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Family-work history and inequalities in old-age cognition in China

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ABSTRACT

Prior work showed that an individual's history of partnership, fertility, or employment was separately linked to old-age cognition, but little is known about how family-work history influences later-life cognition, especially in low- and middle-income countries. Our sample comprised respondents aged 50 and above in 2014 interviewed in regular (2011, 2013, 2015, 2018, and 2020) and life-history (2014) waves of the China Health and Retirement Longitudinal Study (CHARLS, n = 8,535). After conducting sequence analysis and identifying six statistically justifiable and context-attuned family-work trajectories, we investigated how Chinese older adults' family-work history (age 18–50) related to their cognition measured by immediate word recall (0–10) and mental status scores (0–11) cross-sectionally (pairwise comparison) and longitudinally (linear mixed-effects models). We found that older adults in the "early marriage, ≥2 children, agriculturally employed" trajectory had lowest baseline immediate recall and mental status scores compared with whom slower declines in immediate recall rather than mental status were found for those in "late marriage, ≥2 children, agriculturally employed (b = 0.02, 95 % confidence interval (CI): 0.00, 0.03)", "married, ≥2 children, not in labour force (mainly early retirees, b = 0.04, 95 % CI: 0.01, 0.06)", and "married, ≥2 children, non-agriculturally employed in public sector (b = 0.04, 95 % CI: 0.03, 0.06)" trajectories. Our findings imply that inequalities in China's pre-1964 birth cohorts' cognition were affected by marriage timing and, to a greater extent, driven by midlife employment sectors which determined substantial inequalities in access to social welfare.

1. Introduction

In ageing societies across the globe, older adults' cognitive decline and its progression to mild cognitive impairment (MCI) and Alzheimer's Disease and Related Dementias (ADRD) pile growing pressure on healthcare and social care systems. Apart from contemporaneous behavioural, dietary and neuropathological factors, a life-course perspective is critical to understanding early-life and midlife risk factors for later-life cognitive decline (Kuh et al., 2003; Livingston et al., 2024). For example, individuals' educational attainment in young adulthood directly relates to building cognitive reserve (Stern et al., 2020) and it also indirectly affects old-age cognition by exposing individuals to varying levels of cognitive stimulations in family life (marriage, childbearing, and childrearing) and jobs in adulthood (Baldivia et al., 2008). The education-cognition link is often observed: a recent gerontological study using the Harmonized Cognitive Assessment Protocols (HCAPs) showed that across the United States, England, China, India, and Mexico, more education was consistently associated with better general cognitive function (Zhang et al., 2024).

Empirical research on midlife determinants of old-age cognition, mainly conducted in Western countries, often separately scrutinised individuals' histories of partnership (e.g., Håkansson et al., 2009), fertility (e.g., Read and Grundy, 2016; Zhang, 2022), and employment (e.g., Kobayashi and Feldman, 2019). This body of research repeatedly found beneficial effects of stable marriage as well as sustained employment and high-skilled occupations in midlife on old-age cognition, but the evidence regarding fertility history was mixed. As individuals' family life and employment are intertwined (e.g., taking care of children may prevent mothers from returning to the labour force), many studies sought to unveil the association of family-work history across individuals' partnership, fertility, and employment domains with later-life health outcomes (Machů et al., 2022). Although a recent systematic review of 48 studies (Machů et al., 2022) concluded that family-work history characterised by an early transition to parenthood,

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single parenthood, and weak ties to employment were associated with worse old-age health, cognition was rarely tested, especially in low- and middle-income countries (LMICs).

