on the reduced form model continues to identify the linear age regression as the best one. Consistent with previous studies, and in agreement with the non-parametric profile of cognitive ability with respect to age and years of retirement which arises from a visual inspection of Figures 3 to 6, we therefore conclude that the linear age specification is the one which best fits the data.

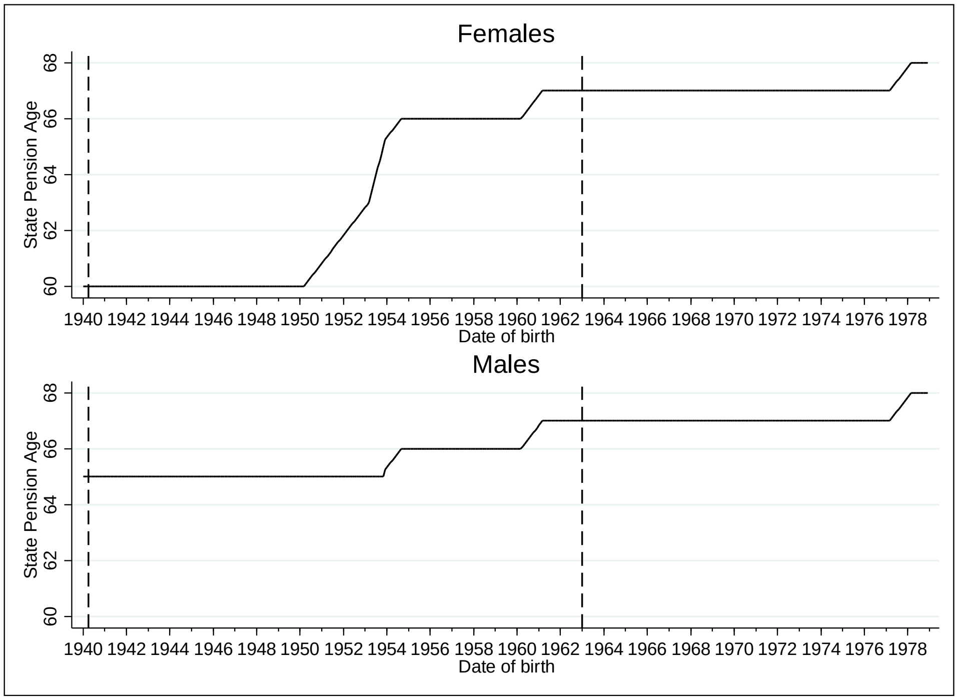
Conclusions

In this paper we have analysed to what extent retirement affects cognitive abilities in Britain and our results indicate that retirement worsens age-related cognitive decline for both males and females. Using four measures of cognitive abilities, specifically immediate word recall, delayed word recall, fluency, and numeric ability, we find that one year of retirement generates a decline in cognitive measures of between 0.035 and 0.089 of a standard deviation for men, and between 0.015 and 0.048 of a standard deviation for women. We have also found evidence of heterogeneity of response with respect to job type, with retirement-induced cognitive decline being significantly smaller, and potentially beneficial, for women who had routine jobs.

During a period in which extending the length of working life represents a priority in the UK policy agenda, our results indicate that postponing retirement could potentially have a positive effect on the cognitive capital of older workers, although women performing routine tasks will benefit less, or potentially suffer, from it. Focusing on cognitive capital only, it should be noted that our analysis leaves aside the effects of retirement on a number of other physical and mental health outcomes, which might well overturn the positive effect on cognitive capital identified here. Within the “use it or lose it” hypothesis, what should be emphasised is the importance of maintaining a healthy and cognitively engaging lifestyle following retirement from work as a way to maintain healthy cognitive functions.

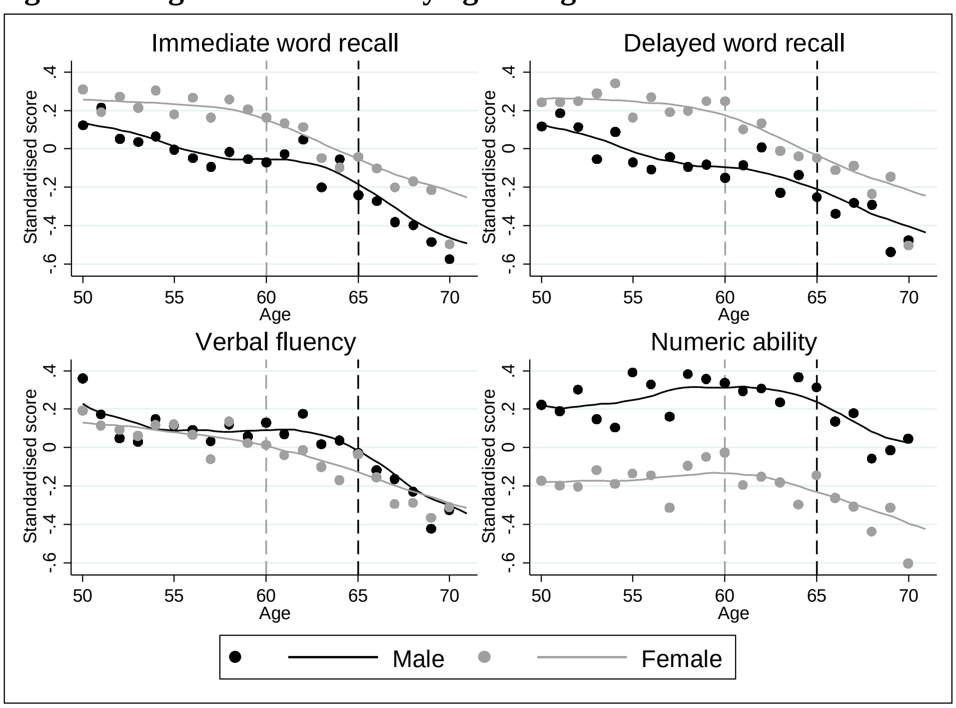
Figures

Figure 1: State pension age by date of birth



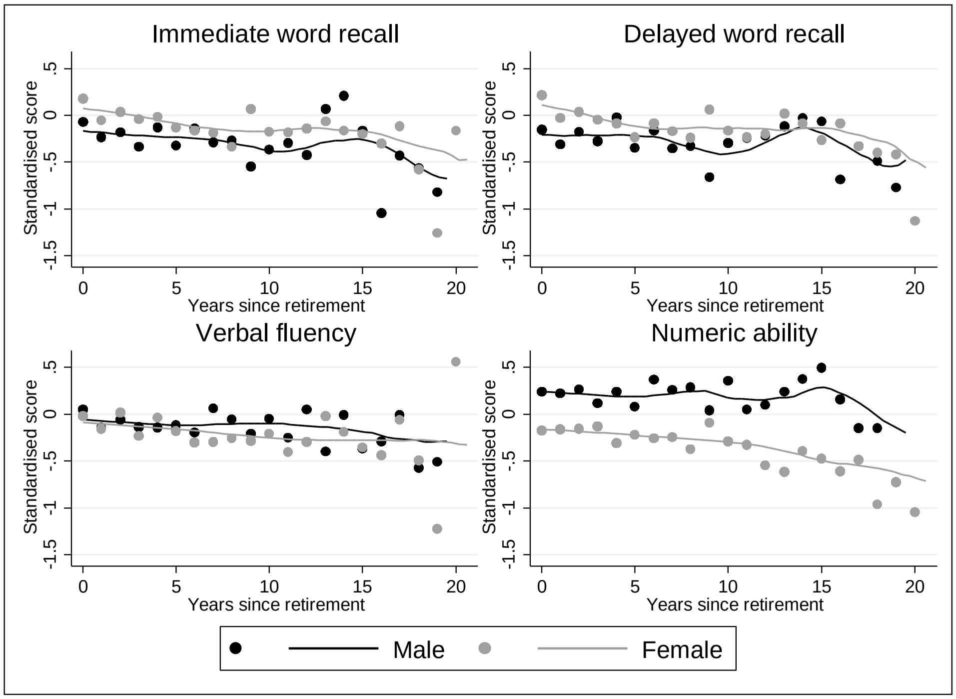
Note: Vertical lines identify the range of our estimation sample

