Published in final edited form as:

Soc Sci Med. 2017 April ; 178: 78–86. doi:10.1016/j.socscimed.2017.01.019.

Mental retirement and health selection: Analyses from the U.S. Health and Retirement Study

Sean Clouston^{*,1} and Nicole Denier^{2,3}

¹Program in Public Health & Department of Preventive Medicine, Stony Brook University, Stony Brook, NY, USA

²Department of Sociology, McGill University, Montréal, QC, Canada

³Department of Sociology, Colby College, Waterville, ME, USA

Abstract

Background—Research has recently suggested that retirement may decrease cognitive engagement, resulting in cognitive aging. Few studies have systematically documented whether or how selectivity into retirement shapes the relationship between retirement and cognitive aging.

Methods—We draw on data from the Health and Retirement Study (1998-2012) to examine the relationship between cognition and retirement for 18,575 labor force participants. Longitudinal regression discontinuity modeling was used to examine performance and decline in episodic memory. Models differentiated three forms of selection bias: indirect and direct selection as well as reverse causation. To further interrogate the disuse hypothesis, we adjust for confounding from health and socioeconomic sources.

Results—Results revealed that individuals who retired over the course of the panel were substantially different in terms of health, wealth and cognition when compared to those who remained employed. However, accounting for observed selection biases, significant associations were found linking longer retirement with more rapid cognitive decline.

Discussion—This study examined respondents who were in the labor force at baseline and transitioned into retirement. Analyses suggested that those who retired over the course of the panel had worse overall functioning, but also experienced more rapid declines after retirement that increased the rate of aging by two-fold, resulting in yearly losses of 3.7% (95% CI=[3.5, 4.0]) of one standard deviation in functioning attributable to retirement. Results are supportive of the view that retirement was associated with more rapid cognitive aging.

*Correspondence to: Prof. Sean Clouston, PhD, Program in Public Health, Stony Brook University, 101 Nichols Rd., Health Sciences Center #3-071, Stony Brook, NY, 11794-8338. Telephone: (631) 444-6593. sean.clouston@stonybrookmedicine.edu. Facsimile: (631) 444-3480.

The authors declare no conflicts of interest.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

United States; Cognitive aging; Memory; Mental Retirement; Longitudinal modeling; Disuse; Regression discontinuity

Five-million Americans have dementia and 15.5 million others care for those with the disease (Alzheimer's Association, 2015). While dementia is an onerous, life-changing disease, it is the end result of years of progressive neuropathological changes prior to reaching diagnostic criteria (Bruscoli & Lovestone, 2004). Cognitive declines often occur across a number of domains including memory, executive functioning, fluency, and mental status (Richards & Deary, 2014), and can thus have broader ripple effects well before disease onset. Cognitive declines are costly, diminishing functioning across a broad range of abilities, including the ability to self-manage healthcare (Clouston, Manganello, & Richards, 2016; Jack et al., 2010; Murray, Johnson, Wolf, & Deary, 2011). As such, there is a need to identify mechanisms that influence cognitive decline, as these could carry substantial long-term benefits.

Retirement has been put forward as a potential cause of cognitive aging, under the assumption that retirees leave employment that requires regular "use" of cognitive skills, to enter "mental retirement" (Rohwedder & Willis, 2010), during which time they may slowly "lose" cognitive capability (Hultsch, Hertzog, Small, & Dixon, 1999; Rohwedder & Willis, 2010). To date, much evidence has established an association between retirement and lower cognitive functioning in both Europe and the United States, but inconsistencies remain across data sources and measures of cognition. Rohwedder and Willis (2010) used cross-sectional data from the United States (U.S.) and Europe and relied on cross-national variation in pension eligibility ages as an instrument for retirement status to find that not working was associated with large reductions in verbal recall. Bingley and Martinello (2013) showed that this effect was overstated, as it did not account for correlations between pension eligibility and variation in educational attainment across nations. Supporting such a notion, cross-sectional studies accounting for education have consistently shown smaller negative effects (Mazzonna & Peracchi, 2012). Coe, von Gaudecker, Lindeboom, and Maurer (2012) further suggested that this effect may not be evident in all worker groups: using pooled cross-sections of the U.S. Health and Retirement Study (HRS) and instrumenting for retirement status with offers of early retirement the authors found that duration spent in retirement had no impact on cognition for white-collar workers and that retirement may actually *benefit* cognition for blue-collar workers. Bonsang, Adam, and Perelman (2012) utilized Social Security eligibility ages as instruments for retirement to analyze the HRS, and found that not working was associated with reduced verbal memory and that the effect occurs shortly after retirement but does not accumulate with time. On the other hand, Celidoni, Dal Bianco, and Weber (2013) use longitudinal data from the Survey of Health, Ageing, and Retirement in Europe (SHARE), and found that duration spent in retirement, not retirement status alone, was associated with an increased likelihood of large (>20%) declines in verbal memory. However, using the same SHARE data, Bianchini and Borella (2015) found that retirement had a net *positive* effect on verbal memory when allowing for non-linear effects of age on cognition. Using a relatively novel approach, Wickrama and

O'Neal (2013) drew on HRS data to model how a change in work status from 1998-2002 impacted subsequent cognitive aging using growth curve analyses, and found that those who transitioned to retirement displayed greater deterioration in verbal learning than those who continued to work.

Taken together, it seems that retirement is linked to cognitive aging, but that a number of inconsistencies remain. Notably, many studies relying on instrumental variable approaches to establish a causal relationship between retirement and cognition, which may be a source of some of these documented inconsistencies. Instrumentation is used when trying to remove bias due to unobserved heterogeneity and endogeneity (Angrist & Krueger, 2001); however, it is not as reliable as other approaches. First, it can mask the specific form of heterogeneity; in many studies "unobserved heterogeneity" includes a laundry list of types of bias including, for example, confounding and selection bias. While instrumentation may help account for various sources of bias, they do little to aid in identifying or understanding them. Additionally, analyses can be fundamentally flawed if any secondary pathway links instrumental variables to outcomes. In the study of retirement and cognition, researchers almost exclusively rely on differences in pension eligibility or retirement ages as instruments; however, pension and retirement ages often correlate with more generous retirement benefits or social transfers that may influence retirement and unemployment, a status that has long been independently and consistently associated with increased stress, greater depression, and lowered cognition (Clark, Georgellis, & Sanfey, 2001; Hessel, Leist, Riumallo-Herl, & Avendano, 2015). Crucially, data from the Organization of Economic Cooperation and Development (2015) suggests that maximal unemployment insurance benefits are associated with both retirement age ($r=-0.29$) and pension age ($r=-0.35$), a level of association that is similar to that between pension spending and retirement age ($r=-0.28$) and larger than that of unemployment insurance and unemployment rate ($r=-0.15$). As such, retirement age policies may not be appropriate instruments for analyses when unemployment is also a possible confounder.

