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Social Capital, Retirement and Cognitive Aging: Evidence from a Japanese longitudinal study*

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Abstract

Beyond the natural cognitive decline that accompanies aging, a growing body of research suggests that social capital can influence this process, particularly after retirement. This study investigates the interplay among social capital, retirement, and cognitive function. Using longitudinal Japanese data from 2007, 2009 and 2011, we assess three cognitive domains - orientation to time and place, short-term memory, and calculation ability - and examine how they can be affected by working status and social capital, proxied by participation in social activities and the size of one's friendship network. The major findings of this study are: (1) the cognitive effects of retirement appear to be complex and dynamic; and (2) social capital and employment interact with each other, with regular participation in social activities playing a protective role in cognitive aging.

Keywords: social capital, retirement, cognitive function, Japan
JEL codes: I18, I14, I11

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1. Introduction

Global population aging leads to a growing risk of significant cognitive decline. For example, the risk of developing Alzheimer's disease, the most common cause of dementia, approximately doubles every five years after the age of 65 (Alzheimer's Association, 2021). In 2021, an estimated 57 million people worldwide were living with dementia worldwide, imposing a substantial burden on public health and care provision (WHO).[1]

In contemporary society, older individuals are increasingly less likely to cohabit with their children. Many live either with their spouses or alone, making retirement a significant turning point in their lifestyle and social engagement. Clinical research has demonstrated that isolation, inactivity or loneliness can accelerate cognitive decline and trigger early symptoms of frailty (Wilson et al., 2007; Donovan et al., 2017; Kojima et al., 2022). At the same time, population aging has led to a rapid increase in the number of older individuals exiting the labor force, which may have significant implications for cognitive functions if working status serves to stimulate or maintain cognitive abilities. A better understanding on how social capital, retirement and cognitive functioning interact is essential for governments seeking to develop policies that promote the well-being of older adults and ensuring the sustainability of healthcare systems. This issue is particularly relevant to ongoing debates concerning efforts to enhance the social capital of older adults.

This study contributes to the literature in three key ways. First, we consider social capital as an important factor of cognitive function and may mediate the relationship between retirement and cognitive function. Social capital is commonly defined as "features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" (Putnam, 1992). To quantify social capital in empirical analysis, economists have employed measures such as local community density, the number of social associations, social networks, and social interaction (Miguel et al., 2005; Rupasingha et al., 2006; Chetty et al., 2022). In this study, we use the total number of friends and participation in social activities to capture individuals' social capital.

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[1] World Health Organization, https://www.who.int/news-room/fact-sheets/detail/dementia, accessed on 2025/07/03.

The second contribution of this study is that we have carefully considered the endogeneity of social involvement and retirement, both of which are behavioral choices. On the one hand, these factors may have an impact on cognitive function and health; on the other hand, they are themselves shaped by various unobservable individual or household characteristics. To address this issue, we employ both panel-data approaches and a regression discontinuity design (RDD) to disentangle these complex interactions.

Lastly, this study utilizes rich longitudinal data collected from the Japanese Study of Ageing and Retirement (JSTAR) to conduct the empirical analysis. Given that Japan faces the most severe population aging challenge in the world, evidence from this context is expected to offer valuable insights for other developed countries that are rapidly approaching a similar demographic structure. Moreover, the JSTAR provides detailed and reliable data on cognitive function, collected through home visits conducted by trained interviewers. We measure cognitive function by scores on orientation to time and place, short-term memory and calculation ability.[2]

Empirically, we assess the three cognitive domains described above and examine how they can be influenced by working status and social capital, proxied by participation in social activities and the size of one's friendship network. The major findings are threefold.

First, the cognitive effects of retirement appear to be complex and dynamic. Maintaining active employment is important for preserving orientation ability; however, retiring from formal employment - while continuing in informal work (hereafter referred to as "retirement from formal employment") - tends to enhance short-term memory and calculation ability. However, complete withdrawal from the labor force is associated with a pronounced decline in short-term memory, indicating the potential cognitive risks of full retirement.

Second, social capital appears to play an interactive role in shaping the cognitive impact of retirement in the long run. Regular participation in social activities plays a protective role in cognitive aging, as individuals who remain socially engaged are more

[2] These measures of cognitive function are commonly used in previous research and were deliberately selected by JSTAR to ensure consistency with other international surveys, such as the Health and Retirement Study (HRS) in the United States and the Survey of Health, Aging and Retirement in Europe (SHARE) (see Ichimura et al., 2012 for more details).

likely to experience improvements, or at least avoid deterioration, in cognitive function in the years following retirement. These effects are particularly evident in the domains of short-term memory and calculation ability, and more pronounced among women.

Third, retirement from formal employment appears to have an immediate negative effect on women's friendship networks, suggesting that formal and part-time employment may paly distinct roles in shaping work-based social connections for women. In contrast, men appear less affected by retirement in terms of social network size, at least in the immediate aftermath.

The remainder of the paper is organized as the follows. Section 2 provides a brief review of the relevant literature, followed by a description of the data in Section 3. Section 4 explains the institutional backgrounds in Japan and presents several stylized facts. Section 5 outlines the identification strategies, and Section 6 reports the empirical results. Finally, Section 6 concludes.

2. Literature Review

There is a substantial body of literature examining the effects of retirement and social capital on cognitive functioning. This study focuses on two major strands of this literature that are most relevant to our research: the cognitive effects of social capital and those of retirement.

A large body of literature has demonstrated that social capital significantly affects cognitive function. Krueger et al. (2009) and Kelly et al. (2017) showed that greater social engagement, including maintaining social connections and participating in social activities, is associated with better cognitive function among older adults. Other studies have also found that loneliness impairs cognition and increases the risk of depression and dementia (e.g., Wilson et al., 2007; Luo et al., 2012; Kojima et al., 2022). A recent study by Cabrera-Haro and Mendes de Leon (2024) further links social involvement to cognitive function in the context of retirement. Using data from 10 waves of the Health and Retirement Study in the United States, they found that higher social engagement is associated with better cognitive function at the time of retirement, though it does not necessarily slow cognitive decline after retirement.

Recently, growing attention has been paid to the health effects of social capital among old adults in Japan. Several studies using Japanese data have found that living in neighborhoods with higher levels of social involvement positively affects health outcomes and reduces psychological distress among male retirees (Watanabe et. al, 2019; Chen et al., 2022; Oshio et. al, 2022). However, these effects appear to depend on the type and frequency of social activities (Ide et. al, 2022).

Another strand of the literature on the cognitive effects of retirement is also highly relevant to the discussion of how social capital influences cognitive outcomes among older adults. Previous research generally fall into two groups with opposing conclusions regarding the effects of retirement: (a) studies reporting significant negative effects on cognitive function, often attributed to reduced mental stimulation and cognitive demands following withdrawal from paid work (e.g., Rohwedder and Willis, 2010; Bonsang et al., 2012; Mazzonna and Peracchi, 2012, 2017); and (b) studies suggesting positive effects on cognitive function and health, largely due to reduced work-related stress and increased leisure time (e.g., Kim and Moen, 2002; Coe et al., 2012; Eibich, 2015).

The positive effects of retirement on cognitive performance reported in previous studies are often conditional. For example, Kim and Moen (2002) found that the transition to the retirement can improve psychological well-being, particularly among individuals with higher levels of personal control, who are more likely to experience sustained benefits over time. Celidoni et al. (2017) showed that early retirement is beneficial for low-skilled workers. Using longitudinal data from Australia, Atalay et al. (2019) found that retirement has a positive effect on women’s cognitive function but a negative effect on men.

Although recent empirical studies on the cognitive effects of retirement have begun to address the endogeneity of retirement decisions, exploiting exogenous variation in retirement behavior generated by policy changes, much of the literature on the cognitive effects of social capital relies on longitudinal data but often fails to account for time-varying unobservable factors that may affect cognitive function. This study contributes to the literature by addressing the endogeneity of both social capital and retirement in a unified framework.

3. Data and descriptive statistics

In this study, we utilize data from the Japanese Study of Ageing and Retirement (RIETI et al., 2007, 2009, 2011), a nationally representative longitudinal panel survey collects detailed information on the economic, health and social conditions of individuals aged 50 and above in Japan. Japanese Study of Ageing and Retirement (JSTAR) is modeled after the Health and Retirement Study (HRS) in the United States and the Survey of Health, Aging and Retirement in Europe (SHARE). It is designed to facilitate cross-national comparisons while capturing the distinctive demographic and institutional characteristics unique to Japan.

The first wave of JSTAR was conducted in 2007 and covered five municipalities, namely, Takizawa, Sendai, Adachi, Shirakawa and Kanazawa, representing the north, northeast, east and central areas of Japan. A random sample of 4,200 individuals aged 50 to 75 was drawn from municipal resident registries. Subsequent waves expanded coverage to include Tosu and Naha in 2009, and Chofu, Hiroshima and Tondabayashi in 2011. In general, the sample retention rate was approximately 80%, which is relatively high compared to other longitudinal studies conducted in Japan. Data collection is conducted through face-to-face interviews by trained survey professionals, which ensures high data quality and consistency across waves. In total, the number of person-year observations with available information used in this analysis is 15,413, comprising 3,546 observations from the 2007 wave, 4,953 from the 2009 wave, and 6,914 from the 2011 wave.[3]

Table 1 presents the summary statistics for the variables used in our analysis by gender. Cognitive outcomes include scores on orientation to time and place, immediate word recall, and calculation ability. See the Appendix for details on the questions used to construct these scores. Due to the absence of data collection in the third wave, the total number of observations available for the orientation to time and place and calculation questions is 8,255 and 8,033, respectively. In contrast, the immediate word recall was measured in all three waves, yielding 6,872 observations in Round 1, 2,294 in Round 2, and 660 in Round 3. Based on the pooled sample, men scored an average of 5.919 out of 6 on orientation, 4.235 out of 10 on immediate word recall, and 5.5 out of 9 on calculation. Women scored 5.923, 4.766, and 5.169 on the respective measures.