Figure 2: Cognitive measures by age and gender



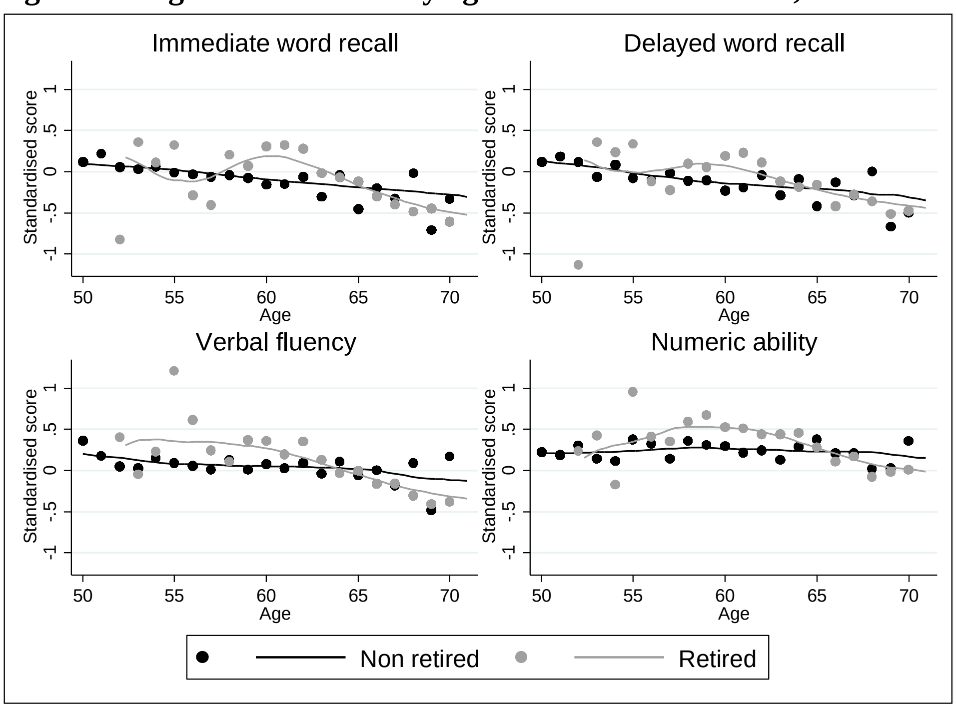
Note: the scatterplot identifies the age and gender specific averages computed by pooling observations in 1 year bands. The line is a local polynomial smoothed line fitted on actual observations. Vertical lines identify typical SPAs for males and females.

Figure 3: Cognitive measures of retired respondents by gender and years since retirement



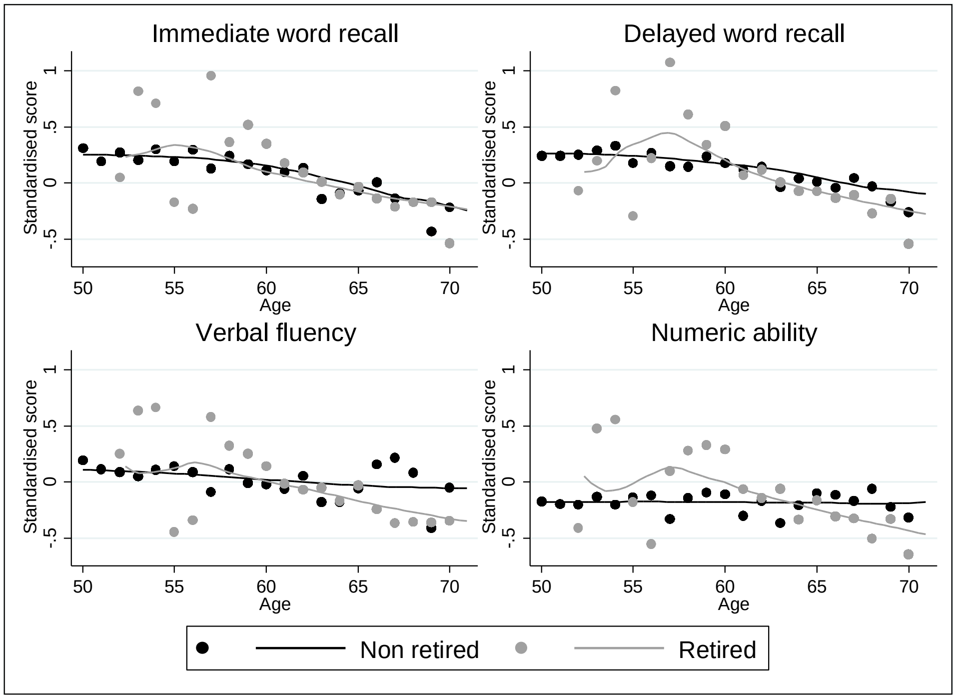
Note: the scatterplot identifies the averages by years in retirement computed by pooling observations in 1 year bands. The line is a local polynomial smoothed line fitted on actual observations.

Figure 4: Cognitive measures by age and retirement status, males



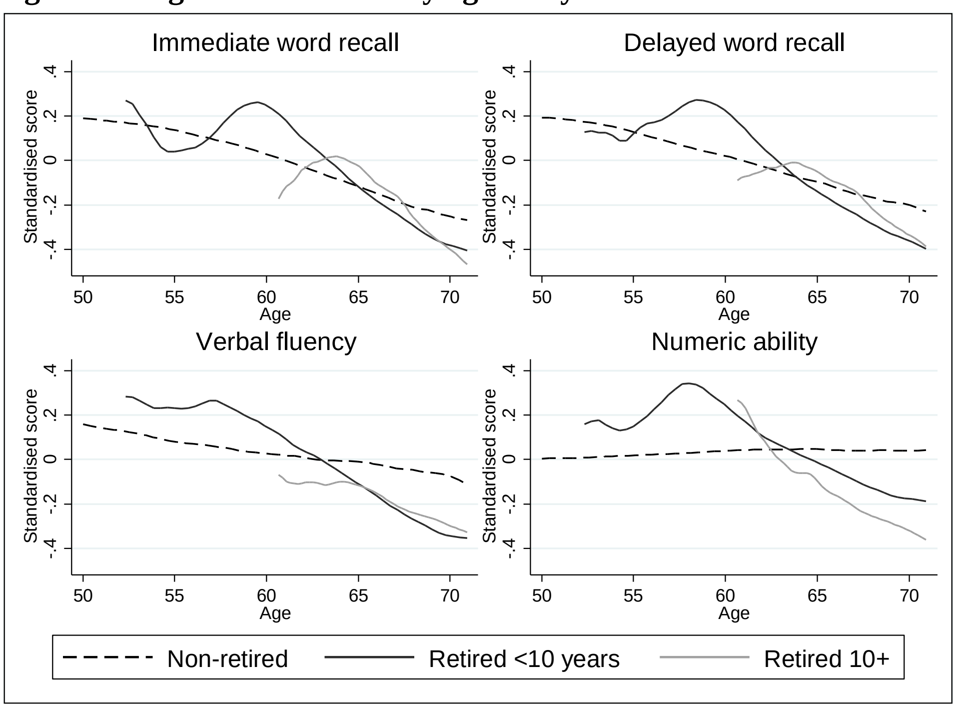
Note: the scatterplot identifies the age-specific averages computed by pooling observations in 1 year bands. The line is a local polynomial smoothed line fitted on actual observations.