Methodological Considerations

Longitudinal analyses, on the other hand, allow us to specifically differentiate sources of bias. For example, noting potential sources of such heterogeneity, prior work has highlighted the role of time-invariant factors such as education, age, sex, poverty, and stress, as well as other hallmarks of aging, including physical functioning and prevalent chronic disease burden, as confounders. Clarifying timing of factors may additionally help to specify the relationships between each construct. For example, those who retire may do so in part because of incident health problems, such as stroke, that are known to cause decreased cognition (Spiro & Brady, 2011). Thus, selection bias results from differences in pre-retirement characteristics that may influence both the risk of retirement and lower cognitive functioning. These forms of bias can be formally differentiated into indirect and direct selection (Goldman, 2001), as well as reverse causation, as discussed below.

Indirect selection is the most commonly discussed form of selection bias and occurs when individual characteristics related to the outcome but not a part of the outcome influence the propensity for retirement. For example, indirect selection may occur if worse physical health

both influences timing of retirement (Jokela et al., 2010), and increases the risk of cognitive decline (Gorelick et al., 2011). Conversely, those who retire may have spent their lives investing in human capital and building wealth, resulting in higher socioeconomic status and less risk of distal outcomes.

In contrast, *direct selection* occurs when individuals differ specifically in the *outcome of interest* in a way that influences the main independent variable of interest. For example, those who have the opportunity to retire may have spent substantial portions of their lives building cognitive reserve (Clouston et al., 2012; Glymour, Kawachi, Jencks, & Berkman, 2008), defined as resilience to exposures and aging gained through long-term investments in human capital (Glymour, Tzourio, & Dufouil, 2012; Richards & Sacker, 2003; Scarmeas & Stern, 2003; Stern, 2002, 2009; Valenzuela & Sachdev, 2005). Indeed, many retirees may also be advantaged in that they have secured pensions and accumulated wealth sufficient to provide retirement security (Banks & Oldfield, 2007; Van Rooij, Lusardi, & Alessie, 2012), indicative of a healthy retiree effect. Those at risk of retirement are first and foremost employed, a fact that may be determined in part by cognitive ability (Deary & Johnson, 2010), and furthermore, those who retire may do so because they are unwilling, unable, or uninterested in working for longer periods of time resulting in healthy survivor effects (Denier, Clouston, Richards, Kuh, & Hofer, 2012).

The second form of direct selection, most appropriately called *reverse causation*, may exist if increased rapidity of cognitive decline results in increased risk of retirement. As noted above, cognitive decline can influence a number of non-cognitive domains of functioning including, for example, emotional disturbances (Shalev et al., 2014) or decreased capacity to understand instructions (Murray et al., 2011) suggesting that individuals may be retiring in part because of reductions in cognitive capacity among those who retire. Yet, other factors may be ongoing. For example, everyday stress, a known predictor of cognitive aging (Munoz, Sliwinski, Scott, & Hofer, 2015), may decrease substantially when workers make the mental transition towards retirement thereby resulting in a *cognitive return to retirement*.

Objective

The objective of this study is to use longitudinal regression discontinuity methods to determine whether there is evidence for a longitudinal relationship between retirement and cognitive aging and if selective factors, specifically baseline cognitive status or pre-retirement cognitive changes, explain associations between retirement and cognition.

Hypotheses

Figure 1 provides a graphical interpretation of potential longitudinal associations between retirement and cognition. Under a straight disuse hypothesis (Panel A) a dose-response association will exist if retirees experience more rapid declines in cognition ($\beta_1 > \beta_0$) following retirement (indicated using R_1), though prior to retirement retirees and continued employees should have similar levels of cognitive capability. Results will remain after accounting for time-invariant indirect selection, and for time-varying confounders. Including selective hypotheses (Panel B), those who retire will have different cognitive functioning compared to those who keep working; a healthy retiree effect would be evident if ($\alpha_1 > \alpha_0$)

while a healthy survivor effect would be evident if ($\alpha_1 < \alpha_0$). Reverse causality will be evidenced by more rapid rates of cognitive decline among retirees prior to retirement ($\beta_1 < \beta_0$). Pre-retirement changes and reduced stress may indicate times of retirement returns ($\beta_1 > \beta_0$). Table 1 provides a summary of these hypotheses.

Data

The Health and Retirement Study (HRS) (2014) is a publically available (<http://hrsonline.isr.umich.edu>) prospective monitoring study of U.S. older adults incorporating cognitive and retirement information biennially from 1992-2012 (overall response rate 81.6%). The earliest longitudinal evidence for cognitive aging has been observed at midlife (Singh-Manoux et al., 2012) so analyses incorporated individuals with valid cognitive information aged 50 and older at baseline. Retirement only occurs amongst individuals who have been regularly employed, so those who were not in the labor force or were already retired at baseline. The resulting analytic sample included 18,575 individuals followed 105,942 times over a total of 182,511.3 person-years.

Measures

Episodic Memory comprises an ordinal-continuous summation of verbal learning and verbal memory measures of cognitive function and forms the basis of the HRS cognitive battery (Brandt, Spencer, & Folstein, 1988; Ofstedal, Fisher, & Herzog, 2005). Briefly, examiners read ten words aloud and subjects were asked to recall them immediately; *verbal learning* recorded the number of words recalled correctly at this stage. Subjects were then distracted for approximately five minutes by filling out other survey items before again being asked to recall the list of ten words; *verbal memory* records the total number of words correctly recalled at this stage. In the first and second waves, a twenty-item word list was used so items were rescaled (divided by two) to range from 0-10. Scores for verbal learning and memory were summed to give an overall measure ranging from 0-20. Both skew and kurtosis were within the normal range.

Retirement

Detailed information about retirement, including duration and post-retirement employment activity were collected. *Retirement* was time-varying and indicates whether individuals report being retired or not at a particular time. While everyone in this sample began the period in the labor force, direct selection was identified by comparing the overall capability at baseline of individuals who retired at some point during observation to that of those who did not retire. *Retirement duration* indicates the number of years since the reported retirement dates; those who do not retire have zero duration.