Regarding working status, 63.6% of men were employed at the time of the survey, compared to 42.0% of women. Average weekly working hours were 26.1 for men and

[3] The use of JSTAR data from 2007 to 2011 offers a valuable and unique opportunity to exploit relatively substantial exogenous variation in both social capital and retirement behavior, driven by institutional changes in pensionable ages during this period. Specifically, the pensionable age for Japan's Basic Pension Insurance began increasing gradually, from 2001 to 2013 for men and from 2006 to 2018 for women. These phased increases introduced discrete shifts in retirement incentives that can be leveraged for quasi-experimental analysis of retirement's effect on cognitive function and social engagement.

12.7 for women. Among those employed, 27.1% of men and 8.5% of women held permanent positions. Part-time employment was reported by 15.8% of men and 19.2% of women, while self-employment rates were 19.6% of men and 13.5% of women. Note that, among the 1,024 men who were full-time employees in Round 1, 68% (n=356) remained in full-time employment in Round 2, while, 15% (n=80) transitioned to part-time work, 4% (n=23) became self-employed, and 12% (n=63) exited the labor force.

Social capital is measured by two indicators: the total number of self-reported friends and regular participation in social activities. On average, men had an average of 15.77 friends, compared to 10.97 for women. Participation in social activities was similar across genders, with 24.0% of men and 23.9% of women reporting regular involvement. Specifically, social activities include community association activities, volunteer activities, religious involvement (e.g., attending church), group learning, and recreational or entertainment- based activities.

Personal and household characteristics show that the average age is 64.7 years for men and 65.0 years for women. Education levels, measured on a 1-7 scale, where1 indicates lower secondary education and 7 corresponds to doctorate degree. The averaged score was 2.6 for men and 2.19 for women. Annual personal disposable income averages 3,125,000 yen for men and 1,355,000 yen for women. The majority of respondents reported having a spouse (86.5% of men and 79.7% of women) and children (87.6% of men and 88.6% of women).

4. Background and stylized facts

4.1 Institutional background

This section provides relevant institutional backgrounds on pension policies and retirement in Japan, along with key patterns of employment, cognitive function and social engagement observed among the study sample.

Japan's public pension system consists of two main components: (a) the Basic Pension Insurance (BPI), which covers all residents aged 20 to 60; and (b) the Employment Pension Insurance (EPI), which applies to individuals employed by firms exceeding a certain size. Part-time workers, self-employed individuals, and the unemployed are typically covered only by BPI. To receive basic pension benefits, individuals must contribute a fixed premium for a minimum of 10 years and can begin to receive payments at age 65. In contrast, those enrolled in EPI are required to pay premiums for at least 10 years. These contributions include both the BPI premium and an additional income-proportional component. In return, they are entitled to a higher level of pension benefits after reaching pensionable age.

In fact, in 2000, the pensionable age in Japan was set at 60. However, based on amendments to the Pension Law in 1994 and 2000, the pensionable age for the BPI began to increase gradually starting in 2001 for men and in 2006 for women. Specifically, the pensionable age was raised by one year every three years, eventually reaching 65 in 2013 for men and by 2018 for women. Subsequently, the pensionable age for the EPI was also scheduled to increase, beginning in 2013 for men and in 2018 for women, with the age rising by one year every three years until reaching 65 by 2025 and 2030, respectively. During the period covered by this study, the BPI pensionable age had been raised to 63 or 64 for men, while the EPI pensionable age remained at 60. For women, the BPI pensionable age had increased to 61 or 62, while the EPI pensionable age also remained at 60.

Traditionally, firms in Japan set their mandatory retirement age at 60. For example, according to the General Survey on Working Conditions conducted in 2006, approximately 90.5% of the surveyed firms had a mandatory retirement age of 60, while 6.2% set it at age 65. However, in response to the gradual increase in pensionable ages, firms have been encouraged to postpone their mandatory retirement age and to expand employment opportunities for individuals aged 60 and above. Correspondingly, an increasing number of firms have introduced reemployment programs for retired employees or have begun to postpone the mandatory retirement age to 65.

By 2012, the proportion of firms setting the mandatory retirement age at 60 had declined to 82.7% while the share setting it at age 65 had increased to 13.6%. Additionally, over 92% of all firms had introduced some form of employment extension programs for retired individuals.[4]

The JSTAR survey asked respondents to report the age at which they retired or expected to retire. As shown in Figure 1, a clear peak is observed at age 60 among men (represented by green bars), with approximately 25% indicating retirement at this age. A secondary peak occurs around age 65. The concentration at age 60 likely reflects Japan's mandatory retirement system, while the second peak may correspond to the termination of reemployment contracts or the commencement of public pension benefits. In contrast, although there is still a peak at age 60, retirement ages among women are more widely distributed, ranging from the late 50s to around age 70, suggesting less concentration compared to men.

4.2 Age profiles of employment, cognitive function and social capital

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[4] The statistics are based on the data from the General Survey of Working Conditions, conducted by the Ministry of Health, Labour and Welfare (MHLW) in 2006 and 2012.

Figure 2 presents the age profiles of employment shares by employment type and gender. In Panel (a), which displays formal employment, a clear discontinuity is observed at age 60 for both men and women. For men, the proportion engaged in part-time employment rises sharply at age 60 in (b-1), suggesting a rapid transition from regular to non-regular employment following mandatory retirement. A further notable decline in employment is observed at the age-64 cutoff. Among women, the share of part-time workers is already at a relatively high level before age 60, but further increases beyond age 60 slightly. However, an obvious decline is again observed at age 64 for both employed men and female part-time workers. In the case of self-employment, as shown in Panel (c), while gradual age-related changes are apparent, no clear discontinuity is detected around age 60, indicating that self-employment may be less sensitive to institutional retirement thresholds.

We further examine the age profiles of active working status and average weekly working hours in Figure 3. Compared to the patterns in Figure 2, the decline in the proportion of actively working individuals appears much more gradual for both men and women, except for a noticeable drop at age 64 for men. This suggests labor force exit generally occur progressively over time. However, the change in the pensionable age to 64 may have prompted more men to retire completely at that age, a pattern not observed among women.

Figure 4 presents the distribution of the three cognitive measures for men and women. In Panel (a), orientation scores for men exhibit a noticeable decline around the age 65, while no clear changes are observed at either age 60 or 65 for women. In Panel (b), immediate word recall scores for men show a temporary increase at both ages 60 and 65, followed by a rapid decline. In contrast, women display a more continuous downward trend, beginning at a relatively earlier age around their late 50s. Lastly, Panel (c) shows that calculation scores decline with age for both genders. Among men, a slight drop is observed at age 65, while among women, the decline is more pronounced.

The panel data also allows us to examine changes over time - that is, differences in cognitive measures between two consecutive rounds, covering a 2- to 3-year period. Figure 5 illustrates the distribution of these changes by age. Since the JSTAR introduced new respondents in each wave, data from consecutive rounds is available for a limited number of observations, resulting in a smaller sample size for the analysis of changes in cognitive function. Consequently, we observe greater variation in the distributions, particularly for orientation and calculation scores. However, in Panel (b), which displays changes in immediate word recall, the age-related fluctuations are relatively modest for both men and women. Notably, a sharp decline in immediate word recall is observed around age 65.

To further explore the role of social engagement in shaping short-term memory outcomes, Figure 6 presents a disaggregated version of Panel (b) from Figure 5, comparing individuals who regularly participate in social activities with those who do not. Interestingly, as shown in Panel (a) of Figure 6, the decline in immediate word recall scores at age 65 disappears among those with regular social engagement. In contrast, a pronounced decline remains evident at age 65 among individuals who do not participate in social activities, for both men and women. These findings suggest that regular social engagement may play an important role in mitigating the cognitive declines in short-term memory after retirement.

Lastly, Figure 7 presents how social capital measures vary by age and gender. Panel (a) shows that the number of friends follows a generally U-shaped pattern: a sharp decline occurs around age 60, particularly for women, followed by a recovery after age 65 for men and a slightly earlier rebound for women. In contrast, participation in social activities remains relatively stable across age groups. A modest decline is observed around age 60, followed by a gradual increase thereafter. These patterns suggest that retirement may lead to a temporary reduction in social capital, particularly in terms of personal networks, but that social capital may increase in the longer term after individuals exit the labor force.

One concern, however, is the timing mismatch between observed changes in cognitive measures and retirement behavior. While significant changes in cognitive outcomes are observed around 65, the most notable discontinuity in complete labor force withdrawal occurs at age 64, highlighting the need for more careful analysis. Overall, these findings are suggestive of cognitive effects of retirement and social capital. For a more rigorous causal assessment, we turn to the identification strategies described in Section 5.

5. Empirical Framework and Identification Strategies

Individuals' cognitive functions are likely to be affected by their work, which often involves various tasks that require continuous mental engagement. Consequently, on the one hand, ceasing working may reduce such stimulation and mental exercise, potentially leading to cognitive decline after retirement. On the other hand, retirement may itself result from cognitive aging, as individuals find it increasingly difficult to meet the cognitive or physical demands of their jobs. Additionally, other factors - such as family environment and social connections – may influence both the decision to retire and cognitive functioning. Therefore, disentangling the relationship between retirement and cognitive function presents a significant empirical challenge.

For our empirical analysis, we focus on three measures of cognitive function as the outcome variables. According to psychological research, cognitive abilities can be typically categorized into two types: (a) *fluid intelligence*, which includes the ability to think critically and quickly, memorize new information, and perform accurate calculations; and (b) *crystallized intelligence*, which refers to accumulated knowledge, language proficiency, and judgement skills (McArdle et al., 2002). In this study, we mainly focus on fluid intelligence, measured by the following three indicators: (a) scores on questions assessing orientation to time and place; (b) scores on immediate word recall; and (c) scores on basic mathematical calculations.