Figure 5: Cognitive measures by age and retirement status, females



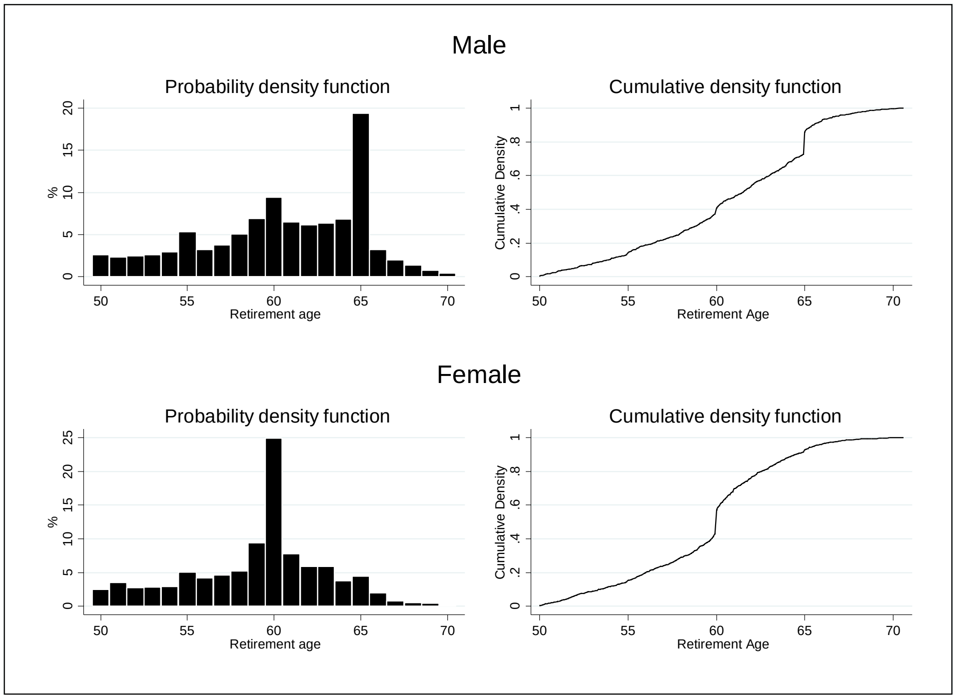
Note: the scatterplot identifies the age specific averages computed by pooling observations in 1 year bands. The line is a local polynomial smoothed line fitted on actual observations.

Figure 6: Cognitive measures by age and years since retirement



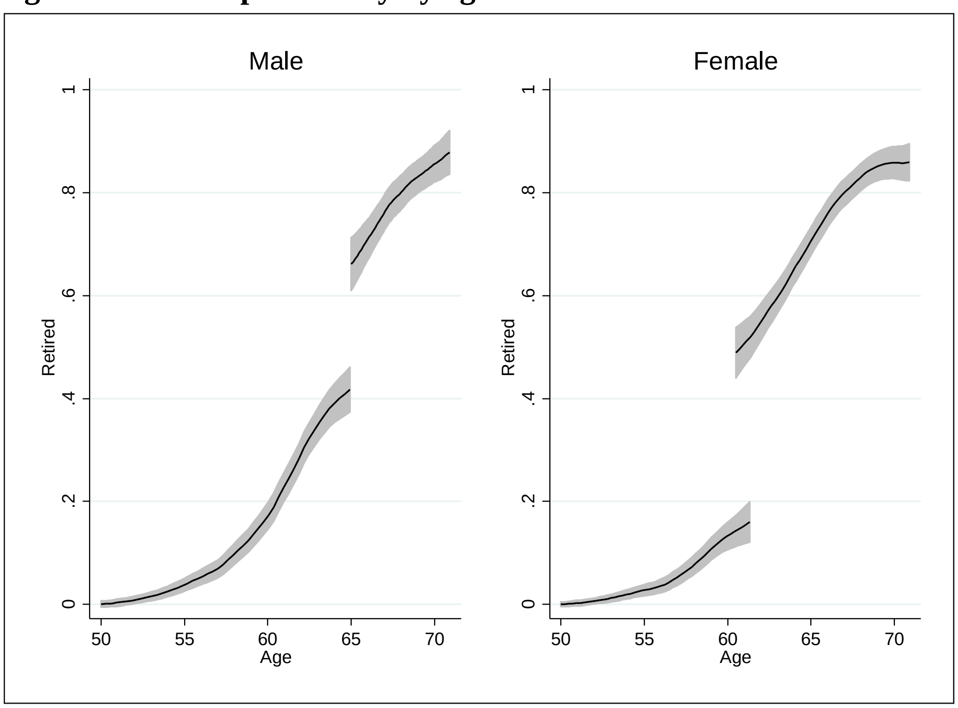
Note: local polynomial smoothed line fitted on actual observations.

Figure 7: Retirement age distribution



Note: Retirement age is only observed for retired respondents.

Figure 8: Retired probability by age



Note: local polynomial smoothed line fitted on actual observations.

Tables

Table 1: Summary Statistics

	All (N=7936)		Male (N=3746)		Female (N=4190)		Retired (N=2553)		Non-retired (N=5383)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PANEL A										
Age	59.85	6.03	60.03	6.08	59.69	5.99	65.71	3.48	57.07	4.89
Male	0.47	0.50	1.00	0.00	0.00	0.00	0.45	0.50	0.48	0.50
Retired	0.32	0.47	0.30	0.46	0.34	0.47	1.00	0.00	0.00	0.00
Years since retirement	1.81	3.60	1.57	3.31	2.03	3.84	5.63	4.34	0.00	0.00
Years since state pension age	1.63	2.76	0.74	1.53	2.43	3.32	4.01	3.19	0.50	1.58
Low qualification	0.27	0.45	0.26	0.44	0.28	0.45	0.36	0.48	0.23	0.42
Routine job	0.11	0.32	0.14	0.35	0.09	0.28	0.12	0.33	0.11	0.31
Lives with partner	0.75	0.43	0.81	0.39	0.71	0.46	0.74	0.44	0.76	0.43
Good general health	0.81	0.39	0.80	0.40	0.82	0.38	0.77	0.42	0.83	0.37
England	0.83	0.38	0.83	0.38	0.83	0.38	0.83	0.38	0.83	0.38
Wales	0.05	0.22	0.05	0.22	0.05	0.22	0.05	0.22	0.05	0.22
Scotland	0.08	0.28	0.09	0.28	0.08	0.28	0.09	0.29	0.08	0.27
Northern Ireland	0.04	0.19	0.04	0.19	0.04	0.19	0.03	0.17	0.04	0.19
PANEL B										
Immediate word recall										
Raw	6.26	1.52	6.10	1.54	6.40	1.50	6.03	1.58	6.37	1.48
Standardised	-0.00	1.00	-0.10	1.01	0.09	0.98	-0.15	1.04	0.07	0.97
Delayed word recall										
Raw	5.13	1.88	4.90	1.85	5.32	1.89	4.84	1.90	5.26	1.86
Standardised	-0.00	1.00	-0.12	0.98	0.11	1.00	-0.15	1.01	0.07	0.99
Numeric ability										
Raw	3.75	1.04	3.99	1.01	3.54	1.03	3.70	1.07	3.78	1.03
Standardised	-0.00	1.00	0.23	0.97	-0.20	0.99	-0.05	1.02	0.02	0.99
Verbal fluency										
Raw	22.33	6.55	22.50	6.63	22.18	6.47	21.40	6.37	22.77	6.58
Standardised	-0.00	1.00	0.03	1.01	-0.02	0.99	-0.14	0.97	0.07	1.01

Table 2: Descriptive statistics by gender, retirement status and whether the respondent is above or below State Pension Age (SPA)

	Male				Female			
	Below SPA		Above SPA		Below SPA		Above SPA	
	Non-retired (N=2390)	Retired (N=375)	Non-retired (N=215)	Retired (N=766)	Non-retired (N=2249)	Retired (N=107)	Non-retired (N=529)	Retired (N=1305)
Immediate word recall	-0.01	0.07	-0.34	-0.40	0.22	0.39	-0.02	-0.12
Delayed word recall	-0.04	-0.01	-0.31	-0.37	0.23	0.46	0.05	-0.12
Numeric ability	0.24	0.47	0.23	0.08	-0.17	0.20	-0.20	-0.29
Verbal fluency	0.10	0.19	-0.08	-0.24	0.08	0.22	-0.04	-0.21
Age	56.55	61.76	67.21	68.02	54.95	58.33	64.32	66.10
Low qualification	0.24	0.15	0.33	0.38	0.20	0.07	0.31	0.44
Routine job	0.14	0.07	0.15	0.17	0.08	0.00	0.08	0.11
Lives with partner	0.80	0.81	0.84	0.81	0.71	0.74	0.71	0.69
Good general health	0.82	0.79	0.83	0.75	0.84	0.88	0.87	0.77
England	0.83	0.86	0.83	0.81	0.83	0.80	0.84	0.83
Wales	0.05	0.04	0.06	0.05	0.05	0.07	0.05	0.05
Scotland	0.08	0.09	0.08	0.09	0.08	0.10	0.07	0.09
Northern Ireland	0.04	0.02	0.04	0.04	0.04	0.02	0.03	0.03

Note: Standardised cognitive measures.