Demographics

Baseline indicators including age in years centered at age 65 and sex. To account for possible acceleration in aging later in life, we allowed within-person rates of cognitive decline to vary by baseline age.

Indirect Selectors

Household wealth and education may result in higher cognitive reserve (Stern, 2012). *Household wealth* from all sources was asked at each wave including real estate, bonds, stocks, checking accounts, certificates of deposit, retirement savings, and other forms. We created a log-transformed summation of wealth from all assets. For descriptive purposes, we also identified how many people were lacking any household wealth. Education was included at baseline and was categorized to indicate whether individuals reported having less than high school, a high school diploma, or a college degree.

Time-varying confounders

Self-reported diagnoses of diabetes, cancer, heart disease, lung disease, stroke, depression, or high blood pressure were included to mark potential health changes that might influence retirement and cognition.

Unfamiliarity with testing and test conditions can result in lower scores in the first wave of measurement (Goldberg, Harvey, Wesnes, Snyder, & Schneider, 2015). We, therefore, included an indicator that was one for each respondent's first cognitive test and zero otherwise.

Methods

Descriptive analyses report means and standard deviations, as well as percentages at baseline. To characterize time-varying covariates, incidence rates (for health conditions) and maximal experiences (for poverty) were also provided. Bivariate analyses provide differences between individuals who are fully employed and retirees. Exact p-values provided were derived from Student's t-tests.

Regression discontinuity designs are quasi-experimental approaches (Lee & Lemieux, 2009) that have a long history that began in psychology and economics research (Cook, 2008). Prior work has found that regression discontinuity designs tend to provide results similar to randomized control trials, but go on to note that discontinuity approaches are more efficient and generalizable (Cook & Wong, 2008). In a longitudinal context, regression discontinuity approaches utilize observed temporal changes in predictor variables to predict change in state of, and temporal trends in, outcomes of interest. To incorporate regression discontinuity assumptions with prospective data and to account for endogeneity extant in repeated measurements, we applied multilevel modeling (Rabe-Hesketh & Skrondal, 2008), a commonly used approach to modeling trajectories of cognitive change (Sliwinski & Buschke, 2004). Longitudinal regression discontinuity designs are increasingly used in public health, with a notable application being an examination of changes in mortality accompanying healthcare policy changes (Sommers & Epstein, 2010), and have also been used to highlight selective differences in health trajectories (Clouston & Quesnel-Vallée, 2012).

The hypotheses shown in Figure 1 can be modeled using equation 1:

$$C_{it} = (\alpha_0 + \alpha_1 r_{it} + \alpha_2 r_o + \gamma_{0i} + \alpha_3 u + \alpha_k X_{kt}) + (\beta_0 + \beta_1 r_o + \gamma_{i1} + \beta_k X_{kt}) * t + \Phi_0 \delta_r + \varepsilon_{it} \quad (1)$$

where cognition (C) is observed among individuals (i) serially measured over time (t); α_0 indicates average sample capability. Models estimate the likely extent of reverse causality by differentiating the rate of decline before retirement among those who retired and comparing it to those who do not retire. Retirement (r_{it}) is time variant and thus α_1 will indicate any immediate changes concurrent with the year of retirement. Those who will retire ($r_0 = \max(r_{it})$) is captured by α_2 . The size of the unfamiliarity (u) effect is captured by α_3 . Examining differences in rates of change over time, β_0 indicates the average rate of longitudinal change in years, β_1 indicates the rate of cognitive decline preceding retirement among those who retired, ϕ_0 indicates the yearly rate of post-retirement decline compared to the rate of decline in individuals who are not retired.

Longitudinal models parse the overall error term into random error (ε_{it}), individual-specific random intercepts (γ_{i0}) that account for time-invariant individual factors determining differences in baseline capability, and individual random slopes (γ_{i1}) that model for individual-specific rates of change and account for heteroskedasticity common in growth models. Further utilizing an unstructured covariance matrix accounts for negative correlations between individual capability (random intercepts) and change over time (random slopes) often indicative of regression to the mean (Liu, Lu, Mogg, Mallick, & Mehrotra, 2009). Indirect selectors were incorporated as time-invariant predictors of baseline cognition ($\alpha_k X_k$).

Confounders

In a temporally variant environment, confounders must be correlated with temporally variant retirement changes and be associated with cognitive performance and cognitive decline. In these analyses, changes in health were allowed to vary and to explain lowered cognition ($\alpha_k X_{kt}$) and were also incorporated as indicators to measure the duration of a disease ($\beta_k X_{kt}$).

Model specifics

All models incorporated age at baseline and sex, both of which were included as time-invariant correlates. Age at baseline was further allowed to predict the rate of decline to account for the possibility that older people experience a more rapid cognitive decline. The base model (Figure 1A) examined a subcomponent of Equation 1 above that removed parameters for selection biases (α_1 , α_2 , & β_1). To this base model, selective, and causal hypotheses were integrated by introducing α_1 (Model 2) followed by α_2 (Model 3) and finally β_1 (Model 4). Confounding analyses built on Model 4 and additionally adjusted for $\alpha_k X_{kt}$ (Model 1) and $\beta_k X_{kt}$ (Model 2) as shown in Equation 1 above.

Assumptions and sensitivity analyses

Common assumptions in longitudinal analyses include that pre- and post-retirement changes occur in a linear fashion and that outcomes are distributed multivariate normal. Multivariate

normality in a multilevel model incorporates random intercepts and slopes, and thus assumes that deviations are normal from the estimated within-person changing mean. Sensitivity analyses assessed the linearity of post-retirement duration by comparing it to previously-used log-duration specifications (Bonsang et al., 2012). Errors are assumed to be distributed multivariate normal; in longitudinal models, multivariate normality occurs when accounting for initial distribution and is equivalent to suggesting that individuals are more likely to have scores that are nearer to prior scores than to all scores in general. Nevertheless, because prior researchers have highlighted ceiling effects in these data (Glymour et al., 2012), sensitivity analyses assessed differences in conclusions when using generalized linear multilevel modeling.

Sex- and age-stratification using 5-year age groups defined at baseline was used to ensure that results were generalizable and consistent. In stratified analyses, we compare coefficients using t-tests and examine heterogeneity between subsamples using Cochrane's Q and I^2 statistics (Hedges & Olkin, 2014). To compare model fit between nested models Akaike's information criteria (AIC) was calculated.