In order to develop a better understanding of the cognitive effects of social capital, we first examine how retirement may affect cognitive function. In many developed countries, mandatory retirement is common and typically determined by firms based on pensionable age or other institutional factors. As a result, individuals often consider themselves retired after leaving their primary, formal employment. However, with the growing participation of older adults in the labor force, it has become increasingly uncommon for individuals to cease working immediately after mandatory retirement. Instead, many continue to work part-time and gradually transition out of the labor market. In this study, we examine both complete withdrawal from the labor force and retirement from formal employment, with particular emphasis on the former which is expected to exert a more substantial impact on cognitive function.

Furthermore, although social capital encompasses a broad range of dimensions, including interpersonal relationships, community heterogeneity, and religious fractionalization, we focus on individuals' social engagement and interpersonal connections to analyze the role of social capital in the context of retirement. Specifically, we measure social capital using two indicators: (a) the size of an individual's friendship network; (b) participation in various forms of social activities, including community volunteering, religious involvement, group learning, and recreational or entertainment-based activities.

To disentangle the relationships among social engagement, retirement, and cognitive function, we employ three major identification strategies. Let C_{it} denote the cognitive ability of individual i, $Work_{it}$ the working status, and $\boldsymbol{SC_{it}}$ the set of social capital variables. As a benchmark model, we estimate the following model using ordinary least squares (OLS):

$$C_{it} = \beta_0 + \beta_1 Work_{it} + \beta_2 \boldsymbol{SC_{it}} + \beta_3 \boldsymbol{X}_{it} + \varepsilon_{it} \qquad (1)$$

where $\boldsymbol{X}_{it}$ is a vector of control variables including age, age squared, educational attainment, marital status (i.e., whether the individual has a spouse), parental status (i.e., whether the individual has children) and year fixed effects. ε_{it} represents the idiosyncratic error term.

Since this study utilizes panel data from the 2007, 2009 and 2011waves of the Japanese Study of Aging and Retirement (JSTAR), our second identification strategy employs panel data methods. Accordingly, Equation (1) is extended to the following model:

$$C_{it} = \beta_0 + \beta_1 Work_{it} + \beta_2 \boldsymbol{SC_{it}} + \beta_3 \boldsymbol{X}_{it} + \mu_{it} + v_{it} \qquad (2)$$

where μ_{it} captures the unobserved individual-specific effects, and v_{it} represents the idiosyncratic error term. Empirically, we estimate Equation (2) using both random-effects and fixed-effects models. In the fixed-effects specification, time-invariant variables, such as educational attainment, marital status, and parental status, are omitted due to their collinearity with individual fixed effects.

Our third identification strategy employs a regression discontinuity design (RDD), leveraging the institutional discontinuities in retirement behavior induced by features of Japan's public pension system. As explained in Subsection 4.1, traditionally, most firms in Japan set the mandatory retirement age at 60, which also marked the pensionable age. However, during our study period, the eligibility age for the basic pension insurance (BPI) was gradually raised to 63 or 64 for men, and to 62 or 63 for women, while the employment pension insurance (EPI) remained accessible at age 60.

These institutional features created substantial discontinuities in employment status at ages 60 and 64, as illustrated in Figures 2 and 3. Accordingly, we adopt a fuzzy regression discontinuity design to estimate the causal effect of retirement on cognitive function, exploiting these age-based eligibility thresholds as instruments for retirement status. More specifically, we estimate the local average treatment effect (LATE) using the following fuzzy regression discontinuity model. Let C^+ and C^- denote the limits of the outcome variable *C* as the running variable, age, approaches the cutoff from the right and the left, respectively. Let R_{it} be a binary indicator for whether individual i is retired at time t, and $R^+ - R^-$ represent the discontinuity in the probability of retirement at the cutoff. Mathematically, the LATE is given by:

$$LATE = E[C_{it} \mid R_{it} = 1] - E[C_{it} \mid R_{it} = 0] = \frac{C^+ - C^-}{R^+ - R^-} \ . \qquad (3)$$

Empirically, the limits of cognitive outcomes, C^+ and C^-, are estimated as the intercepts from separate local linear regressions of cognitive outcomes on standardized age, using samples on the right and left sides of the cutoff, respectively. Similarly, the limits of retirement, R^+ and R^-, are estimated as the intercepts from the regressions of retirement status on standardized age, using observations on either side of the cutoff. Following standard practice in the literature, standard errors are computed using a two-stage estimation procedure, with the retirement decision estimated in the first stage.

In our analysis, we focus on different types of retirement at the age thresholds of 60 and 64. At age 60, we observe a significant drop in formal employment, which allows us to examine the effect of ceasing formal employment. In contrast, at age 64, we observe a marked decline in the probability of working positive hours among men, enabling us to assess the impact of complete withdrawal from the labor force. Additionally, given that a substantial proportion of survey respondents reported retiring at age 65, we also conduct robustness checks using the combined ages of 64 and 65 as an alternative cutoff.

We estimate the fuzzy RDD using both the current level of cognitive function, C_{it}, and the differenced cognitive measures, i.e. $C_{it} - C_{i,t-1}$. Using the current cognitive level allows us to maximize the sample size, thereby improving estimation precision. If the discontinuity at the cutoff is exogenously driven, the fuzzy RDD provides unbiased estimates. Alternatively, using the differenced measures enables us to control for the baseline cognitive ability, improving the precision of estimation. We can also examine changes in cognitive function over the subsequent 2-3 years. However, this approach has the drawback of substantial sample attrition due to missing data in the second or third waves, potentially introducing sample selection bias.

Lastly, a potential concern is the existence of a *learning curve effect* among individuals who were repeatedly asked to complete the word recall task, one of the key cognitive function measures. Given that the words used across survey waves were similar, respondents may have become familiar with the task or even memorized the words. Indeed, Hashimoto (2013) documents an increase in average word recall scores between waves, "contrary to physiological decline in memory function". While such a learning effect, if present, may introduce downward bias in our OLS and panel estimates, it is unlikely to affect our RDD estimates. This is because the regression discontinuity design remains valid as long as the learning effect does not exhibit a discontinuous shift at the cutoff age.

6. Results

This section reports the estimation results based on the three identification strategies outlined in Section 5. All analyses are conducted separately for men and women, given the substantial gender differences in labor force participation, social engagement, and cognitive function.

6.1 Effects of social capital on cognitive function

We begin by presenting the OLS estimates, based on the pooled sample, for the three measures of cognitive function in Tables 2-4. For both men and women, three regressions are estimated, each controlling for the variables specified in Equation (1). The key difference across these regressions lies in whether social capital variables are included.

In Columns (1) and (4), where social capital variables are excluded, whether an individual is working or not is significantly and positively associated with orientation to time and place (Table 2). When controlling for social capital proxy variables, although they are statistically insignificant, the coefficient and statistical significance of working status also decline, suggesting a potentially complex relationship between working, social capital, and the ability to understand temporal and spatial context. Educational attainment and having a spouse are positively associated with stronger orientation ability for both sexes, whereas having children appears to be more relevant for men than for women.

As shown in Table 3, working status is not significantly associated with short-term memory, as measured by immediate word recall scores. The result holds for both men and women, regardless of whether social capital variables are included. However, participation in social activities is positively associated with short-term memory ability in Columns (2) and (5). For men, this association becomes statistically insignificant once the number of friends is controlled for, whereas it remains significant for women. Overall, the findings suggest that social capital may play a more important role in preserving short-term memory among older adults, with men benefiting more from broader friendship and women from active participation in social activities.

The final set of OLS estimates for calculation ability scores is presented in Table 4. The results indicate that, after controlling for social capital, neither working status nor social capital has a significant impact on calculation ability for men. In contrast, calculation ability is significantly and positively associated with participation in social activities for women.

These OLS results underscore the importance of considering the effects of social capital among older adults, particularly for the short-term memory and calculation ability. However, merely including social capital variables as controls may not sufficiently address the endogeneity of working decisions and social engagement. To further address potential endogeneity, particularly that arising from time-invariant unobserved heterogeneity, we turn to panel data methods.

6.2 Estimates based on panel-data models

As shown in Tables 5-7, we estimate both random-effects and fixed-effects models separately for men and women. For each specification, the models are estimated with and without controlling for the participation in social activities. Since information on the number of friends was not collected in subsequent waves of the JSTAR, this variable is excluded from the panel-data analysis.

Consistent with the OLS results, the estimates for working status remain mostly statistically significant and positively associated with individuals' orientation to time and place, whereas the effects of social involvement are generally statistically insignificant (Table 5). Haussman tests reject the null hypothesis that the differences between the coefficients of the RE and FE models are not systematic, indicating that the RE model is appropriate and more efficient in this context.

In contrast, the results presented in Table 6 suggest that working status has no significant effect on short-term memory scores for either men or women, which remains consistent with the findings from the OLS estimates. While the coefficients on social capital are positive and statistically significant in the random-effects models, the FE estimates indicate that neither working status nor social capital appears to have a significant impact on individuals' short-term memory.

Regarding the results for calculation scores, the random-effects estimates suggest that working status does not have a significant effect once regular participation in social activities is included. However, like the OLS estimates, social engagement itself has a strong positive effect on women's calculation ability. The fixed-effects estimates are generally statistically insignificant. Interestingly, the Haussman tests fail to reject the null hypothesis, indicating that the random-effects model may be preferrable in this context.

In sum, the panel data analysis yields results largely consistent with those from the OLS estimates, although the fixed-effects (FE) models tend to have reduced statistical power due to larger standard errors. The findings suggest that active working status is positively associated with orientation to time and place, whereas short-term memory and calculation ability are more likely to be influenced by participation in social activities, particularly among women.

6.3 Interplay of retirement, social capital and cognitive function

We now turn to the results based on the fuzzy regression discontinuity design (RDD) described in Section 5. We exploit the age 60 threshold for both men and women to estimate the effect of retiring from formal employment. To ensure robustness of the findings, the estimation is conducted on the samples defined by bandwidths of three and four years around age 60. Table 8 presents the results under both specifications. As noted at the end of Section 4, we further investigate age 64 independently, as well as the combined ages of 64 and 65, as alternative cutoffs to identify the effects of complete withdrawal from the labor force for men only. This is because women's working status appears to change continuously around these ages, making RDD unsuitable in that context.