Table 3: OLS results

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.022***	-0.022***	0.003	-0.018***	-0.018***	-0.017***	0.006*	-0.012***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Years since retirement	-0.003	0.000	-0.005	-0.003	-0.000	-0.004	-0.005	-0.004
	(0.006)	(0.006)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Low qualification	-0.470***	-0.377***	-0.628***	-0.292***	-0.464***	-0.404***	-0.569***	-0.413***
	(0.038)	(0.037)	(0.037)	(0.039)	(0.034)	(0.034)	(0.032)	(0.034)
Routine job	-0.214***	-0.179***	-0.374***	-0.234***	-0.358***	-0.287***	-0.527***	-0.310***
	(0.046)	(0.044)	(0.047)	(0.046)	(0.058)	(0.057)	(0.054)	(0.050)
Lives with partner	0.077*	0.039	0.193***	0.166***	0.032	0.050	0.101***	0.087***
	(0.041)	(0.039)	(0.039)	(0.041)	(0.032)	(0.033)	(0.032)	(0.033)
Good health	0.261***	0.210***	0.243***	0.214***	0.222***	0.239***	0.220***	0.163***
	(0.041)	(0.039)	(0.041)	(0.041)	(0.040)	(0.040)	(0.040)	(0.037)
Northern Ireland	-0.134	0.046	0.180**	-0.289***	-0.037	0.060	0.163**	-0.370***
	(0.087)	(0.080)	(0.076)	(0.092)	(0.080)	(0.083)	(0.074)	(0.084)
Wales	0.021	-0.124*	-0.078	-0.248***	-0.184***	-0.242***	-0.146**	-0.290***
	(0.062)	(0.070)	(0.070)	(0.063)	(0.066)	(0.064)	(0.068)	(0.056)
Scotland	-0.031	0.010	0.007	-0.004	-0.058	-0.002	0.121**	-0.202***
	(0.054)	(0.052)	(0.052)	(0.059)	(0.054)	(0.054)	(0.053)	(0.052)
_cons	0.012	0.030	0.068	0.035	0.243***	0.196***	-0.300***	0.096**
	(0.057)	(0.054)	(0.056)	(0.056)	(0.049)	(0.050)	(0.050)	(0.049)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: IV First stage

	MALES	FEMALES
	(1)	(2)
	Years since retirement	Years since retirement
Age	0.155***	0.021**
	(0.009)	(0.010)
Years since SPA	0.768***	0.752***
	(0.058)	(0.030)
Low qualification	-0.255**	0.342***
	(0.105)	(0.116)
Routine job	-0.343***	-0.323*
	(0.124)	(0.167)
Lives with partner	0.043	0.040
	(0.110)	(0.096)
Good health	-0.311***	-0.539***
	(0.119)	(0.121)
Northern Ireland	0.215	0.001
	(0.237)	(0.193)
Wales	-0.276*	0.231
	(0.163)	(0.220)
Scotland	0.109	0.254
	(0.161)	(0.165)
_cons	-0.231	0.309**
	(0.144)	(0.123)
N	3746	4190
Fstat	173.959	641.567

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: IV-Second stage

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.003	-0.012*	0.028***	0.004	-0.003	0.000	0.019***	-0.008
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Years since retirement	-0.070***	-0.035*	-0.089***	-0.078***	-0.041***	-0.048***	-0.040***	-0.015
	(0.020)	(0.019)	(0.019)	(0.019)	(0.013)	(0.013)	(0.013)	(0.013)
Low qualification	-0.485***	-0.385***	-0.647***	-0.309***	-0.444***	-0.383***	-0.552***	-0.408***
	(0.039)	(0.037)	(0.038)	(0.040)	(0.035)	(0.035)	(0.033)	(0.034)
Routine job	-0.233***	-0.189***	-0.398***	-0.255***	-0.367***	-0.296***	-0.535***	-0.313***
	(0.047)	(0.045)	(0.048)	(0.047)	(0.058)	(0.058)	(0.054)	(0.050)
Lives with partner	0.080*	0.040	0.196***	0.169***	0.031	0.050	0.100***	0.087***
	(0.042)	(0.039)	(0.040)	(0.041)	(0.032)	(0.033)	(0.032)	(0.033)
Good health	0.240***	0.198***	0.216***	0.190***	0.199***	0.214***	0.200***	0.157***
	(0.043)	(0.040)	(0.043)	(0.042)	(0.040)	(0.040)	(0.040)	(0.037)
Northern Ireland	-0.114	0.057	0.205***	-0.267***	-0.034	0.063	0.166**	-0.369***
	(0.089)	(0.080)	(0.073)	(0.091)	(0.081)	(0.084)	(0.074)	(0.085)
Wales	0.004	-0.133*	-0.099	-0.267***	-0.177***	-0.234***	-0.139**	-0.288***
	(0.062)	(0.070)	(0.070)	(0.063)	(0.067)	(0.065)	(0.069)	(0.056)
Scotland	-0.024	0.014	0.015	0.004	-0.048	0.009	0.129**	-0.199***
	(0.054)	(0.053)	(0.053)	(0.061)	(0.054)	(0.054)	(0.053)	(0.052)
_cons	-0.056	-0.006	-0.019	-0.043	0.186***	0.134**	-0.349***	0.080
	(0.061)	(0.057)	(0.059)	(0.061)	(0.052)	(0.053)	(0.053)	(0.052)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Reduced form estimates

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.014***	-0.017***	0.014***	-0.008**	-0.004	-0.001	0.018***	-0.008
	(0.004)	(0.004)	(0.003)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Years since SPA	-0.053***	-0.027*	-0.068***	-0.060***	-0.031***	-0.036***	-0.030***	-0.012
	(0.015)	(0.014)	(0.014)	(0.014)	(0.010)	(0.010)	(0.010)	(0.010)
Low qualification	-0.467***	-0.376***	-0.625***	-0.289***	-0.458***	-0.399***	-0.566***	-0.413***
	(0.038)	(0.037)	(0.037)	(0.039)	(0.034)	(0.034)	(0.032)	(0.034)
Routine job	-0.209***	-0.177***	-0.368***	-0.229***	-0.354***	-0.281***	-0.522***	-0.308***
	(0.046)	(0.044)	(0.047)	(0.046)	(0.058)	(0.057)	(0.054)	(0.050)
Lives with partner	0.077*	0.039	0.192***	0.166***	0.030	0.048	0.098***	0.087***
	(0.041)	(0.039)	(0.039)	(0.041)	(0.032)	(0.033)	(0.032)	(0.033)
Good health	0.262***	0.209***	0.244***	0.214***	0.221***	0.240***	0.221***	0.165***
	(0.041)	(0.039)	(0.041)	(0.041)	(0.040)	(0.040)	(0.040)	(0.037)
Northern Ireland	-0.129	0.049	0.186**	-0.283***	-0.034	0.063	0.166**	-0.369***
	(0.087)	(0.080)	(0.075)	(0.091)	(0.080)	(0.083)	(0.074)	(0.085)
Wales	0.024	-0.123*	-0.074	-0.246***	-0.186***	-0.245***	-0.148**	-0.292***
	(0.062)	(0.070)	(0.069)	(0.062)	(0.066)	(0.065)	(0.068)	(0.056)
Scotland	-0.031	0.010	0.006	-0.005	-0.059	-0.004	0.119**	-0.203***
	(0.053)	(0.053)	(0.052)	(0.060)	(0.054)	(0.054)	(0.052)	(0.052)
_cons	-0.040	0.002	0.002	-0.024	0.174***	0.119**	-0.361***	0.076
	(0.058)	(0.056)	(0.056)	(0.058)	(0.053)	(0.054)	(0.055)	(0.054)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Interaction with low level of qualifications, 1st Stage