Adjusted pseudo- R^2 was provided to help contextualize the predictive power of each model. Beta coefficients, standard errors, and exact p-values are provided throughout. Because interpretation may rely on effect size calculations, marginal cognitive trajectories were provided setting covariates to mean values. Stata version 14.1/IC (College Station, TX) was used for analyses. Analyses were deemed not human subjects research by the Institutional ethics review board (#498619).

Results

At baseline, individuals with valid cognitive information were more likely to be women and in their mid-sixties (Table 2). Approximately half (48.2%) of respondents transitioned to retirement during the period of observation. Of those in the labor force, most worked full time, while a small minority were unemployed and looking for work. The majority of the sample had at least a high school education, and between 1/5-1/10 reported diagnoses of hypertension, depression and heart disease, while fewer reported other chronic diseases. Bivariate analyses (Table 2) suggested that most respondents reported either working or being retired. Those who retired during observation were older, less healthy, were less likely to have any wealth, had less wealth overall, and had lower cognition.

Retirement Differences

The average age at any incident retirement was 66.3 (SD=7.0). Respondents recorded having as many as five separate retirement spells during the observational period, though 91.3% (95% CI=[90.9, 91.7]) reported at most one retirement spell, while only 13 respondents retired more than three times. Age at first retirement was 65.4 (SD=6.8) years of age. Among those who retired, respondents spent approximately 3.7 waves employed prior to their first retirement.

Model Fit

Examining model fit (Table S1) revealed that accounting solely for individual random intercepts (Model 2) improved over fixed-effects models including only time in study and retirement duration (Model 1). Further accounting for random slopes improved model fit. However, accounting for random post-retirement slopes did not. Finally, accounting for correlations between intercepts and slopes significantly improved model fit, justifying the models reported below.

Retirement Model

Baseline models (Table 3, Model 1) revealed an association between retirement duration and cognition after adjusting for age, sex, and unfamiliarity with test conditions. Results remained when adjusting for possible changes at retirement onset (Model 2). Accounting for direct selection revealed a negative association between retirement and overall cognition (Model 3), supportive of a healthy survivor effect. This adjustment did not attenuate retirement effects but did reveal net-positive onset effects. Accounting for change reverse causation (Model 4) suggested that respondents who retired fared better than average prior to retirement than the population, an association that explained the net-positive onset associations shown in Model 3. Results suggested that those who retired were worse off, on average, than those who did not. However, it also revealed a small pre-retirement benefit in comparison to those who retired.

Indirect selection and confounding

Modeling the association between retirement duration and cognition among those who retired found an association between retirement duration and declines in working memory when incorporating prevalent and incident health conditions. Accounting for the associations between health conditions did not attenuate retirement results (Table S2, Model 1). Further accounting for associations between health conditions and change over time revealed no substantive differences in results, though the size of retirement effects diminished marginally (Model 2). Secondly, analyses revealed that diabetes, pulmonary disease, hypertension, stroke, and depression were associated with worse cognitive function and all except depression were associated with more rapid cognitive aging (results not shown).

Modeling associations between household wealth and education as both indirect selectors and potential time-varying confounding (Table S3) revealed that accounting for socioeconomic factors marginally reduced the size of retirement effects (Model 1). Further accounting for the association between socioeconomic factors and change over time did not change conclusions (Model 2). Secondly, analyses found associations between education and wealth at baseline and also revealed marginal associations between higher education and more rapid declines as well as between higher wealth and less rapid declines over time (results not shown).

Retirement effect

Providing graphical results aids interpretation, taking the form of the hypothesis figures (Figure 3). Longitudinal results shown here were derived from Table 2, Model 4, since these were complete and, since health and socioeconomic factors did not explain associations

between retirement and cognition, parsimonious models of retirement (Table S1). As should be evident, those who retired were worse off, to begin with, but also ultimately experienced more rapid aging over time.

Effect Sizes

The size of retirement effects was small, but may be non-trivial. First, noting that the standard deviation for cognition was 3.6 words, the retirement effect was associated with a yearly loss of 3.7% (95% CI=[3.5, 4.0]) of one standard deviation in cognitive functioning, a small effect. However, utilizing results from Table 2, Model 4, the rate of decline in those who retired was, on average for someone aged 65 years at baseline, about twice (2.2) as fast as among those who did not retire.

Sensitivity analyses

Sensitivity analyses revealed that the linear model performed better than the log-linear specification for retirement duration ($AIC_{lin-log}=-151$, $Pseudo-R^2=0.001$, $p<0.001$). Results stratified into 5-year age groups by age at baseline visit showed similar results ($Q=-0.01$, $p=0.999$, $\hat{P}=0.0\%$). Stratification by sex supported results shown above and showed no difference in the retirement effect between sexes ($p=0.707$).

Discussion

Key Findings

This study examined potential routes for associations between retirement duration and episodic memory in the U.S. *Health and Retirement Survey* while examining the potential for endogeneity evident in three different types of selection bias, specifically, indirect and direct selection and reverse causation. A longitudinal regression discontinuity approach was used to estimate retirement-related declines in episodic memory while accounting for individual differences in capability. While those who retired were more likely to have lower cognition prior to retirement, retirement was associated with a more rapid decline in cognition. Retirement was associated with a two-fold increase in the yearly rate of cognitive decline among retirees. This result was consistent when adjusting for health or socioeconomic status. Results are therefore suggestive of a cumulative “mental retirement” effect.

Interpretation

Results support prior findings suggesting that retirement is associated with cognition (Anzel et al., 2015; Bonsang et al., 2012; Coe et al., 2012; Hultsch et al., 1999; Roberts, Fuhrer, Marmot, & Richards, 2010; Rohwedder & Willis, 2010). These analyses used a form of longitudinal modeling that provides more reliable estimates of effects than cross-sectional estimates because they consider the potential for direct selection and for reverse causation. To our knowledge, this is the first study of cognitive aging after retirement that accounts for a variety of forms of endogeneity including direct selection and also to adjust for unfamiliarity with test conditions.