The first row of Table 8 reports the discontinuity in working status at various age cutoffs. Specifically, compared to individuals aged 59, the proportion of men retiring from formal employment increases by over 21% at age 60, while the corresponding increase among women is smaller, at approximately 10.5%. At age 64, the rate of complete labor force exit among men rises by an estimated 13.5%. When age 65 is included in the cutoff, the estimated increase slightly declines to 13.1%.

Considering the interplay between employment status, social capital and cognitive function, we begin by examining the effect of retirement on social engagement, with the results presented in Panel A. Subsequently, we assess the cognitive effects of retirement: Panel B reports the estimates for cognitive outcomes in levels, while Panel C presents the estimates for changes in cognitive function between survey waves. It is important to note that the estimated effect of retirement on cognitive function should be interpreted as a composite effect – encompassing both the direct impact of working status and the indirect pathways through social capital. This is because retirement may directly alter an individual's level of social engagement, and these interrelated effects cannot be fully disentangled within the current empirical framework.

Overall, the results indicate that retirement does not appear to have a statistically significantly impact on either measure of social capital for men - namely, the size of friendship network and the likelihood of participating social activities – across various age cutoffs. However, this finding does not preclude the possibility that retirement affects social capital over a longer horizon, as individuals may gradually adjust their social engagement behavior post-retirement, which the regression discontinuity design (RDD) may fail to capture due to its focus on local effects around the cutoff.

In contrast, for women, the number of reported friends declines significantly at age 60, indicating that formal employment likely plays an important role in maintaining social connections. Furthermore, the likelihood of women participating in social activities increases significantly following retirement, although this effect appears sensitive to the choice of bandwidth, suggesting that the result should be interpreted with caution.

As shown in Columns (1) and (2) for men and Columns (5) and (6) for women, retirement from formal employment at age 60 appears to have a limited impact on orientation ability scores. This may be because many retirees continue to engage in part-time employment. However, a reduction in work-related stress and pressure following retirement may contribute to a short-term improvement in short-term memory, particularly for men, as suggested by the significant positive effects reported in Panel B. In contrast, calculation ability exhibits a temporary decline after retirement, which appears to be partially reversed in subsequent years, as shown in Panel C. Notably, these effects are statistically significant only for men, suggesting a gendered difference in how retirement influences cognitive function across various domains.

Furthermore, the estimates of the effect of completely withdrawal from the labor force are more sensitive to the choice of cutoff age and are only available for men due to the lack of discontinuity in retirement for women. Specifically, when using age 64 as the threshold (Column 3), the results tend to be statistically insignificant, likely due to substantial fluctuations in cognitive outcomes around ages 64 and 65. However, when adopting a combined cutoff, that is, comparing individuals aged 61-63 to those aged 65-67, the estimates (Column 4) become more robust and statistically significant. These results suggest that following full retirement, men experience a significant decline in orientation ability, potentially driven by the sudden cessation of cognitive engaging activities associated with working. Simultaneously, short-term memory improves temporarily, perhaps due to reduced stress and increased leisure time, but this gain deteriorates rapidly in the subsequent years, as indicated by the decline in differenced outcomes between two survey waves. In contrast to retirement from formal employment, complete withdrawal from labor force does not appear to have a statistically significant impact on calculation ability.

6.4 Heterogeneous effects of retirement by social engagement

The effects of retirement on cognitive function are likely to interact with social capital, particularly when examining changes over time, as individuals may require an adjustment period to reconfigure their social engagement after retirement. Therefore, focusing on differenced outcome measures, we further investigate whether the long-term cognitive consequences of retirement differ according to individuals' level of participation in social activities during the subsequent 2-3 years.

According to the results presented in Table 9, individuals who regularly engage in social activities generally exhibit improvements or are able to prevent declines in cognitive functions following retirement. For instance, among men, retirement from formal employment is associated with improvements in calculation ability for those actively engaged in social activities. In contrast, men who do not engage in such activities tend to experience a substantial decline in short-term memory in the years following complete withdrawal from the labor force.

For women, the differences are even more pronounced. Those who do not involved in social activities suffer greater declines in both orientation ability and short-term memory after retiring from formal employment. This pattern aligns with the finding reported in Table 8, which shows a significant reduction in the number of friends following retirement among women. These results suggest that social activities may play a particularly crucial role in preserving cognitive function among older women, possibly compensating for the loss of social connections that accompanies labor market exit.

7 Conclusions

Dementia poses an increasing threat to the health of older adults and places a growing burden on healthcare systems worldwide. At the same time, contemporary lifestyles are marked by a heightened risk of isolation and loneliness in old age, particularly following retirement. This study aims to advance our understanding of the relationships among social capital, retirement and cognitive function.

Using longitudinal data from Japan, this study investigates the effects of social capital on three key domains of cognitive function commonly analyzed in the literature: orientation to time and place, short-term memory and calculation ability. Furthermore, we explored the interactive effects of retirement and social capital on cognitive outcomes, while addressing potential endogeneity concerns through the application of both panel data methods and a fuzzy regression discontinuity design. Our findings suggest that cognitive functioning among older adults is significantly influenced by social engagement, retirement transitions, and the interaction between the two.

In summary, the results highlight three key insights. First, maintaining active employment appears essential for preserving orientation ability, while short-term memory and calculation ability tend to improve after retirement from formal employment. However, complete withdrawal from the labor force is associated with a sharp decline in short-term memory. Second, individuals who engage regularly in social activities are more likely to experience improvements - or at least avoid deterioration – in cognitive function in the years following retirement. These effects are particularly more pronounced in the domains of short-term memory and calculation ability, and are more evident among women. Third, retirement from formal employment appears to have an immediate negative impact on the size of women's friendship networks, whereas men are less likely to be affect directly after retirement.

These findings underscore the importance of supporting social engagement among retirees. In particular, policies that facilitate active social involvement, especially for men following complete retirement, may serve as effective interventions to delay cognitive decline. Given that women often experience a sudden reduction in the size of their friendship networks upon retirement from formal employment, targeted community-based programs may help foster new social connections and mitigate the adverse cognitive consequences of social isolation.

Lastly, several limitations of this study should be acknowledged. First, due to the gradual increase in the probability of labor force exit among women with age, it is not feasible to fully implement the regression discontinuity design (RDD) for the female sample. Second, the discontinuity in the retirement probability at the cutoff is relatively modest, which raises concerns that the estimated treatment effects may be overstated due to weak first-stage relevance. Lastly, owing to data limitation, we are unable to assess the long-term impacts of social capital and retirement, such as those manifesting over a five- to ten- year period.

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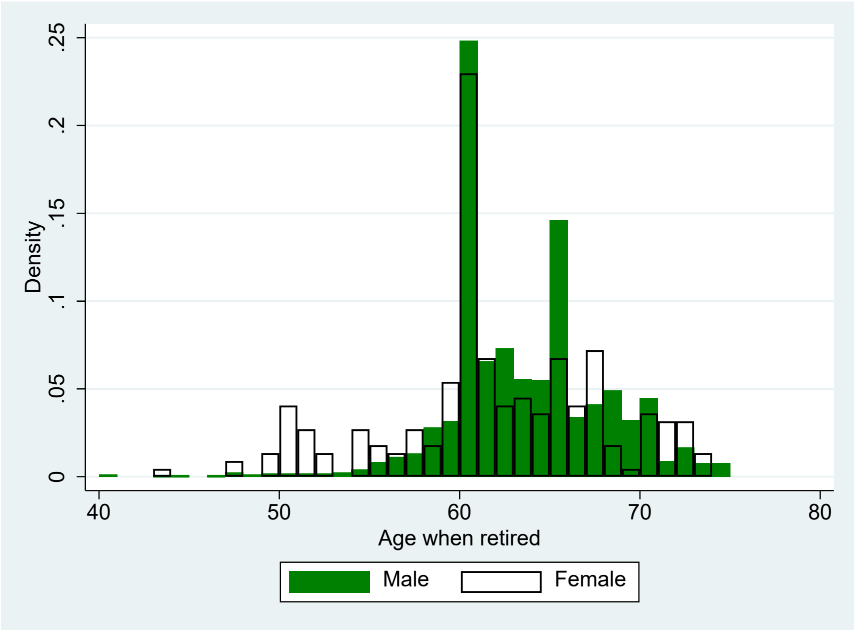
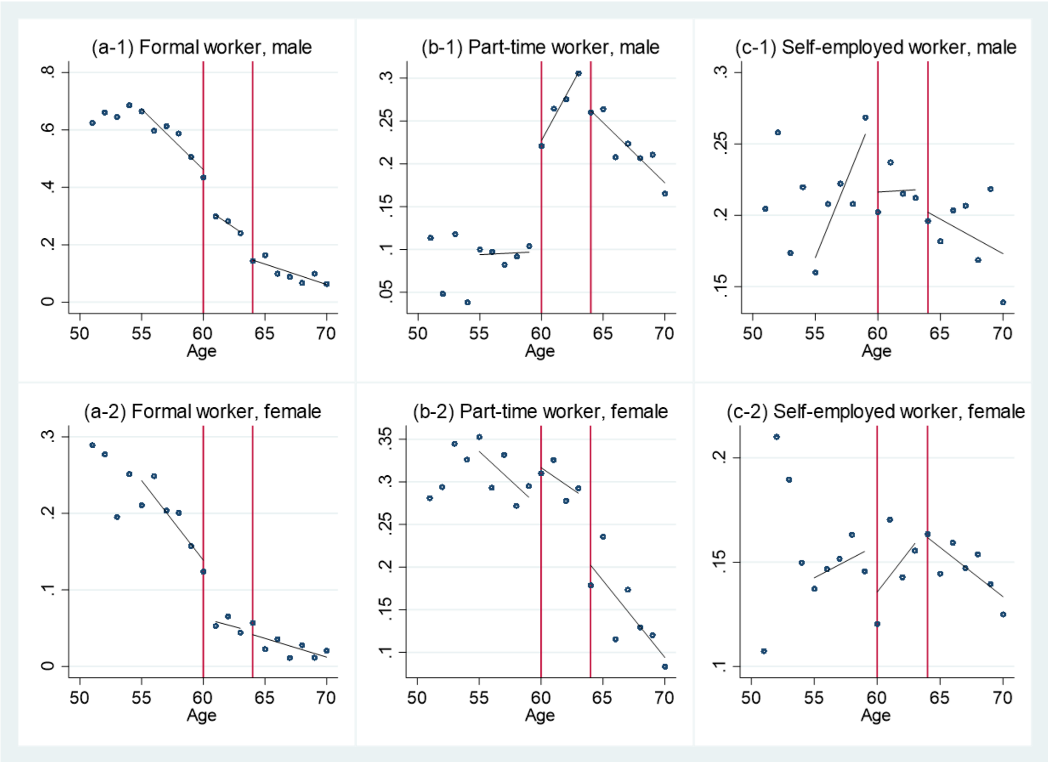
Figures and Tables

Figure 1. The distribution of self-reported actual or expected retirement age.