	MALES		FEMALES	
	(1)	(2)	(3)	(4)
	Years since retirement	Low qualification * Years since retirement	Years since retirement	Low qualification * Years since retirement
Age	0.164***	-0.000	0.029***	-0.000
	(0.011)	(0.000)	(0.011)	(0.001)
Years since SPA	0.731***	0.001	0.697***	0.000
	(0.071)	(0.002)	(0.037)	(0.002)
Low qualification	0.033	-0.587***	-0.002	-0.075
	(0.116)	(0.103)	(0.085)	(0.074)
Low qualification *				
Age	-0.037*	0.129***	-0.004	0.026
	(0.022)	(0.019)	(0.023)	(0.020)
Years since SPA	0.132	0.860***	0.126*	0.823***
	(0.127)	(0.105)	(0.065)	(0.054)
Routine job	-0.344***	-0.027	-0.320*	-0.181
	(0.124)	(0.096)	(0.167)	(0.153)
Lives with partner	0.046	-0.020	0.041	-0.049
	(0.110)	(0.064)	(0.096)	(0.062)
Good health	-0.316***	-0.227***	-0.535***	-0.260***
	(0.119)	(0.075)	(0.121)	(0.086)
Northern Ireland	0.198	0.205	-0.013	0.209*
	(0.236)	(0.165)	(0.191)	(0.127)
Wales	-0.273*	-0.060	0.214	0.120
	(0.163)	(0.101)	(0.220)	(0.155)
Scotland	0.103	0.070	0.253	0.289***
	(0.162)	(0.085)	(0.163)	(0.106)
_cons	-0.290**	0.199**	0.346***	0.229***
	(0.144)	(0.084)	(0.121)	(0.081)
N	3746	3746	4190	4190
Fstat	87.046	33.437	295.966	117.533

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Interaction with low level of qualifications, 2nd stage

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.000	-0.014**	0.028***	0.004	-0.001	0.002	0.019***	-0.004
	(0.008)	(0.007)	(0.007)	(0.008)	(0.006)	(0.007)	(0.007)	(0.007)
Years since retirement	-0.079***	-0.031	-0.092***	-0.094***	-0.043***	-0.053***	-0.041**	-0.021
	(0.025)	(0.023)	(0.023)	(0.024)	(0.016)	(0.017)	(0.016)	(0.017)
Low qualification	-0.457***	-0.477***	-0.678***	-0.449***	-0.406***	-0.343***	-0.560***	-0.295***
	(0.100)	(0.101)	(0.104)	(0.105)	(0.087)	(0.093)	(0.088)	(0.095)
Low qualification *								
Age	-0.007	0.011	0.002	0.009	-0.006	-0.008	0.000	-0.017
	(0.014)	(0.013)	(0.014)	(0.014)	(0.013)	(0.014)	(0.013)	(0.013)
Years since retirement	0.027	-0.018	0.004	0.026	0.011	0.018	0.003	0.027
	(0.042)	(0.039)	(0.042)	(0.040)	(0.028)	(0.028)	(0.028)	(0.027)
Routine job	-0.236***	-0.187***	-0.399***	-0.258***	-0.366***	-0.295***	-0.535***	-0.310***
	(0.047)	(0.045)	(0.049)	(0.048)	(0.058)	(0.058)	(0.054)	(0.050)
Lives with partner	0.081*	0.039	0.196***	0.169***	0.032	0.051	0.100***	0.090***
	(0.042)	(0.039)	(0.040)	(0.042)	(0.032)	(0.033)	(0.032)	(0.033)
Good health	0.243***	0.197***	0.217***	0.195***	0.200***	0.216***	0.200***	0.160***
	(0.043)	(0.040)	(0.043)	(0.043)	(0.040)	(0.040)	(0.040)	(0.038)
Northern Ireland	-0.120	0.061	0.204***	-0.272***	-0.036	0.059	0.165**	-0.375***
	(0.089)	(0.081)	(0.073)	(0.092)	(0.081)	(0.084)	(0.075)	(0.085)
Wales	0.004	-0.134*	-0.100	-0.270***	-0.178***	-0.236***	-0.139**	-0.292***
	(0.062)	(0.070)	(0.070)	(0.063)	(0.067)	(0.065)	(0.069)	(0.056)
Scotland	-0.026	0.015	0.015	0.001	-0.051	0.005	0.129**	-0.205***
	(0.055)	(0.053)	(0.053)	(0.061)	(0.055)	(0.054)	(0.053)	(0.052)
_cons	-0.068	0.014	-0.015	-0.025	0.178***	0.124**	-0.348***	0.056
	(0.065)	(0.063)	(0.063)	(0.066)	(0.055)	(0.057)	(0.057)	(0.056)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Interaction with routine job, 1st Stage

	MALES		FEMALES	
	(1)	(2)	(3)	(4)
	Years since retirement	Routine x Years since retirement	Years since retirement	Routine x Years since retirement
Age	0.157***	-0.001	0.023**	-0.000
	(0.010)	(0.000)	(0.010)	(0.000)
Years since SPA	0.813***	-0.001	0.750***	-0.001
	(0.064)	(0.001)	(0.032)	(0.001)
Low qualification	-0.254**	0.061	0.344***	0.039
	(0.105)	(0.041)	(0.116)	(0.027)
Routine job	0.010	-0.600***	-0.178*	-0.056
	(0.145)	(0.131)	(0.107)	(0.084)
Routine job *				
Age	-0.012	0.141***	-0.023	0.005
	(0.029)	(0.027)	(0.030)	(0.028)
Years since SPA	-0.257*	0.561***	0.034	0.788***
	(0.154)	(0.140)	(0.087)	(0.081)
Lives with partner	0.047	-0.101**	0.039	-0.010
	(0.110)	(0.049)	(0.096)	(0.030)
Good health	-0.307**	-0.054	-0.537***	-0.146***
	(0.119)	(0.048)	(0.121)	(0.046)
Northern Ireland	0.187	-0.009	0.001	0.144*
	(0.236)	(0.014)	(0.193)	(0.082)
Wales	-0.285*	-0.090*	0.231	-0.064
	(0.160)	(0.050)	(0.220)	(0.071)
Scotland	0.090	0.080	0.254	0.048
	(0.161)	(0.067)	(0.165)	(0.059)
_cons	-0.282*	0.119**	0.297**	0.119***
	(0.146)	(0.054)	(0.124)	(0.043)
N	3746	3746	4190	4190
Fstat	88.101	8.146	324.505	47.137

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Interaction with routine job, 2^{nd} Stage

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.005	-0.015^{**}	0.025^{***}	0.006	-0.000	0.003	0.022^{***}	-0.007
	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)
Years since retirement	-0.069^{***}	-0.031^{*}	-0.081^{***}	-0.089^{***}	-0.048^{***}	-0.056^{***}	-0.048^{***}	-0.022^{*}
	(0.020)	(0.019)	(0.019)	(0.020)	(0.013)	(0.014)	(0.013)	(0.013)
Low qualification	-0.485^{***}	-0.383^{***}	-0.641^{***}	-0.317^{***}	-0.443^{***}	-0.381^{***}	-0.551^{***}	-0.406^{***}
	(0.039)	(0.038)	(0.039)	(0.041)	(0.035)	(0.035)	(0.033)	(0.034)
Routine job	-0.378^{***}	-0.387^{***}	-0.488^{***}	-0.266^{**}	-0.269^{**}	-0.198	-0.437^{***}	-0.375^{***}
	(0.121)	(0.121)	(0.134)	(0.126)	(0.134)	(0.147)	(0.136)	(0.135)
Routine job *								
Age	0.017	0.025	0.019	-0.010	-0.028	-0.029	-0.029	-0.009
	(0.020)	(0.019)	(0.022)	(0.019)	(0.021)	(0.021)	(0.022)	(0.020)
Years since retirement	-0.020	-0.046	-0.076	0.084	0.082^{*}	0.085^{*}	0.084^{*}	0.062
	(0.072)	(0.070)	(0.083)	(0.068)	(0.048)	(0.046)	(0.048)	(0.042)
Lives with partner	0.077^{*}	0.034	0.188^{***}	0.177^{***}	0.032	0.051	0.101^{***}	0.089^{***}
	(0.043)	(0.041)	(0.042)	(0.042)	(0.032)	(0.033)	(0.032)	(0.033)
Good health	0.238^{***}	0.195^{***}	0.214^{***}	0.190^{***}	0.209^{***}	0.224^{***}	0.210^{***}	0.163^{***}
	(0.043)	(0.040)	(0.043)	(0.043)	(0.041)	(0.041)	(0.040)	(0.038)
Northern Ireland	-0.108	0.063	0.203^{***}	-0.259^{***}	-0.048	0.048	0.151^{**}	-0.382^{***}
	(0.089)	(0.080)	(0.073)	(0.091)	(0.082)	(0.085)	(0.076)	(0.085)
Wales	0.006	-0.133^{*}	-0.103	-0.261^{***}	-0.170^{**}	-0.227^{***}	-0.132^{*}	-0.283^{***}
	(0.062)	(0.070)	(0.070)	(0.063)	(0.067)	(0.066)	(0.070)	(0.056)
Scotland	-0.019	0.021	0.020	0.001	-0.050	0.007	0.127^{**}	-0.199^{***}
	(0.054)	(0.054)	(0.054)	(0.061)	(0.054)	(0.054)	(0.053)	(0.052)
_cons	-0.035	0.024	-0.001	-0.047	0.169^{***}	0.117^{**}	-0.366^{***}	0.077
	(0.064)	(0.061)	(0.062)	(0.065)	(0.053)	(0.054)	(0.055)	(0.054)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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Appendix