Though retirement was associated with cognitive decline, those who retired had higher cognition at baseline than those who remained employed. To date, this is the first study to examine the differences in cognition before retirement in conjunction with post-retirement declines. We could not interrogate reasons for this selective difference, though no analyses attenuated this association, possibly implicating mechanisms of cognitive reserve (Glymour et al., 2012; Richards & Sacker, 2003; Scarmeas & Stern, 2003; Stern, 2002, 2009; Valenzuela & Sachdev, 2005). For example, results may suggest that lifetime investments in cognitively stimulating activities may influence later patterns of cognitive decline and engagement in activities (Clouston et al., 2012; Glymour et al., 2008). Furthermore, prior research has shown that physical activity, cognitive engagement, and social interaction may help to prevent cognitive decline (Aichberger et al., 2010; Hall et al., 2009; Verdelho et al., 2012); these are all indicators of time-use that may help researchers to identify mechanisms through which retirement influences cognition. It is interesting that similar differences exist among individuals who are employed in different occupations, potentially highlighting mechanisms through which class structure may influence cognitive aging. Future research is warranted examining possible occupational selective factors, along with behavioral mediators, explaining associations between retirement and cognition.

Strengths and Limitations

Longitudinal modeling was used to examine associations between retirement duration and episodic memory. Models account for regression to the mean, and endogeneity in the outcome, and are robust to data that are missing because of factors not related to the rapidity of cognitive decline. However, because we assume linear trajectories of decline, results may be biased by acceleration in declines occurring before dementia (Clouston, Glymour, & Muñoz-Terrera, 2015) or near death (Muñoz-Terrera, Minett, Brayne, & Matthews, 2014). Models adjusted for health conditions that may result in cognitive decline, retirement, and death, but chances for unobserved variability remain. For example, Denier, Clouston, Richards, and Hofer (2017) note relationships between retirement and cognition depend on class and by reason for retirement. We did not differentiate reasons for retirement, nor did we examine whether activities, such as volunteering, hobbies, or social activities engaged with during retirement, may modify the risk of cognitive decline. However, insofar as these factors indicate time-invariant individual characteristics, random intercepts used here will capture such unobserved heterogeneity.

Cognitive measures used capture episodic memory; though providing a strong characterization of cognitive ability that is sensitive to cognitive impairment and dementia, normative cut-offs do not exist for measures that qualify whether observed functioning or declines therein reflect specific levels or types of cognitive impairment. Analyses did not utilize proxy reports, though such reports may be informative when diagnosing cognitive impairment and dementia (Crimmins, Kim, Langa, & Weir, 2011). It is worth noting, however, that such inclusions are most likely to affect results among individuals who are retired and cognitively compromised, suggesting that results shown here may be conservative. Finally, though cognition was objectively assessed, retirement in this study was self-reported by participants, potentially introducing reporting and informational biases.

Consistent with earlier research, there was an improvement in scores the first and following waves (Goldberg et al., 2015). The current study is, to our knowledge, the first study to examine retirement after adjusting for unfamiliarity in cognitive testing. While unfamiliarity effects were relatively important to the overall results, they did not explain retirement results. However, the period of observation used in this study is relatively long, potentially suggesting that shorter studies may find that such effects are more impactful, especially if such effects are associated with overall levels of functioning (Rast, 2011). Future analyses must consider unfamiliarity effects when using longitudinal models because they fit the definition of influential data when using random slopes analyses since they are located at the extreme values (at first wave) and have unusually low scores.

Conclusion and Policy Recommendations

While retirement is itself a common experience, the potential influence of different types of selection bias, as well as the relative benefit versus costs of retirement, may differ substantially across the world, driven in part by explicit policy differences. Globally, retirement policies often detail specific ages at which individuals in the workforce may receive social security benefits that allow them to retire, regardless of their financial situation. For example, in Europe and the U.S. many employers offer retirement packages in addition to retirement security income that welfare states often provide at a common statutory age. In the past, retirement age was 65 but this age has been incrementally raised in most European countries to reach a goal age between 67-70 over the next 20 years as a way to meet budget shortfalls in old age security programs (Social Security Administration, 2014). A relationship between retirement and episodic memory may be interpreted as an additional reason for delaying the retirement age. However, while results supported the disuse hypothesis, it also suggested that this effect was small and temporally rapid, and could be readily remedied by reentry into the labor market. A number of alternatives to employment have been forwarded as methods for keeping individuals actively engaged in the community and in social activities. Furthermore, employers are increasingly allowing workers flexibility to reduce work hours while maintaining active employment in their transitions towards retirement. Policymakers should facilitate the transition to active and engaged retirement periods in hopes of both improving community connectedness and healthy aging in elderly people.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The Stony Brook University internal review board declared this not human subjects research. The HRS (Health and Retirement Study) is sponsored by the National Institute on Aging (U01 AG009740) and is conducted by the University of Michigan. This study was funded in part by the National Institute on Aging (P01 AG043362) as part of the *Integrative Analysis of Longitudinal Studies on Aging* (IALSA) research network. The funders played no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript. The corresponding author had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