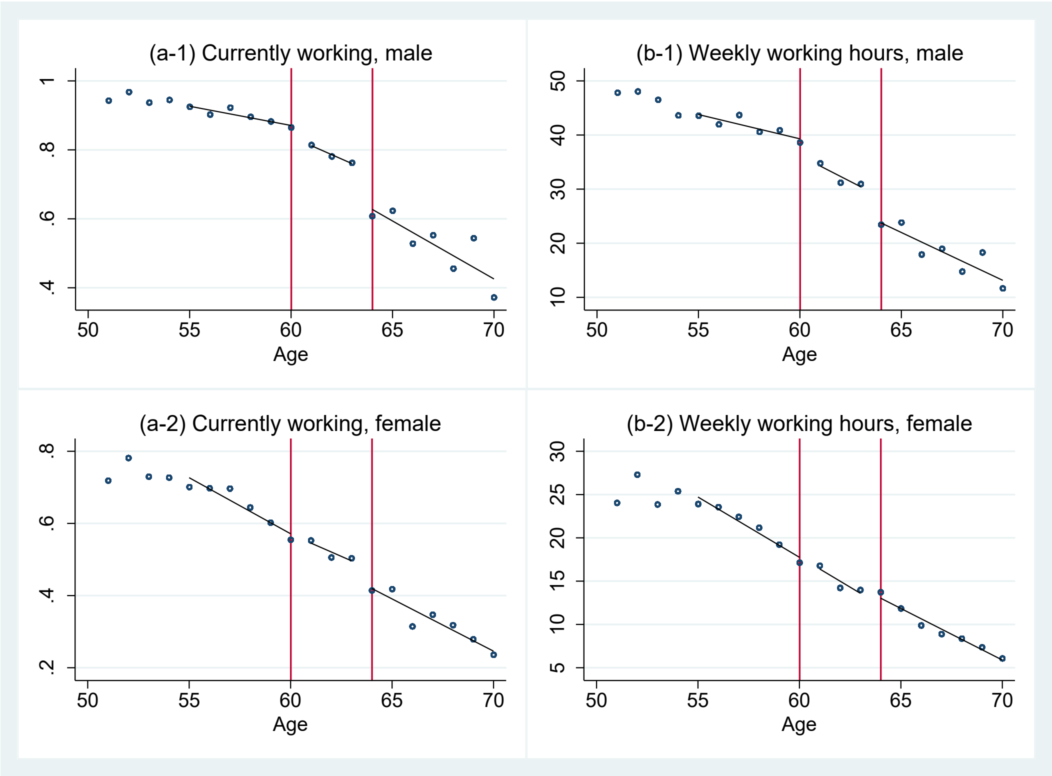
Source: Japanese Study of Ageing and Retirement (JSTAR)

Figure 2. Proportion of individuals by employment status and age



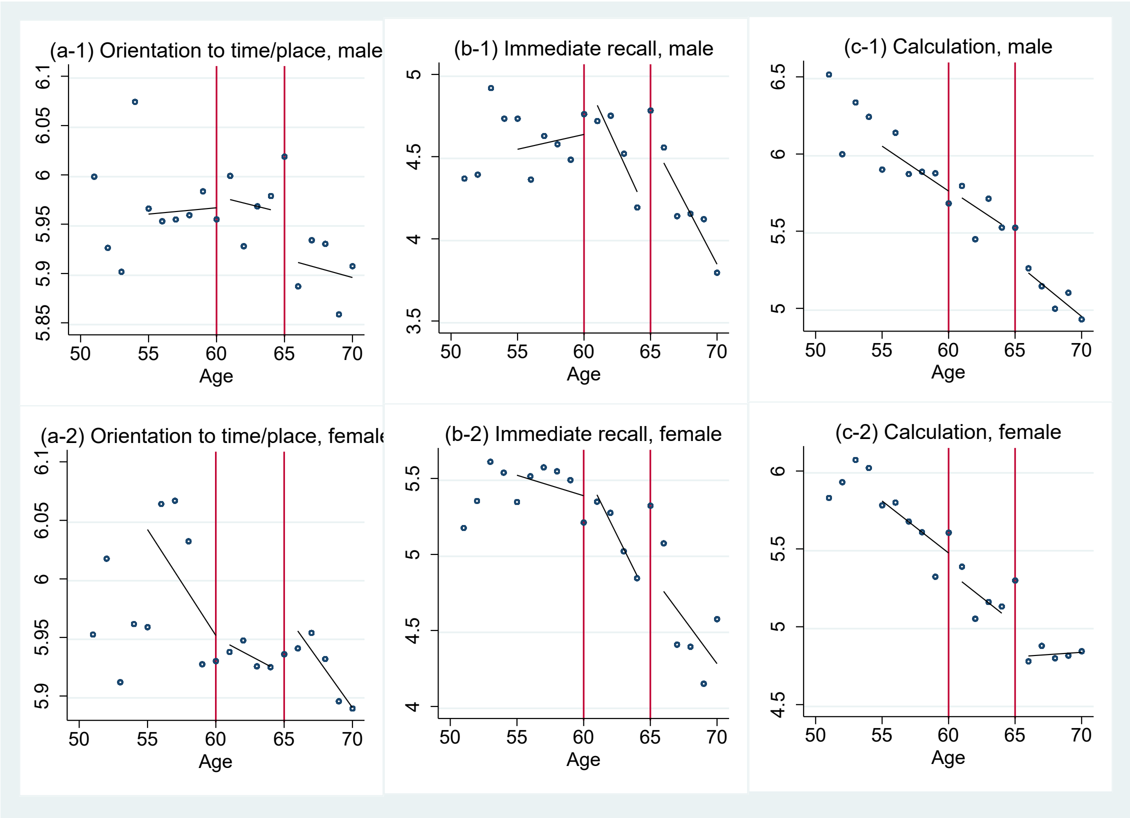
Source: Japanese Study of Ageing and Retirement (JSTAR)

Figure 3. Proportion of working individuals and average working hours by age



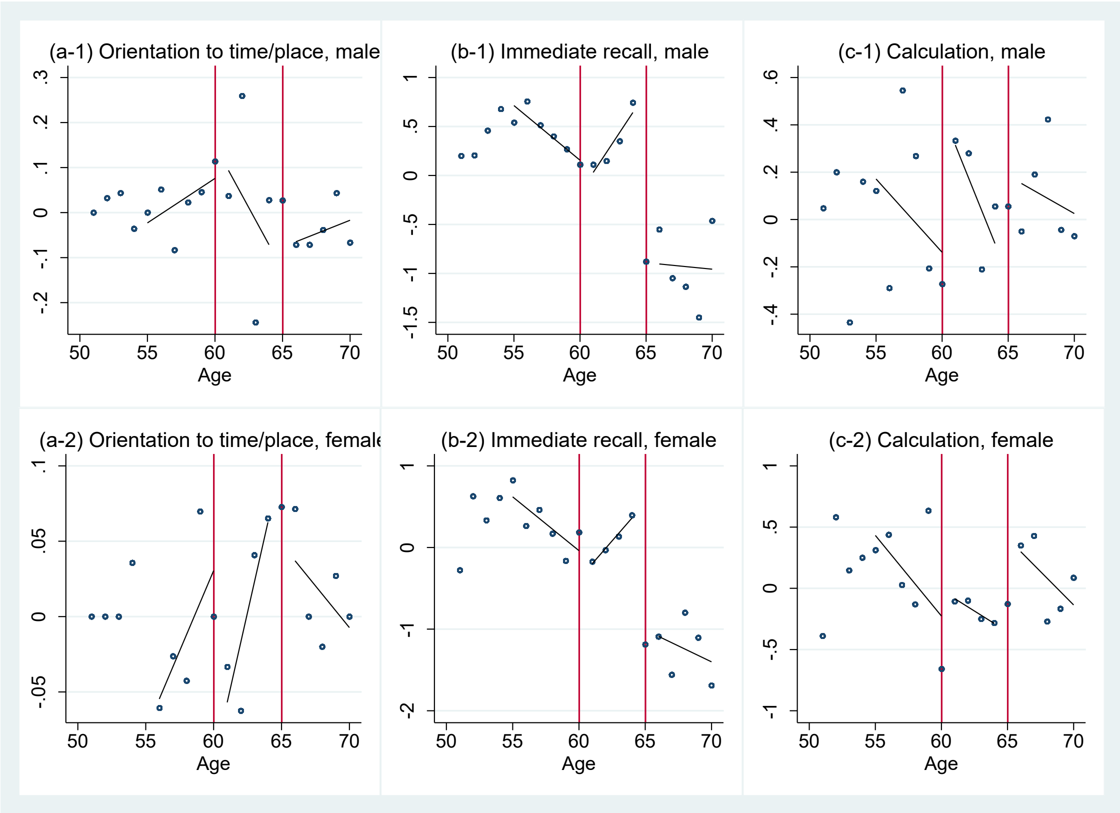
Source: Japanese Study of Ageing and Retirement (JSTAR)