Table A1: Akaike's information criterion after reduced form, anticipation of SPA, placebo

	MALES				FEMALES			
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Years since SPA	10285.084	10201.892	9768.525	10462.664	11262.491	11531.770	11176.614	11398.528
Years since SPA-2	10286.599	10202.684	9769.247	10463.321	11263.305	11533.202	11179.668	11398.850
Years since SPA-4	10290.163	10204.053	9770.209	10467.633	11265.363	11535.901	11183.302	11399.202
Years since SPA-6	10294.292	10205.094	9771.049	10471.927	11267.581	11537.914	11186.161	11399.761
Years since SPA-8	10296.845	10205.420	9777.469	10476.310	11270.040	11540.714	11187.025	11399.970
Years since SPA-10	10298.541	10205.015	9783.792	10478.965	11272.020	11543.251	11186.639	11399.952

Table A2: Akaike's information criterion after reduced form, posticipation of SPA, placebo

	MALES				FEMALES			
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Years since SPA	10285.084	10201.892	9768.525	10462.664	11262.491	11531.770	11176.614	11398.528
Years since SPA+1	10285.434	10202.033	9768.041	10462.459	11262.837	11532.272	11177.998	11398.689
Years since SPA+2	10286.599	10202.684	9769.247	10463.321	11263.305	11533.202	11179.668	11398.850
Years since SPA+3	10287.956	10203.076	9769.887	10465.479	11264.180	11534.439	11181.483	11398.997
Years since SPA+4	10290.163	10204.053	9770.209	10467.633	11265.363	11535.901	11183.302	11399.202
Years since SPA+5	10292.296	10204.624	9769.525	10469.771	11266.624	11537.100	11185.054	11399.525

Table A3: IV estimates excluding people who retired before reaching state pension age

	MALE				FEMALE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.019***	-0.022***	0.010**	-0.010**	-0.011**	-0.008	0.011**	-0.011**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
Years since retirement	-0.030	0.006	-0.088***	-0.070**	-0.039**	-0.053***	-0.034*	-0.011
	(0.035)	(0.033)	(0.033)	(0.033)	(0.020)	(0.020)	(0.019)	(0.019)
Low qualification	-0.485***	-0.387***	-0.624***	-0.298***	-0.461***	-0.389***	-0.530***	-0.401***
	(0.042)	(0.042)	(0.041)	(0.044)	(0.038)	(0.038)	(0.036)	(0.037)
Routine job	-0.223***	-0.183***	-0.378***	-0.228***	-0.366***	-0.285***	-0.531***	-0.319***
	(0.049)	(0.048)	(0.051)	(0.051)	(0.063)	(0.062)	(0.059)	(0.055)
Lives with partner	0.083*	0.020	0.168***	0.186***	0.017	0.032	0.096***	0.110***
	(0.046)	(0.044)	(0.043)	(0.045)	(0.035)	(0.036)	(0.035)	(0.036)
Good health	0.202***	0.182***	0.193***	0.206***	0.209***	0.222***	0.224***	0.155***
	(0.048)	(0.045)	(0.047)	(0.046)	(0.044)	(0.043)	(0.045)	(0.041)
Northern Ireland	-0.136	0.077	0.304***	-0.232**	-0.063	0.041	0.151*	-0.390***
	(0.098)	(0.092)	(0.074)	(0.103)	(0.084)	(0.086)	(0.077)	(0.088)
Wales	0.014	-0.141*	-0.037	-0.261***	-0.184**	-0.231***	-0.165**	-0.309***
	(0.069)	(0.080)	(0.075)	(0.069)	(0.076)	(0.072)	(0.079)	(0.063)
Scotland	-0.028	-0.018	0.044	0.005	-0.039	0.014	0.108*	-0.219***
	(0.061)	(0.060)	(0.060)	(0.067)	(0.061)	(0.059)	(0.060)	(0.058)
_cons	0.012	0.040	0.087	-0.048	0.200***	0.148***	-0.327***	0.064
	(0.065)	(0.062)	(0.062)	(0.063)	(0.054)	(0.055)	(0.056)	(0.054)
N	2916	2916	2916	2916	3554	3554	3554	3554

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: IV estimates including intercept and slope effect of retirement on cognitive abilities

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.006	-0.017*	0.022**	-0.002	-0.004	-0.000	0.014*	-0.011
	(0.010)	(0.009)	(0.009)	(0.010)	(0.008)	(0.008)	(0.008)	(0.008)
Retired	0.117	0.183	0.211	0.226	0.045	0.017	0.160	0.118
	(0.349)	(0.326)	(0.325)	(0.321)	(0.175)	(0.181)	(0.175)	(0.170)
Years since retirement	-0.079**	-0.049	-0.105***	-0.095***	-0.043***	-0.049***	-0.050***	-0.022
	(0.037)	(0.034)	(0.035)	(0.034)	(0.016)	(0.016)	(0.016)	(0.015)
Low qualification	-0.483***	-0.382***	-0.644***	-0.305***	-0.445***	-0.383***	-0.553***	-0.408***
	(0.039)	(0.037)	(0.039)	(0.040)	(0.035)	(0.035)	(0.033)	(0.034)
Routine job	-0.233***	-0.188***	-0.398***	-0.255***	-0.366***	-0.296***	-0.533***	-0.312***
	(0.047)	(0.045)	(0.048)	(0.047)	(0.058)	(0.058)	(0.054)	(0.050)
Lives with partner	0.081*	0.042	0.198***	0.171***	0.031	0.049	0.100***	0.087***
	(0.042)	(0.039)	(0.040)	(0.042)	(0.032)	(0.033)	(0.032)	(0.033)
Good health	0.240***	0.199***	0.217***	0.190***	0.200***	0.214***	0.203***	0.159***
	(0.043)	(0.040)	(0.043)	(0.042)	(0.040)	(0.040)	(0.041)	(0.038)
Northern Ireland	-0.111	0.061	0.210***	-0.261***	-0.033	0.063	0.171**	-0.366***
	(0.089)	(0.081)	(0.074)	(0.092)	(0.081)	(0.084)	(0.074)	(0.084)
Wales	0.005	-0.133*	-0.098	-0.267***	-0.175***	-0.233***	-0.135*	-0.285***
	(0.062)	(0.070)	(0.070)	(0.063)	(0.067)	(0.066)	(0.069)	(0.056)
Scotland	-0.025	0.013	0.014	0.002	-0.048	0.009	0.129**	-0.199***
	(0.054)	(0.053)	(0.054)	(0.061)	(0.054)	(0.054)	(0.053)	(0.052)
_cons	-0.048	0.007	-0.004	-0.027	0.189***	0.135**	-0.339***	0.088
	(0.063)	(0.061)	(0.062)	(0.063)	(0.053)	(0.054)	(0.055)	(0.054)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: IV estimates including intercept and slope effect of retirement on cognitive abilities, routine versus non routine occupations