References

- Aichberger MC, Busch MA, Reischies FM, Ströhle A, Heinz A, Rapp MA. Effect of physical inactivity on cognitive performance after 2.5 years of follow-up: Longitudinal results from the Survey of Health, Ageing, and Retirement (SHARE). *The Journal of Gerontopsychology and Geriatric Psychiatry*. 2010; 23(1):7–15. DOI: 10.1024/1662-9647/a000003
- Alzheimer's Association. Alzheimer's disease: facts and figures. *Alzheimers Dement*. 2015; 8(2):131–168.
- Andel R, Infurna FJ, Rickenbach EAH, Crowe M, Marchiondo L, Fisher GG. Job strain and trajectories of change in episodic memory before and after retirement: results from the Health and Retirement Study. *Journal of Epidemiology and Community Health*. 2015 jech-2014-204754.
- Angrist J, Krueger AB. Instrumental variables and the search for identification: From supply and demand to natural experiments. 2001 Retrieved from.
- Banks J, Oldfield Z. Understanding pensions: Cognitive function, numerical ability and retirement saving. *Fiscal studies*. 2007:143–170.
- Bianchini L, Borella M. Retirement and memory in Europe. *Ageing & Society*, FirstView. 2015; :1–25. DOI: 10.1017/S0144686X15000434
- Bingley P, Martinello A. Mental retirement and schooling. *European Economic Review*. 2013; 63:292–298.
- Bonsang E, Adam S, Perelman S. Does retirement affect cognitive functioning? *Journal of Health Economics*. 2012; 31(3):490–501. [PubMed: 22538324]
- Brandt J, Spencer M, Folstein M. The Telephone Interview for Cognitive Status. *Cognitive and Behavioral Neurology*. 1988; 1(2):111–118.
- Bruscoli M, Lovestone S. Is MCI really just early dementia? A systematic review of conversion studies. *International Psychogeriatrics*. 2004; 16(02):129–140. [PubMed: 15318760]
- Celidoni M, Dal Bianco C, Weber G. Early retirement and cognitive decline. A longitudinal analysis using SHARE data. 2013 Retrieved from.
- Clark AE, Georgellis Y, Sanfey P. Scarring: The Psychological Impact of Past Unemployment. *Economica*. 2001; 68(270):221–241.
- Clouston S, Glymour M, Muñoz-Terrera G. Educational inequalities in aging-related declines in fluid cognition and the onset of cognitive pathology. *Alzheimer's & Dementia: Diagnosis, Assessment, and Disease Monitoring*. 2015; 1(3):303–310.
- Clouston S, Kuh D, Herd P, Elliott J, Richards M, Hofer SM. Benefits of educational attainment on adult fluid cognition: International evidence from three birth cohorts. *International Journal of Epidemiology*. 2012; 41(6):1729–1736. DOI: 10.1093/ije/dys148 [PubMed: 23108707]
- Clouston S, Manganello JA, Richards M. A life course approach to health literacy: the role of gender, educational attainment, and lifetime cognitive capability. *Age and Ageing*. 2016:1–7. 0((ePub ahead of print)).
- Clouston S, Quesnel-Vallée A. The role of defamilialization in the relationship between partnership and self-rated health: A cross-national comparison of Canada and the United States. *Social Science and Medicine*. 2012; 75(8):1342–1350. DOI: 10.1016/j.socscimed.2012.05.034 [PubMed: 22800920]
- Coe NB, von Gaudecker HM, Lindeboom M, Maurer J. The effect of retirement on cognitive functioning. *Health Economics*. 2012; 21(8):913–927. [PubMed: 21818822]
- Cook TD. “Waiting for Life to Arrive”: A history of the regression-discontinuity design in Psychology, Statistics and Economics. *Journal of Econometrics*. 2008; 142(2):636–654. <http://dx.doi.org/10.1016/j.jeconom.2007.05.002>.
- Cook TD, Wong VC. Empirical tests of the validity of the regression discontinuity design. *Annales d'Economie et de Statistique*. 2008:127–150.
- Crimmins EM, Kim JK, Langa KM, Weir DR. Assessment of Cognition Using Surveys and Neuropsychological Assessment: The Health and Retirement Study and the Aging, Demographics, and Memory Study. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*. 2011; 66B(suppl 1):i162–i171. DOI: 10.1093/geronb/gbr048

- Deary I, Johnson W. Intelligence and education: causal perceptions drive analytic processes and therefore conclusions. *International Journal of Epidemiology*. 2010; 39(5):1362–1369. DOI: 10.1093/ije/dyq072 [PubMed: 20504860]
- Denier, N., Clouston, S., Richards, M., Kuh, D., Hofer, S. Retirement and cognition: selective relationships and causal declines; Paper presented at the American Sociological Association; Denver, CO. 2012.
- Denier N, Clouston SAP, Richards M, Hofer SM. Retirement and cognition: A life course view. *Advances in Life Course Research*. 2017; 31:11–21. <http://dx.doi.org/10.1016/j.alcr.2016.10.004>.
- Glymour MM, Kawachi I, Jencks CS, Berkman LF. Does childhood schooling affect old age memory or mental status? Using state schooling laws as natural experiments. *Journal of Epidemiology and Community Health*. 2008; 62(6):532–537. DOI: 10.1136/jech.2006.059469 [PubMed: 18477752]
- Glymour MM, Tzourio C, Dufouil C. Is Cognitive Aging Predicted by One's Own or One's Parents' Educational Level? Results From the Three-City Study. *American Journal of Epidemiology*. 2012; 175(8):750–759. DOI: 10.1093/aje/kwr509 [PubMed: 22472116]
- Goldberg TE, Harvey PD, Wesnes KA, Snyder PJ, Schneider LS. Practice effects due to serial cognitive assessment: Implications for preclinical Alzheimer's disease randomized controlled trials. *Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring*. 2015; 1(1):103–111.
- Goldman N. Social Inequalities in Health: Disentangling the Underlying Mechanisms. *Annals of the New York Academy of Sciences*. 2001; 954(1):118. [PubMed: 11797854]
- Gorelick PB, Scuteri A, Black SE, DeCarli C, Greenberg SM, Iadecola C, Seshadri S, et al. Vascular Contributions to Cognitive Impairment and Dementia: A Statement for Healthcare Professionals From the American Heart Association/American Stroke Association. *Stroke*. 2011; 42(9):2672–2713. DOI: 10.1161/STR.0b013e3182299496 [PubMed: 21778438]
- Hall CB, Lipton RB, Sliwinski M, Katz MJ, Derby CA, Verghese J. Cognitive activities delay onset of memory decline in persons who develop dementia. *Neurology*. 2009; 73(5):356–361. DOI: 10.1212/WNL.0b013e3181b04ae3 [PubMed: 19652139]
- Health and Retirement Study (HRS). Health and Retirement Study, public use dataset. 2014
- Hedges, LV., Olkin, I. Statistical method for meta-analysis. Academic press; 2014.
- Hessel, P., Leist, A., Riumallo-Herl, CJ., Avendano, M. Recessions, unemployment and the brain: Do individual and aggregate economic shocks prior to retirement leave a cognitive 'scar'? 2015. Paper presented at the <http://paa2015.princeton.edu>
- Hultsch DF, Hertzog C, Small BJ, Dixon RA. Use it or lose it: Engaged lifestyle as a buffer of cognitive decline in aging? *Psychology and Aging*. 1999; 14(2):245. [PubMed: 10403712]
- Jack CR, Knopman DS, Jagust WJ, Shaw LM, Aisen PS, Weiner MW, Trojanowski JQ. Hypothetical model of dynamic biomarkers of the Alzheimer's pathological cascade. *The Lancet Neurology*. 2010; 9(1):119–128. [PubMed: 20083042]
- Jokela M, Ferrie JE, Gimeno D, Chandola T, Shipley MJ, Head J, Kivimäki M, et al. From midlife to early old age: health trajectories associated with retirement. *Epidemiology (Cambridge, Mass)*. 2010; 21(3):284.
- Lee DS, Lemieux T. Regression discontinuity designs in economics. 2009 Retrieved from.
- Liu GF, Lu K, Mogg R, Mallick M, Mehrotra DV. Should baseline be a covariate or dependent variable in analyses of change from baseline in clinical trials? *Statistics in Medicine*. 2009; 28(20):2509–2530. [PubMed: 19610129]
- Mazzonna F, Peracchi F. Ageing, cognitive abilities and retirement. *European Economic Review*. 2012; 56(4):691–710.
- Muñiz-Terrera G, Minett T, Brayne C, Matthews FE. Education associated with a delayed onset of terminal decline. *Age and Ageing*. 2014; 43(1):26–31. DOI: 10.1093/ageing/aft150 [PubMed: 24136340]
- Munoz E, Sliwinski MJ, Scott SB, Hofer S. Global perceived stress predicts cognitive change among older adults. *Psychology and Aging*. 2015; 30(3):487. [PubMed: 26121285]
- Murray C, Johnson W, Wolf MS, Deary IJ. The association between cognitive ability across the lifespan and health literacy in old age: The Lothian Birth Cohort 1936. *Intelligence*. 2011; 39(4):178–187.