Figure 4. Distribution of cognitive function measures by age



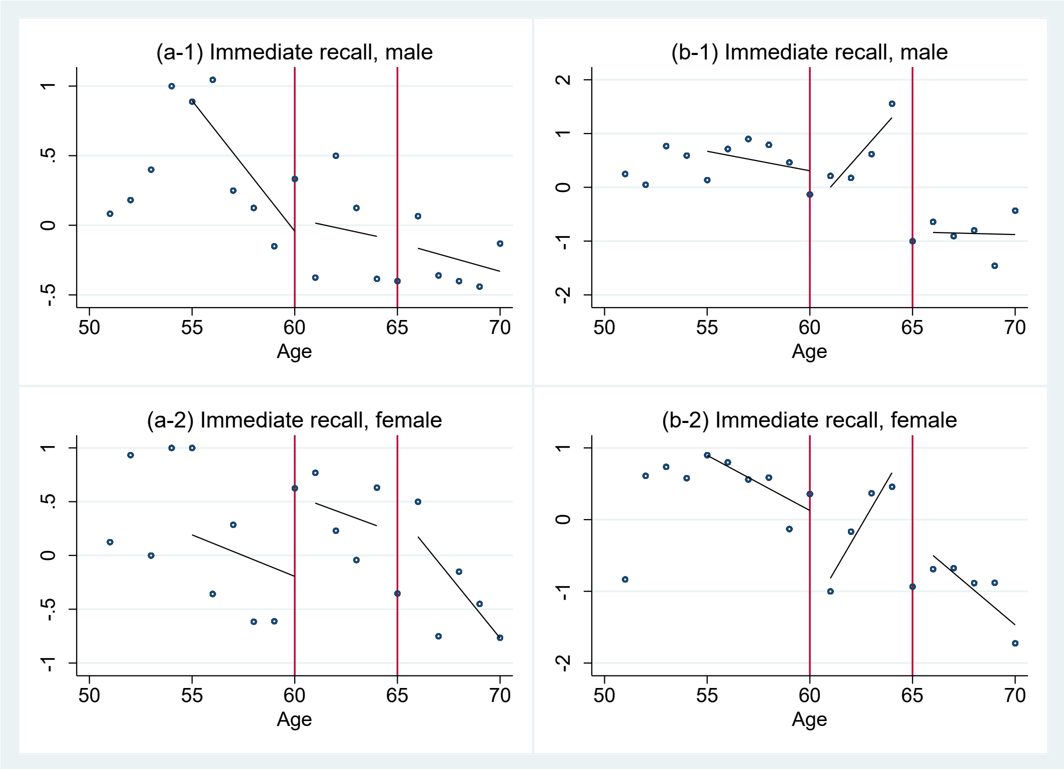
Source: Japanese Study of Ageing and Retirement (JSTAR)

Figure 5. Distribution of changes in cognitive function measures by age



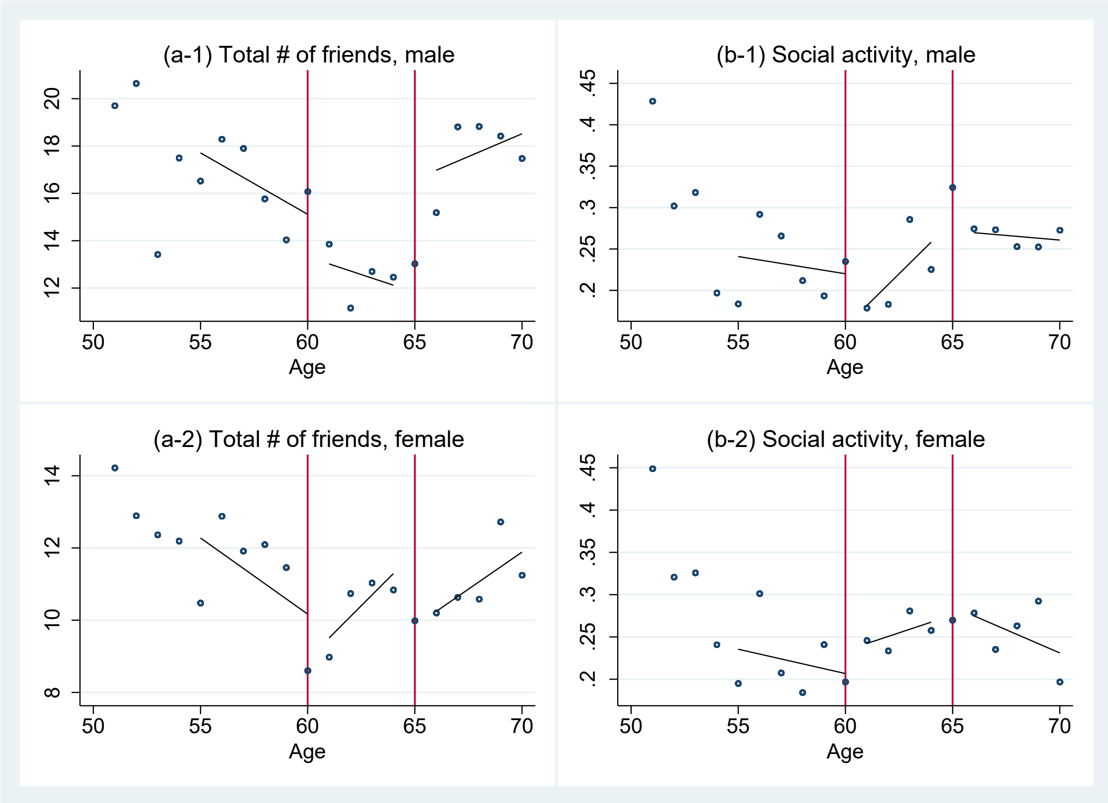
Source: Japanese Study of Ageing and Retirement (JSTAR)

Figure 6. Distribution of changes in cognitive function measures by participation in social activities



Source: Japanese Study of Ageing and Retirement (JSTAR)

Figure 7. Distribution of social capital measures by age



Source: Japanese Study of Ageing and Retirement (JSTAR)

Table 1. Descriptive statistics

	Male			Female		
	Obs.	Mean	S.D.	Obs.	Mean	S.D.
Cognitive measures						
Score on orientation to time/place	3,861	5.919	0.363	4,394	5.923	0.336
Score on immediate word recall	4,685	4.235	2.254	5,141	4.766	2.240
Score on calculation questions	3,765	5.500	2.112	4,268	5.169	2.109
Working status						
Whether currently working (1 = yes)	6,079	0.636	0.481	6,388	0.420	0.494
Weekly working hours	5,795	26.1	23.9	6,187	12.7	18.5
If working, whether permanent employee (1 = yes)	6,079	0.271	0.444	6,388	0.085	0.278
If working, whether part-time employee (1 = yes)	6,079	0.158	0.365	6,388	0.192	0.394
If working, whether self-employed (1 = yes)	6,079	0.196	0.397	6,388	0.135	0.342
Social capital measures						
Total number of friends	2,596	15.769	20.363	3,032	10.969	14.997
Whether participating social activities (1 = yes)	4,169	0.240	0.427	4,487	0.239	0.426
Personal and household characteristics						
Age	7,455	64.7	7.217	7,958	65.0	7.380
Education level*	7,430	2.604	1.569	7,912	2.188	1.160
Annual personal disposable income (10,000)	3,791	312.5	192.5	3,944	135.5	138.1
Whether has a spouse (1 = yes)	7,449	0.865	0.342	7,955	0.727	0.446
Whether has children (1 = yes)	7,451	0.876	0.330	7,951	0.886	0.318

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: *1: lower secondary; 2: upper secondary; 3: short-term college; 4: vocational school; 5: four-year university; 6: master level graduate school; 7: doctor level graduate school.

Table 2. Determinants of orientation to time and place: OLS estimates

	Men			Women		
	(1)	(2)	(3)	(4)	(5)	(6)
Whether currently working (1=yes)	0.053***	0.047***	0.036**	0.027**	0.024*	0.014
	[0.015]	[0.015]	[0.017]	[0.012]	[0.014]	[0.015]
Whether participating in social activity (1=yes)		0.006	0.014		0.011	0.008
		[0.013]	[0.013]		[0.012]	[0.013]
Total # of friends			0.000			0.000
			[0.000]			[0.000]
Age	0.014	0.025	0.005	0.041***	0.047***	0.037**
	[0.016]	[0.019]	[0.019]	[0.014]	[0.017]	[0.017]
Age squred	0	0	0	-0.000***	-0.000***	-0.000**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
educ==2	0.051***	0.054***	0.059**	0.072***	0.063***	0.069***
	[0.018]	[0.020]	[0.023]	[0.015]	[0.018]	[0.020]
educ==3	0.041	0.057*	0.080**	0.083***	0.069***	0.072***
	[0.033]	[0.034]	[0.032]	[0.018]	[0.021]	[0.023]
educ==4	0.045*	0.045	0.080***	0.071***	0.057***	0.055**
	[0.025]	[0.029]	[0.027]	[0.019]	[0.022]	[0.025]
educ==5	0.053***	0.058***	0.068***	0.082***	0.074***	0.076***
	[0.018]	[0.020]	[0.024]	[0.020]	[0.022]	[0.025]
educ==6	0.078***	0.100***	0.106***	0.121***	0.102***	0.074*
	[0.026]	[0.019]	[0.021]	[0.021]	[0.026]	[0.043]
educ==7	0.098***	0.102***	0.109***	0.112***	0.115***	
	[0.020]	[0.024]	[0.022]	[0.017]	[0.029]	
Whether having spouse (1=yes)	0.065***	0.058***	0.019	0.024*	0.043***	0.036**
	[0.021]	[0.023]	[0.024]	[0.013]	[0.016]	[0.017]
Whether having child (1=yes)	0.038*	0.055**	0.047*	0.000	-0.004	-0.024
	[0.022]	[0.025]	[0.027]	[0.017]	[0.020]	[0.018]
wave==2009	-0.008	0.003	-0.019	0.004	0.004	-0.002
	[0.014]	[0.015]	[0.022]	[0.012]	[0.015]	[0.018]
wave==2011	0.047***	0.043***	0.046***	0.028**	0.038***	0.041***
	[0.012]	[0.013]	[0.014]	[0.012]	[0.012]	[0.014]
Constant	5.396***	5.048***	5.674***	4.602***	0.000	4.767***
	[0.500]	[0.572]	[0.585]	[0.450]	[0.527]	[0.538]
Observations	3,843	2,898	2,081	4,365	3,319	2,544
R-squared	0.028	0.033	0.026	0.027	0.031	0.032