	NON ROUTINE OCCUPATIONS				ROUTINE OCCUPATIONS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.006	-0.011	0.017***	-0.006	-0.015	-0.016	0.014	-0.010
	(0.007)	(0.007)	(0.006)	(0.007)	(0.013)	(0.013)	(0.014)	(0.014)
Retired	-0.121	0.014	0.012	-0.054	0.219	0.379	-0.140	-0.060
	(0.184)	(0.183)	(0.171)	(0.177)	(0.307)	(0.278)	(0.327)	(0.253)
Years since retirement	-0.027	-0.033**	-0.044***	-0.026	-0.031	-0.046	-0.004	0.031
	(0.017)	(0.017)	(0.015)	(0.016)	(0.043)	(0.040)	(0.045)	(0.034)
Male	-0.216***	-0.245***	0.399***	0.024	-0.044	-0.108	0.547***	0.196***
	(0.023)	(0.024)	(0.023)	(0.025)	(0.077)	(0.074)	(0.074)	(0.069)
Low qualification	-0.473***	-0.381***	-0.597***	-0.353***	-0.388***	-0.416***	-0.540***	-0.347***
	(0.028)	(0.027)	(0.026)	(0.028)	(0.070)	(0.069)	(0.070)	(0.067)
Lives with partner	0.057**	0.058**	0.127***	0.129***	-0.002	-0.039	0.207***	0.053
	(0.027)	(0.027)	(0.026)	(0.028)	(0.076)	(0.075)	(0.080)	(0.073)
Good health	0.229***	0.219***	0.237***	0.204***	0.197**	0.164**	0.125	0.047
	(0.031)	(0.031)	(0.032)	(0.031)	(0.080)	(0.076)	(0.079)	(0.070)
Northern Ireland	-0.105*	0.039	0.155***	-0.318***	0.114	0.245	0.320	-0.467**
	(0.062)	(0.062)	(0.055)	(0.066)	(0.211)	(0.156)	(0.199)	(0.197)
Wales	-0.069	-0.153***	-0.094*	-0.268***	-0.215*	-0.387***	-0.217	-0.241**
	(0.049)	(0.051)	(0.052)	(0.046)	(0.128)	(0.137)	(0.152)	(0.109)
Scotland	-0.031	0.015	0.075*	-0.093**	-0.079	-0.013	0.039	-0.185**
	(0.041)	(0.041)	(0.040)	(0.044)	(0.103)	(0.097)	(0.106)	(0.085)
_cons	0.192***	0.190***	-0.362***	0.011	-0.179	-0.020	-0.896***	-0.240**
	(0.043)	(0.042)	(0.042)	(0.043)	(0.116)	(0.120)	(0.118)	(0.112)
N	7034	7034	7034	7034	902	902	902	902

Table A6: IV estimates with people aged 50 to 80

	MALE				FEMALE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.008**	-0.010**	0.016***	-0.006	-0.003	-0.002	0.016***	-0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Years since retirement	-0.047***	-0.043***	-0.048***	-0.038***	-0.037***	-0.041***	-0.033***	-0.021***
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
Low qualification	-0.414***	-0.339***	-0.595***	-0.277***	-0.402***	-0.344***	-0.523***	-0.403***
	(0.032)	(0.030)	(0.032)	(0.033)	(0.030)	(0.031)	(0.029)	(0.029)
Routine job	-0.226***	-0.189***	-0.399***	-0.240***	-0.298***	-0.247***	-0.489***	-0.244***
	(0.039)	(0.038)	(0.042)	(0.039)	(0.049)	(0.048)	(0.045)	(0.041)
Lives with partner	0.068*	0.025	0.206***	0.157***	0.027	0.022	0.084***	0.087***
	(0.035)	(0.033)	(0.035)	(0.035)	(0.028)	(0.029)	(0.028)	(0.028)
Good health	0.252***	0.184***	0.233***	0.216***	0.211***	0.208***	0.189***	0.154***
	(0.034)	(0.033)	(0.036)	(0.034)	(0.034)	(0.034)	(0.034)	(0.032)
Northern Ireland	-0.052	0.102	0.185***	-0.289***	-0.077	0.012	0.102	-0.336***
	(0.070)	(0.067)	(0.067)	(0.075)	(0.070)	(0.073)	(0.069)	(0.073)
Wales	-0.026	-0.110*	-0.064	-0.249***	-0.127**	-0.209***	-0.148**	-0.261***
	(0.054)	(0.060)	(0.059)	(0.054)	(0.057)	(0.055)	(0.059)	(0.049)
Scotland	-0.027	0.017	0.058	-0.017	-0.064	0.004	0.103**	-0.185***
	(0.047)	(0.047)	(0.049)	(0.053)	(0.049)	(0.048)	(0.046)	(0.045)
_cons	0.093*	0.139***	0.063	0.092*	0.301***	0.287***	-0.244***	0.182***
	(0.052)	(0.049)	(0.052)	(0.053)	(0.045)	(0.046)	(0.047)	(0.046)
N	4798	4798	4798	4798	5169	5169	5169	5169

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A7: IV estimates excluding general health from the regressors

	MALES				FEMALES			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Immediate recall	Delayed recall	Numeric ability	Fluency	Immediate recall	Delayed recall	Numeric ability	Fluency
Age	-0.003	-0.012^{**}	0.027^{***}	0.004	-0.003	0.000	0.019^{***}	-0.008
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Years since retirement	-0.070^{***}	-0.036^{*}	-0.090^{***}	-0.079^{***}	-0.041^{***}	-0.049^{***}	-0.041^{***}	-0.016
	(0.020)	(0.019)	(0.019)	(0.019)	(0.013)	(0.013)	(0.013)	(0.013)
Low qualification	-0.507^{***}	-0.403^{***}	-0.667^{***}	-0.326^{***}	-0.461^{***}	-0.400^{***}	-0.569^{***}	-0.420^{***}
	(0.039)	(0.037)	(0.038)	(0.040)	(0.035)	(0.036)	(0.033)	(0.034)
Routine job	-0.243^{***}	-0.197^{***}	-0.407^{***}	-0.263^{***}	-0.388^{***}	-0.319^{***}	-0.555^{***}	-0.329^{***}
	(0.047)	(0.045)	(0.048)	(0.047)	(0.058)	(0.058)	(0.054)	(0.050)
Lives with partner	0.092^{**}	0.050	0.207^{***}	0.178^{***}	0.047	0.066^{**}	0.116^{***}	0.100^{***}
	(0.042)	(0.040)	(0.040)	(0.042)	(0.032)	(0.033)	(0.032)	(0.033)
Northern Ireland	-0.107	0.063	0.212^{***}	-0.261^{***}	-0.028	0.069	0.172^{**}	-0.365^{***}
	(0.089)	(0.080)	(0.072)	(0.092)	(0.080)	(0.083)	(0.075)	(0.084)
Wales	-0.008	-0.143^{**}	-0.110	-0.277^{***}	-0.182^{***}	-0.240^{***}	-0.145^{**}	-0.293^{***}
	(0.062)	(0.070)	(0.070)	(0.063)	(0.067)	(0.065)	(0.069)	(0.056)
Scotland	-0.025	0.013	0.015	0.003	-0.039	0.019	0.139^{***}	-0.191^{***}
	(0.054)	(0.054)	(0.053)	(0.061)	(0.055)	(0.054)	(0.053)	(0.052)
_cons	0.140^{***}	0.156^{***}	0.158^{***}	0.113^{**}	0.345^{***}	0.305^{***}	-0.189^{***}	0.206^{***}
	(0.052)	(0.050)	(0.050)	(0.053)	(0.043)	(0.045)	(0.045)	(0.047)
N	3746	3746	3746	3746	4190	4190	4190	4190

Robust standard errors in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A8: Different age specifications, IV-Estimates, male