- Ofstedal, MB., Fisher, GG., Herzog, AR. Documentation of cognitive functioning measures in the Health and Retirement Study (DR-006). Ann Arbor, MI: 2005. Retrieved from
- Organization of Economic Cooperation and Development. OECD Data. 2015 Retrieved from: data.oecd.org.
- Rabe-Hesketh, S., Skrondal, A. Multilevel and longitudinal modeling using Stata. STATA press; 2008.
- Rast P. Verbal knowledge, working memory, and processing speed as predictors of verbal learning in older adults. *Developmental Psychology*. 2011; 47(5):1490. [PubMed: 21574701]
- Richards, M., Deary, IJ. A life course approach to cognitive capability. In: Kuh, D.Cooper, R.Hardy, R.Richards, M., Ben-Shlomo, Y., editors. *A Life Course Approach to Healthy Ageing*. Oxford: Oxford University Press; 2014. p. 32-45.
- Richards M, Sacker A. Lifetime antecedents of cognitive reserve. *Journal of Clinical and Experimental Neuropsychology*. 2003; 25(5):614–624. [PubMed: 12815499]
- Roberts BA, Fuhrer R, Marmot M, Richards M. Does retirement influence cognitive performance? The Whitehall II Study. *Journal of Epidemiology and Community Health*. 2010; doi: 10.1136/jech.2010.111849
- Rohwedder S, Willis RJ. Mental Retirement. *Journal of Economic Perspectives*. 2010; 24(1):119–138. [PubMed: 20975927]
- Scarmeas N, Stern Y. Cognitive reserve and lifestyle. *Journal of Clinical and Experimental Neuropsychology*. 2003; 25(5):625–633. [PubMed: 12815500]
- Shalev AY, Freedman S, Peri T, Brandes D, Sahar T, Orr SP, Pitman RK. Prospective study of posttraumatic stress disorder and depression following trauma. *American Journal of Psychiatry*. 2014
- Singh-Manoux A, Kivimaki M, Glymour MM, Elbaz A, Berr C, Ebmeier KP, Dugravot A, et al. Timing of onset of cognitive decline: results from Whitehall II prospective cohort study. *BMJ: British Medical Journal*. 2012; 344
- Sliwinski MJ, Buschke H. Modeling intraindividual cognitive change in aging adults: Results from the Einstein aging studies. *Aging, Neuropsychology, and Cognition*. 2004; 11(2):196–211.
- Social Security Administration. Social security programs throughout the world: Europe. Washington, DC: Government Printing Office; 2014.
- Sommers BD, Epstein AM. Medicaid expansion—the soft underbelly of health care reform? *New England Journal of Medicine*. 2010; 363(22):2085–2087. [PubMed: 21105788]
- Spiro A, Brady CB. Integrating health into cognitive aging: toward a preventive cognitive neuroscience of aging. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*. 2011; 66(suppl 1):i17.
- Stern Y. What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society*. 2002; 8:448–460. [PubMed: 11939702]
- Stern Y. Cognitive reserve. *Neuropsychologia*. 2009; 47(10):2015–2028. [PubMed: 19467352]
- Stern Y. Cognitive reserve in ageing and Alzheimer's disease. *The Lancet Neurology*. 2012; 11(11): 1006–1012. [PubMed: 23079557]
- Valenzuela MJ, Sachdev P. Brain reserve and dementia: A systematic review. *Psychological Medicine*. 2005; 36:441–454. DOI: 10.1017/S0033291705006264 [PubMed: 16207391]
- Van Rooij MC, Lusardi A, Alessie RJ. Financial literacy, retirement planning and household wealth*. *The Economic Journal*. 2012; 122(560):449–478.
- Verdelho A, Madureira S, Ferro JM, Baezner H, Blahak C, Poggesi A. Study o. b. o. t. L. Physical Activity Prevents Progression for Cognitive Impairment and Vascular Dementia: Results From the LADIS (Leukoaraiosis and Disability) Study. *Stroke*. 2012; 43(12):3331–3335. DOI: 10.1161/strokeaha.112.661793 [PubMed: 23117721]
- Wickrama KK, O'Neal CW. The influence of working later in life on memory functioning. *Advances in Life Course Research*. 2013; 18(4):288–295. [PubMed: 24796712]

Highlights

- Retirement has been linked with lower cognition indicative of cognitive aging.
- Longitudinal regression-discontinuity modeling was used to account for selection.
- Confounders include socioeconomic factors and time-varying health outcomes.
- Retirement duration was associated with more rapid cognitive decline.

Figure 1.

Hypothetical changes in the rate of cognitive decline comparing individuals who do not retire (solid lines) to those who do (dashed line). Retirement is marked as occurring at the vertical gray line.

Legend: Panel A shows the hypothesized retirement effect, starting at full retirement. Panel B provides a full accounting of hypothesized selective and causal relationships. In the above figure, an individual's retirement occurs at time R_t . The effects of retirement are evident in cognition when observed through time-varying retirement observations. Average capability is modeled in α_0 , while α_1 indicates immediate drops in cognition during retirement periods and direct selection is modeled using α_2 to capture pre-retirement differences between those who retired and those who did not. Furthermore, β_0 indicates the average rate of aging for the population, β_1 indicates the rate of cognitive decline preceding retirement among those who retired, and ϕ_0 indicates the average rate of change as a function of retirement duration among those who retired.

Figure 2.