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 3. Determinants of short-term memory: OLS estimates

	Men			Women		
	(1)	(2)	(3)	(4)	(5)	(6)
Whether currently working (1=yes)	0.095	0.095	-0.028	0.060	0.022	-0.029
	[0.074]	[0.087]	[0.109]	[0.065]	[0.074]	[0.083]
Whether participating in social activity (1=yes)		0.281***	0.110		0.481***	0.244***
		[0.085]	[0.097]		[0.076]	[0.079]
Total # of friends			0.005**			0.003
			[0.002]			[0.003]
Age	0.497***	0.472***	0.284**	0.391***	0.437***	0.237**
	[0.083]	[0.099]	[0.131]	[0.076]	[0.089]	[0.108]
Age squred	-0.004***	-0.004***	-0.002**	-0.004***	-0.004***	-0.002***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
educ==2	0.447***	0.480***	0.481***	0.370***	0.417***	0.408***
	[0.075]	[0.090]	[0.115]	[0.069]	[0.080]	[0.092]
educ==3	0.547**	0.394	0.182	0.788***	0.722***	0.571***
	[0.256]	[0.308]	[0.381]	[0.122]	[0.139]	[0.153]
educ==4	0.789***	0.837***	0.954***	0.612***	0.547***	0.577***
	[0.160]	[0.189]	[0.233]	[0.105]	[0.120]	[0.134]
educ==5	0.874***	0.855***	0.832***	0.488***	0.346**	0.443**
	[0.094]	[0.111]	[0.136]	[0.149]	[0.176]	[0.191]
educ==6	0.715**	0.587*	0.706**	0.555	0.393	-0.685
	[0.289]	[0.322]	[0.357]	[1.445]	[1.800]	[1.991]
educ==7	0.385	-0.238	0.721	1.071***	0.938***	
	[0.813]	[0.913]	[1.448]	[0.173]	[0.178]	
Whether having spouse (1=yes)	-0.082	-0.208*	-0.312**	0.176***	0.266***	0.136
	[0.095]	[0.108]	[0.134]	[0.067]	[0.079]	[0.089]
Whether having child (1=yes)	0.395***	0.397***	0.563***	0.243**	0.202*	0.284**
	[0.108]	[0.123]	[0.151]	[0.103]	[0.115]	[0.128]
wave==2009	0.210***	0.218**	-0.245*	0.203***	0.172**	-0.353***
	[0.070]	[0.087]	[0.126]	[0.063]	[0.078]	[0.105]
wave==2011	-0.866***	-0.654***	-0.163	-0.712***	-0.520***	0.054
	[0.087]	[0.099]	[0.117]	[0.079]	[0.088]	[0.098]
Constant	-10.903***	-10.300***	-4.809	-5.810**	-7.505***	-1.716
	[2.646]	[3.139]	[4.097]	[2.414]	[2.827]	[3.403]
Observations	4649	3409	2328	5084	3765	2710
R-squared	0.099	0.077	0.034	0.132	0.123	0.057

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 4. Determinants of calculation ability: OLS estimates

	Men			Women		
	(1)	(2)	(3)	(4)	(5)	(6)
Whether currently working (1=yes)	0.178**	0.138	0.054	0.073	0.009	-0.078
	[0.079]	[0.090]	[0.106]	[0.068]	[0.077]	[0.087]
Whether participating in social activity (1=yes)		0.127	0.13		0.262***	0.323***
		[0.081]	[0.092]		[0.077]	[0.083]
Total # of friends			0.002			-0.003
			[0.002]			[0.003]
Age	-0.221***	-0.144	-0.078	-0.05	-0.063	-0.092
	[0.085]	[0.099]	[0.120]	[0.078]	[0.091]	[0.106]
Age squred	0.001**	0.001	0.000	0.000	0.000	0.000
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
educ==2	1.073***	1.180***	1.128***	0.985***	0.958***	1.043***
	[0.084]	[0.098]	[0.120]	[0.079]	[0.092]	[0.108]
educ==3	1.479***	1.306***	0.979***	1.270***	1.146***	1.262***
	[0.228]	[0.265]	[0.343]	[0.123]	[0.140]	[0.153]
educ==4	0.720***	0.709***	0.580**	0.968***	0.892***	0.961***
	[0.169]	[0.198]	[0.236]	[0.112]	[0.128]	[0.145]
educ==5	1.763***	1.696***	1.641***	1.828***	1.746***	1.814***
	[0.096]	[0.112]	[0.133]	[0.132]	[0.148]	[0.165]
educ==6	1.678***	1.652***	1.708***	1.911*	1.232	1.088
	[0.241]	[0.288]	[0.295]	[1.024]	[1.206]	[1.383]
educ==7	2.867***	2.708***	2.243*	3.425***	3.143***	
	[0.518]	[0.638]	[1.184]	[0.188]	[0.175]	
Whether having spouse (1=yes)	0.267***	0.273**	0.209	0.177**	0.156*	0.116
	[0.100]	[0.114]	[0.134]	[0.073]	[0.085]	[0.095]
Whether having child (1=yes)	0.194*	0.111	0.169	0.09	0.073	-0.11
	[0.108]	[0.120]	[0.140]	[0.101]	[0.113]	[0.125]
wave==2009	0.016	-0.082	-0.248**	-0.064	-0.083	-0.369***
	[0.073]	[0.089]	[0.121]	[0.070]	[0.086]	[0.111]
wave==2011	0.340***	0.376***	0.490***	0.147*	0.189**	0.122
	[0.088]	[0.095]	[0.105]	[0.082]	[0.088]	[0.098]
Constant	12.066***	9.856***	7.905**	6.936***	7.456***	8.587***
	[2.687]	[3.119]	[3.737]	[2.477]	[2.873]	[3.320]
Observations	3,752	2,839	2,049	4,241	3,234	2,490
R-squared	0.149	0.153	0.146	0.121	0.12	0.128

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 5. Determinants of orientation to time and place: panel data estimates

	Male				Female			
	RE		FE		RE		FE	
Whether currently working	0.055***	0.047***	0.110***	0.130*	0.028**	0.024*	0.021	0.048
	[0.014]	[0.015]	[0.041]	[0.070]	[0.012]	[0.013]	[0.041]	[0.067]
Whether participating social activity		0.006		-0.030		0.011		-0.072
		[0.014]		[0.058]		[0.013]		[0.050]
Age	0.018	0.025	0.153**	0.158	0.040***	0.047***	0.035	0.120
	[0.016]	[0.017]	[0.069]	[0.118]	[0.014]	[0.015]	[0.060]	[0.097]
Age squred	-0.000	-0.000*	-0.001**	-0.001	-0.000***	-0.000***	-0.000	-0.001
	[0.000]	[0.000]	[0.001]	[0.001]	[0.000]	[0.000]	[0.000]	[0.001]
educ==2	0.052***	0.054***			0.077***	0.064***		
	[0.015]	[0.016]			[0.013]	[0.015]		
educ==3	0.040	0.057			0.089***	0.070***		
	[0.044]	[0.045]			[0.021]	[0.023]		
educ==4	0.050*	0.045			0.077***	0.058***		
	[0.030]	[0.031]			[0.020]	[0.022]		
educ==5	0.056***	0.058***			0.091***	0.077***		
	[0.018]	[0.019]			[0.025]	[0.027]		
educ==6	0.079	0.100*			0.127	0.103		
	[0.053]	[0.054]			[0.176]	[0.197]		
educ==7	0.100	0.102			0.117	0.117		
	[0.113]	[0.118]			[0.237]	[0.333]		
Whether having spouse	0.066***	0.058***			0.024*	0.043***		
	[0.019]	[0.019]			[0.012]	[0.014]		
Whether having child	0.034*	0.055***			-0.001	-0.004		
	[0.020]	[0.020]			[0.017]	[0.019]		
wave==2009	-0.008	0.003			0.005	0.004		
	[0.012]	[0.015]			[0.011]	[0.014]		
wave==2011	0.047***	0.043***			0.030**	0.039***		
	[0.016]	[0.017]			[0.014]	[0.015]		
Constant	5.280***	5.048***	1.090	0.812	4.641***	4.428***	4.711**	2.286
	[0.506]	[0.533]	[2.257]	[3.828]	[0.432]	[0.482]	[1.971]	[3.182]
Observations	3843	2898	3843	2898	4365	3319	4365	3319
R-squared			0.014	0.014			0.001	0.009
rho	0.176	0.000	0.522	0.441	0.244	0.070	0.552	0.509

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 6. Determinants of short-term memory: panel data estimates