	Immediate recall			Delayed recall			Numeric ability			Fluency		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Age	-0.003	-0.056*		-0.012*	-0.057**		0.028***	0.013		0.004	-0.056*	
	(0.006)	(0.029)		(0.006)	(0.027)		(0.006)	(0.025)		(0.006)	(0.030)	
Years since ret.	-0.070***	-0.238**	-0.123**	-0.035*	-0.178*	-0.091*	-0.089***	-0.137	-0.044	-0.078***	-0.271**	-0.091*
	(0.020)	(0.118)	(0.055)	(0.019)	(0.105)	(0.049)	(0.019)	(0.096)	(0.044)	(0.019)	(0.121)	(0.049)
Age*Age/10		0.050*			0.042			0.014			0.057*	
		(0.030)			(0.028)			(0.025)			(0.031)	
53-55			-0.069			-0.130**			0.002			-0.088
			(0.053)			(0.056)			(0.053)			(0.059)
56-58			-0.106*			-0.161***			0.126**			-0.061
			(0.057)			(0.058)			(0.053)			(0.063)
59-61			-0.045			-0.140**			0.193***			-0.015
			(0.068)			(0.065)			(0.060)			(0.071)
62-64			0.046			-0.073			0.203**			0.049
			(0.112)			(0.103)			(0.092)			(0.104)
65-67			0.093			-0.033			0.257			0.076
			(0.195)			(0.179)			(0.159)			(0.173)
68-70			0.233			0.070			0.190			0.097
			(0.323)			(0.292)			(0.258)			(0.292)
low qualification	-0.485***	-0.529***	-0.500***	-0.385***	-0.422***	-0.400***	-0.647***	-0.660***	-0.636***	-0.309***	-0.359***	-0.313***
	(0.039)	(0.055)	(0.043)	(0.037)	(0.049)	(0.040)	(0.038)	(0.046)	(0.040)	(0.040)	(0.057)	(0.043)
routine job	-0.233***	-0.289***	-0.250***	-0.189***	-0.236***	-0.207***	-0.398***	-0.414***	-0.384***	-0.255***	-0.320***	-0.259***
	(0.047)	(0.065)	(0.051)	(0.045)	(0.060)	(0.048)	(0.048)	(0.057)	(0.049)	(0.047)	(0.067)	(0.050)
lives with partner	0.080*	0.089*	0.083*	0.040	0.048	0.044	0.196***	0.199***	0.195***	0.169***	0.179***	0.170***
	(0.042)	(0.048)	(0.043)	(0.039)	(0.044)	(0.041)	(0.040)	(0.041)	(0.039)	(0.041)	(0.050)	(0.042)
Good health	0.240***	0.184***	0.221***	0.198***	0.151***	0.178***	0.216***	0.200***	0.230***	0.190***	0.126**	0.184***
	(0.043)	(0.062)	(0.046)	(0.040)	(0.056)	(0.043)	(0.043)	(0.055)	(0.043)	(0.042)	(0.064)	(0.045)
Northern Ireland	-0.114	-0.070	-0.098	0.057	0.094	0.072	0.205***	0.218***	0.195***	-0.267***	-0.216**	-0.261***
	(0.089)	(0.107)	(0.092)	(0.080)	(0.093)	(0.083)	(0.073)	(0.078)	(0.074)	(0.091)	(0.110)	(0.093)
Wales	0.004	-0.046	-0.013	-0.133*	-0.176**	-0.153**	-0.099	-0.113	-0.090	-0.267***	-0.324***	-0.275***
	(0.062)	(0.078)	(0.065)	(0.070)	(0.081)	(0.072)	(0.070)	(0.077)	(0.070)	(0.063)	(0.083)	(0.064)
Scotland	-0.024	-0.008	-0.018	0.014	0.027	0.020	0.015	0.020	0.011	0.004	0.022	0.005
	(0.054)	(0.067)	(0.057)	(0.053)	(0.063)	(0.056)	(0.053)	(0.056)	(0.052)	(0.061)	(0.074)	(0.061)
_cons	-0.056	0.107	0.002	-0.006	0.132	0.053	-0.019	0.027	0.041	-0.043	0.144	0.020
	(0.061)	(0.109)	(0.066)	(0.057)	(0.100)	(0.063)	(0.059)	(0.097)	(0.062)	(0.061)	(0.113)	(0.065)
N	3746	3746	3746	3746	3746	3746	3746	3746	3746	3746	3746	3746
AIC	10285.084	10286.385	10292.769	10201.892	10202.514	10208.416	9768.525	9769.237	9775.878	10462.664	10463.746	10471.657
BIC	10347.368	10354.898	10386.196	10264.176	10271.027	10301.842	9830.810	9837.750	9869.305	10524.949	10532.258	10565.084

Robust standard errors in parentheses; AIC and BIC from reduced form estimates; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A9: Different age specifications, IV- Estimates, female

	Immediate recall			Delayed recall			Numeric ability			Fluency		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Age	-0.003	0.003		0.000	0.005		0.019***	0.019		-0.008	-0.002	
	(0.006)	(0.023)		(0.006)	(0.024)		(0.006)	(0.023)		(0.006)	(0.024)	
Years since ret.	-0.041***	-0.026	-0.105***	-0.048***	-0.035	-0.087**	-0.040***	-0.040	-0.078**	-0.015	-0.001	-0.056
	(0.013)	(0.066)	(0.038)	(0.013)	(0.068)	(0.037)	(0.013)	(0.067)	(0.035)	(0.013)	(0.067)	(0.035)
Age*Age/10		-0.006			-0.005			-0.000			-0.006	
		(0.024)			(0.025)			(0.024)			(0.025)	
53-55			-0.017			0.028			0.041			-0.024
			(0.048)			(0.051)			(0.050)			(0.053)
56-58			0.010			0.007			0.049			-0.052
			(0.052)			(0.055)			(0.051)			(0.053)
59-61			0.013			0.044			0.200***			-0.065
			(0.059)			(0.059)			(0.059)			(0.059)
62-64			0.114			0.106			0.317***			0.014
			(0.115)			(0.111)			(0.106)			(0.105)
65-67			0.295			0.232			0.524***			0.124
			(0.195)			(0.187)			(0.181)			(0.180)
68-70			0.455			0.305			0.572**			0.141
			(0.299)			(0.291)			(0.278)			(0.268)
low qualification	-0.444***	-0.450***	-0.420***	-0.383***	-0.388***	-0.369***	-0.552***	-0.552***	-0.539***	-0.408***	-0.413***	-0.393***
	(0.035)	(0.042)	(0.039)	(0.035)	(0.042)	(0.039)	(0.033)	(0.041)	(0.036)	(0.034)	(0.041)	(0.037)
routine job	-0.367***	-0.362***	-0.389***	-0.296***	-0.292***	-0.309***	-0.535***	-0.535***	-0.548***	-0.313***	-0.308***	-0.326***
	(0.058)	(0.062)	(0.062)	(0.058)	(0.062)	(0.060)	(0.054)	(0.058)	(0.056)	(0.050)	(0.054)	(0.052)
Lives with partner	0.031	0.031	0.032	0.050	0.049	0.050	0.100***	0.100***	0.101***	0.087***	0.087***	0.088***
	(0.032)	(0.032)	(0.033)	(0.033)	(0.033)	(0.034)	(0.032)	(0.032)	(0.033)	(0.033)	(0.033)	(0.033)
Good health	0.199***	0.207***	0.167***	0.214***	0.221***	0.194***	0.200***	0.200***	0.182***	0.157***	0.165***	0.137***
	(0.040)	(0.053)	(0.045)	(0.040)	(0.054)	(0.044)	(0.040)	(0.056)	(0.044)	(0.037)	(0.053)	(0.040)
Northern Ireland	-0.034	-0.035	-0.035	0.063	0.062	0.062	0.166**	0.166**	0.167**	-0.369***	-0.370***	-0.370***
	(0.081)	(0.080)	(0.083)	(0.084)	(0.083)	(0.085)	(0.074)	(0.075)	(0.075)	(0.085)	(0.085)	(0.085)
Wales	-0.177***	-0.180***	-0.162**	-0.234***	-0.237***	-0.226***	-0.139**	-0.139**	-0.131*	-0.288***	-0.292***	-0.279***
	(0.067)	(0.068)	(0.070)	(0.065)	(0.066)	(0.068)	(0.069)	(0.071)	(0.070)	(0.056)	(0.058)	(0.057)
Scotland	-0.048	-0.052	-0.032	0.009	0.005	0.018	0.129**	0.129**	0.140**	-0.199***	-0.203***	-0.188***
	(0.054)	(0.057)	(0.057)	(0.054)	(0.057)	(0.055)	(0.053)	(0.056)	(0.055)	(0.052)	(0.055)	(0.053)
_cons	0.186***	0.172**	0.203***	0.134**	0.122	0.135**	-0.349***	-0.349***	-0.297***	0.080	0.066	0.085
	(0.052)	(0.079)	(0.056)	(0.053)	(0.080)	(0.056)	(0.053)	(0.080)	(0.057)	(0.052)	(0.080)	(0.055)
N	4190	4190	4190	4190	4190	4190	4190	4190	4190	4190	4190	4190
AIC	11262.491	11264.129	11268.902	11531.770	11533.387	11539.676	11176.614	11178.481	11175.095	11398.528	11400.394	11405.805
BIC	11325.896	11333.874	11364.008	11595.174	11603.132	11634.783	11240.018	11248.226	11270.202	11461.933	11470.139	11500.912

Robust standard errors in parentheses; AIC and BIC from reduced form estimates; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$