Sample descriptive characteristics, Health and Retirement Study 1992-2012

Note: N: sample size; O: number of observations; P-Y: number of person-years of information.

Figure 3.

Predicted trajectories of cognition between ages 60-75 for two hypothetical people: one who did not retire (solid lines), one who retired at age 65 (dashed line). Age at hypothetical retirement (65 years) was marked by a vertical gray line. Health and Retirement Survey 1992-2012

Note: Results calculated using Model 4 of Table 2.

Table 1

Synopsis of hypotheses being examined in this study

Hypothesis	Parameter	Hypothesis
Healthy Retiree	α_2	$\alpha_2 > \alpha_0$
Healthy Survivor	α_2	$\alpha_2 < \alpha_0$
Reverse Causality	β_1	$\beta_1 < 0$
Retirement Return	β_1	$\beta_1 > 0$
Retirement Drop (immediate effect)	α_1	$\alpha_1 < 0$
Cognitive Return to retirement	α_1	$\alpha_1 > 0$
Retirement Duration (dose-response effect)	ϕ_0	$\phi_0 < 0$

Table 2

Baseline descriptive characteristics for the overall sample of respondents who were in the labor force at baseline. Descriptive characteristics of time-varying covariates provided in parentheses. Bivariate analyses separated by individuals with and without an observed retirement transition. Health Retirement Survey 1992-2012

	<u>Overall Sample</u>		<u>Sample who worked throughout (51.80%)</u>		<u>Sample who retired (48.20%)</u>		P
	Mean	SD	Mean	SD	Mean	SD	
Working Memory	9.16	3.63	10.15	3.42	8.09	3.55	<0.001
Age in years	56.08	5.83	54.69	4.64	57.58	6.56	<0.001
Ln Household Wealth	8.03	2.62	7.94	2.77	8.12	2.43	<0.001
	Percent		Percent		Percent		
Male Sex	48.85%		48.88%		48.82%		0.392
Labor force status							
Works Full Time	77.69%		78.22%		77.12%		<0.001
Works Part Time	16.39%		15.21%		17.67%		<0.001
Unemployed	5.92%		6.57%		5.22%		<0.001
Retirement Status							
Not retired	70.92%		94.66%		53.91%		<0.001
Retired	23.83%		3.97%		38.06%		<0.001
Retired with Bridge Job	5.25%		1.36%		8.03%		<0.001
Any Wealth	95.31%		94.35%		96.34%		<0.001
Education							
No High School	21.62%		17.83%		25.70%		<0.001
High School	53.60%		53.53%		53.69%		0.334
University Degree	24.78%		28.65%		20.62%		<0.001
Diabetes	10.76%		11.65%		9.81%		<0.001
Prevalence at baseline	(1.64%)		(1.53%)		(1.69%)		<0.001
(Incidence rate per year)							0.025
Cancer	5.38%		5.18%		5.60%		0.001
	(1.19%)		(0.97%)		(1.29%)		<0.001
Heart Disease	10.27%		8.71%		11.94%		<0.001
	(1.93%)		(1.31%)		(2.21%)		<0.001
Lung Disease	4.86%		3.64%		6.16%		<0.001
	(0.83%)		(0.59%)		(0.93%)		<0.001
Stroke	1.84%		1.73%		1.95%		0.003
	(0.59%)		(0.27%)		(0.73%)		<0.001
							-0.46%

	<u>Overall Sample</u>		<u>Sample who worked throughout (51.80%)</u>		<u>Sample who retired (48.20%)</u>		
	Mean	SD	Mean	SD	Mean	SD	P
Hypertension	38.01% (4.69%)		36.97% (4.19%)		39.12% (4.94%)		2.15% -0.75% <0.001
Depression	12.54% (2.77%)		11.24% (2.6%)		13.95% (2.84%)		2.71% -0.24% <0.001 0.009

Note: P-values are derived from t-tests and test whether the difference between those who worked and those who retired was different. Diff.: The difference between sample who retired and those who were employed throughout.

Table 3

Beta coefficients, standard errors, and p-values estimating change in cognition in relation to retirement, Health & Retirement Survey 1992-2012

	Model 1		Model 2		Model 3		Model 4		
	B	SE	B	SE	B	SE	B	SE	
Age at baseline	(α_4)	-0.081	0.004 *	-0.082	0.004 *	-0.063	0.004 *	-0.057	0.004 *
Years in study	(β_0)	-0.045	0.019 *	-0.047	0.019 *	-0.053	0.019 *	-0.105	0.019 *
Age x Years	(β_2)	-0.007	0.000 *	-0.007	0.000 *	-0.007	0.000 *	-0.007	0.000 *
Male sex	(α_5)	-1.123	0.037 *	-1.123	0.037 *	-1.150	0.036 *	-1.150	0.037 *
Unfamiliarity	(α_3)	-1.378	0.027 *	-1.370	0.027 *	-1.394	0.027 *	-1.425	0.028 *
Retirement duration	(Φ_0)	-0.099	0.004 *	-0.103	0.005 *	-0.095	0.005 *	-0.133	0.005 *
Retirement onset	(α_1)		0.088	0.030 <i>t</i>	0.227	0.030 *	0.052	0.032	
Direct selection	(α_2)				-0.888	0.039 *	-1.186	0.043 *	
Reverse Causation	(β_1)						0.090	0.005 *	
Constant	(α_0)	10.241	0.205	10.225	0.206	10.855	0.204	11.087	0.204
Random Effects									
Slopes		0.100	0.003 *	0.101	0.003 *	0.097	0.003 *	0.101	0.003 *
Intercepts		2.264	0.019 *	2.267	0.019 *	2.203	0.019 *	2.204	0.019 *
Corr(1, S)		-0.389	0.018 *	-0.390	0.018 *	-0.348	0.019 *	-0.337	0.019 *
Model Fit									
Pseudo-R ²			0.064 *		0.064 *		0.065 *		0.066 *
Pseudo-R ²					0.000		0.001 *		0.000 *

Note: Significance levels:

* p<0.001;

*t*_p=0.003.

Models fit variations on equation 1: $C_{it} = (\alpha_0 + \alpha_1 r_{it} + \alpha_2 r_{0t} + \gamma_0 a_i + \alpha_3 u + \alpha_4 X_{kt}) + (\beta_0 + \beta_1 r_{0t} + \gamma_1 a_i + \beta_2 X_{kt}) * t + \phi_0 b_{it} + \epsilon_{it}$. Age in years was centered at age 65.