	Male				Female			
	RE		FE		RE		FE	
Whether currently working	0.087	0.113	0.023	0.102	0.085	0.015	0.246	-0.138
	[0.081]	[0.093]	[0.151]	[0.228]	[0.071]	[0.080]	[0.176]	[0.263]
Whether participating social activity		0.276***		-0.135		0.486***		0.114
		[0.083]		[0.213]		[0.078]		[0.207]
Age	0.693***	0.588***	-0.194	-0.163	0.542***	0.573***	-0.752**	-0.848*
	[0.089]	[0.101]	[0.308]	[0.469]	[0.079]	[0.090]	[0.308]	[0.433]
Age squred	-0.006***	-0.005***	-0.003	-0.003	-0.005***	-0.005***	0.000	0.000
	[0.001]	[0.001]	[0.002]	[0.003]	[0.001]	[0.001]	[0.002]	[0.003]
educ==2	0.468***	0.494***			0.437***	0.454***		
	[0.096]	[0.105]			[0.084]	[0.094]		
educ==3	0.632**	0.460			0.896***	0.766***		
	[0.271]	[0.290]			[0.134]	[0.146]		
educ==4	0.856***	0.904***			0.701***	0.609***		
	[0.190]	[0.206]			[0.126]	[0.139]		
educ==5	0.962***	0.884***			0.610***	0.422**		
	[0.112]	[0.122]			[0.149]	[0.165]		
educ==6	0.843***	0.700**			0.224	-0.161		
	[0.320]	[0.345]			[1.016]	[1.149]		
educ==7	0.448	-0.229			1.193	1.143		
	[0.610]	[0.655]			[1.512]	[2.116]		
Whether having spouse	-0.129	-0.200			0.173**	0.248***		
	[0.115]	[0.127]			[0.077]	[0.085]		
Whether having child	0.407***	0.404***			0.248**	0.170		
	[0.118]	[0.128]			[0.105]	[0.116]		
wave==2009	0.304***	0.320***	1.528***	1.545***	0.297***	0.298***	1.681***	2.003***
	[0.062]	[0.081]	[0.081]	[0.128]	[0.062]	[0.076]	[0.078]	[0.118]
wave==2011	-1.074***	-0.752***			-0.887***	-0.661***		
	[0.078]	[0.091]			[0.072]	[0.082]		
Constant	-17.064***	-14.006***	29.769***	27.380*	-10.624***	-11.743***	51.219***	57.027***
	[2.839]	[3.176]	[10.607]	[16.187]	[2.522]	[2.839]	[10.629]	[14.992]
Observations	4649	3409	4649	3409	5084	3765	5084	3765
r2_o	0.098	0.077	0.041	0.026	0.131	0.121	0.092	0.078
rho	0.495	0.470	0.897	0.885	0.385	0.422	0.910	0.932

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 7. Determinants of calculation ability: panel data estimates

	Male				Female			
	RE		FE		RE		FE	
Whether currently working	0.175**	0.128	0.007	-0.162	0.069	0.007	0.053	0.052
	[0.080]	[0.090]	[0.200]	[0.306]	[0.071]	[0.079]	[0.221]	[0.343]
Whether participating social activity		0.130		-0.129		0.278***		0.219
		[0.081]		[0.255]		[0.078]		[0.259]
Age	-0.208**	-0.136	-0.280	-0.009	-0.041	-0.058	0.294	0.295
	[0.091]	[0.103]	[0.344]	[0.525]	[0.084]	[0.095]	[0.332]	[0.510]
Age squred	0.001*	0.001	0.002	0.000	0.000	0.000	-0.002	-0.002
	[0.001]	[0.001]	[0.003]	[0.004]	[0.001]	[0.001]	[0.003]	[0.004]
educ==2	1.059***	1.155***			1.008***	0.970***		
	[0.089]	[0.100]			[0.083]	[0.093]		
educ==3	1.456***	1.233***			1.285***	1.168***		
	[0.252]	[0.277]			[0.132]	[0.144]		
educ==4	0.705***	0.670***			0.954***	0.901***		
	[0.173]	[0.193]			[0.123]	[0.135]		
educ==5	1.736***	1.663***			1.837***	1.762***		
	[0.105]	[0.117]			[0.149]	[0.166]		
educ==6	1.686***	1.649***			1.836*	0.974		
	[0.299]	[0.327]			[1.070]	[1.252]		
educ==7	2.880***	2.699***			3.465**	3.163		
	[0.622]	[0.690]			[1.405]	[1.983]		
Whether having spouse	0.267**	0.276**			0.193**	0.166**		
	[0.106]	[0.120]			[0.076]	[0.085]		
Whether having child	0.214*	0.118			0.065	0.046		
	[0.113]	[0.125]			[0.106]	[0.115]		
wave==2009	0.051	-0.038			-0.029	-0.047		
	[0.063]	[0.080]			[0.060]	[0.078]		
wave==2011	0.390***	0.416***			0.198**	0.227**		
	[0.091]	[0.099]			[0.083]	[0.090]		
Constant	11.613***	9.584***	13.213	5.599	6.552**	7.224**	-4.310	-6.166
	[2.868]	[3.241]	[11.202]	[17.076]	[2.643]	[2.975]	[10.838]	[16.674]
Observations	3752	2839	3752	2839	4241	3234	4241	3234
r2_o	0.149	0.153	0.033	0.045	0.120	0.120	0.006	0.043
rho	0.354	0.370	0.638	0.649	0.373	0.321	0.629	0.648

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 8. Effects of retirement on social capital and cognitive function measures: fuzzy RDD estimates

	Men				Women	
Cutoff	60		64	64/65	60	
Bandwidth	(1) BW=3	(2) BW=4	(3) BW=3	(4) BW=3	(5) BW=3	(6) BW=4
$R^+ - R^-$	0.211	0.212	0.135	0.131	0.105	0.105
$(C^+ - C^-)/(R^+ - R^-)$						
A1: Number of friends						
RD point estimate	-3.713	-5.680	1.497	10.46	-22.4 ***	-18.6 ***
Standard error	5.071	3.857	6.981	7.273	7.603	5.854
Obs.	687	910	652	634	742	997
A2: Likelihood of participating in social activities						
RD point estimate	-0.118	-0.033	0.165	-0.053	0.066	0.337 **
Standard error	0.081	0.064	0.142	0.153	0.202	0.153
Obs.	1,131	1,464	1,046	1,023	1,099	1,131
B1: Orientation ability scores						
RD point estimate	0.021	0.005	-0.059	-0.701 ***	0.124	0.067
Standard error	0.066	0.047	0.110	0.109	0.165	0.113
Obs.	995	1,292	972	979	1,047	1,373
B2: Immediate word recall scores						
RD point estimate	1.253 **	1.205 ***	-1.734 ***	2.637 ***	-1.129	-1.230
Standard error	0.492	0.368	0.616	0.641	1.078	0.778
Obs.	1,113	1,447	1,058	1,087	1,096	1,448
B3: Calculation ability scores						
RD point estimate	-0.809 *	-0.577 *	-0.289	-0.461	-0.403	-0.877
Standard error	0.464	0.352	0.670	0.679	1.239	0.889
Obs.	970	1,260	945	952	1,020	1,341
C1: Orientation ability scores (differenced)						
RD point estimate	0.440 **	0.241	0.888	1.468 **	-1.004	-0.924 **
Standard error	0.214	0.148	0.726	0.678	0.882	0.399
Obs.	241	316	210	205	239	318
C2: Immediate word recall scores (differenced)						
RD point estimate	-0.877	-1.148 *	-0.333	-8.924 ***	-0.204	-1.399
Standard error	1.015	0.660	2.370	1.988	3.108	1.760
Obs.	247	327	260	304	242	324
C3: Calculation ability scores (differenced)						
RD point estimate	2.827 **	1.408 **	1.729	3.353	-5.238	-3.708
Standard error	0.953	0.671	3.041	3.154	5.037	2.495
Obs.	224	298	199	205	229	307

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Table 9. Heterogeneous effects of retirement on changes in short-term memory by social activity participation: fuzzy RDD estimates

Cutoff	60				65	
	Male		Female		Male	
	With SA	Without SA	With SA	Without SA	With SA	Without SA
Differenced orientation score						
RD point estimate	-0.110	0.839 ***	0.294	-2.473 **	0.659	2.722
Standard error	0.342	0.278	58.6	1.192	0.532	2.600
Obs.	82	133	96	125	75	110
Differenced immediate recall						
RD point estimate	-0.130	-1.730	20.39 *	-11.3 **	-2.667	-15.1 ***
Standard error	2.258	1.200	11.1	5.340	2.629	5.790
Obs.	80	139	95	128	87	148
Differenced calculation score						
RD point estimate	10.8 ***	0.886	-9.64	-6.686	3.389	-1.750
Standard error	2.37	0.987	351.8	4.410	3.286	10.590
Obs.	77	121	91	121	70	104

Source: Japanese Study of Ageing and Retirement (JSTAR)
Notes: Standard errors in brackets; * p<0.10 ** p<0.05 *** p<0.01

Appendix A: Questions used to assess cognitive abilities in the JSTAR survey

A. Orientation to time and place

1. First, I'd like to ask about today's date. What year is it this year? You may answer using either the Japanese era or the Western calendar.
2. What month is it now?
3. What is today's date?
4. What day of the week is it today?
5. What is the name of the prefecture for this location?
6. What is the name of the city/ward/town/village for this location?

B. Immediate word recall

The interviewer will read the following list aloud only once:

"Dog...package...train...baseball...cat...vegetable...horse...airplane...sea... swimming...bicycle"

Now, I will ask you to recall and say out loud as many of the words I just read as you can remember.

C. Calculation questions

1. Now, please subtract 7 from 100.
2. Then, please subtract 7 again from that number.
3. Then, please subtract 7 again.
4. Then, please subtract 7 again.
5. Then, please subtract 7 again from that number.
6. Please estimate the answer using mental calculation. Assume the following situation: Suppose 10 percent of people in a certain town have a disease. If the town has a population of 1,000, about how many people are expected to have the disease?
    1) 100 people
    2) 10 people
    3) 30 people
    4) 900 people
    5) Other answer
    6) Don't know
    7) Refused to answer

7. A store decides to have a half-price sale on all items. If an item was originally sold for 300 yen, how much would it cost during the sale?

1) 150 yen
2) 600 yen
3) Other answer
4) Don't know
5) Refused to answer

8. A used car is being sold for 6,000 yen. This is one-third of the price of a new car of the same model. What is the price of the new car?

1) 9,000 yen
2) 4,000 yen
3) 8,000 yen
4) 12,000 yen
5) 18,000 yen
6) Other answer
7) Don't know
8) Refused to answer

9. This is a compound interest problem. Suppose you deposit 2,000 yen into a savings account, and it earns 10% interest annually. Without additional deposits or withdrawals, how much will the account balance be at the end of two years?

1) 2,420 yen
2) 2,020 yen
3) 2,100 yen
4) 2,200 yen
5) 2,400 yen
6) Other answer
7) Don't know
8) Refused to answer