The lack of evidence on family-work history and old-age cognition in LMICs warrants further investigation. Given that the numbers of older adults with dementia are greater and rising faster in LMICs than in high-income countries (HICs) (Livingston et al., 2020), there is a pressing need to understand modifiable early-life and midlife risk factors for later-life cognition in LMICs to facilitate preventions and interventions so as to improve the cognitive function of future older generations. However, prior work from LMICs either only examined fertility history in South Africa (Phillips et al., 2023) and China (Du et al., 2023; Heys et al., 2011; Li et al., 2016; Weng and Yang, 2023; Yang et al., 2022) or only explored employment history in South Africa (Yu et al., 2024) and China (Wang et al., 2024). To the best of our knowledge, only Zhao and Gao (2023) investigated the joint history of fertility and employment in China but the measure of cognition was not refined and employment sectors were not distinguished. In this study, we focus on China who has a large and rapidly ageing population with a high prevalence of dementia (6 %, about 15 million older adults) and MCI (15.5 %, about 39 million older adults) among citizens aged 60+ (Jia et al., 2020). Using data from the life-history wave (2014) and regular waves (2011, 2013, 2015, 2018, 2020) of the nationally representative China Health and Retirement Longitudinal Study (CHARLS), we aim to assess how respondents' family-work history across partnership, fertility, and employment domains relates to inequality in later-life cognition cross-sectionally and longitudinally.

2. Background

2.1. Family-work history and old-age cognition: biological and psychosocial pathways

Due to the sparse research on the associations between family-work history and old-age cognition (Ice et al., 2020; Mayeda et al., 2020; Zhao and Gao, 2023), we first reviewed literature that investigated only one domain (partnership, fertility, or employment) of individuals' family-work history. In regards to partnership history, a protective effect of staying in marriage against cognitive decline was found: lifelong singlehood (being never married) (Sironi, 2023; Skirbekk et al., 2023; Sommerlad et al., 2018), being persistently widowed or divorced in midlife (Håkansson et al., 2009), and being intermittently divorced from age 44 to 68 (Skirbekk et al., 2023) were associated with worse cognition. Among previously married individuals, older age at first marriage or shorter duration spent unmarried was separately linked to better initial memory performance (Zaheed et al., 2021). Couples may enjoy health benefits from shared economic resources, mutual psychological support and greater social engagement. Besides, history of marital disruptions and loss was linked to impaired immune system and compromised cardiovascular and metabolic functioning (Rote, 2017), which may be correlated with worse cognition.

A voluminous body of research used various indicators for fertility history: parenthood status, age at first birth (i.e., the timing of parenthood), age at last birth, parity, age at menopause, and reproductive span (i.e., years between menarche and menopause), but the definitions of low and high parity, as well as early or late parenthood, varied across studies. Researchers have long speculated that becoming a parent at the desirable time of one's life and having an "optimal" number of children would discourage health-damaging behaviour, build wider social network, and expose parents to more cognitively stimulating activities. In comparison, off-time early transition to parenthood, high parity, and other non-standard family profile may hinder human capital accumulation and labour force participation, dilute socio-economic resources, increase childrearing stress and marital strain, and incur social sanctions (Arpino et al., 2023; Zhang, 2022), with long-term implications for later-life cognition. Specifically for women whose longer estrogen exposure is beneficial for old-age cognition which is reduced during pregnancy, lower parity is supposedly linked to better cognitive performance in later life (Li et al., 2016).

Empirical work, however, produced mixed findings. On the one hand, prior work had repeatedly found the associations of worse cognition with low parity (including childlessness) (Bae et al., 2020; Bordone and Weber, 2012; Heys et al., 2011; Mekonnen et al., 2025; Read and Grundy, 2016; Saenz et al., 2019; Sironi, 2023; Zhang, 2022), high parity (Bae et al., 2020; Bonsang and Skirbekk, 2022; Bordone and Weber, 2012; Du et al., 2023; Fu et al., 2023; Gemmill and Weiss, 2021; Li et al., 2016; Mekonnen et al., 2025; Read and Grundy, 2016; Saenz et al., 2019; Weng and Yang, 2023; Yang et al., 2022; Zhang, 2022), early parenthood (Fu et al., 2023; Gemmill and Weiss, 2021; Read and Grundy, 2016; Thomeer et al., 2024; Zhang, 2022), late parenthood (Yang et al., 2022; Zhang, 2022), very early/late age at last birth (Yang et al., 2022; Zhang, 2022), and premature/early or late menopause (Guo et al., 2025). Nevertheless, some associations disappeared when socio-economic status and health were adjusted for (Gemmill and Weiss, 2021; Read and Grundy, 2016; Sironi, 2023). On the other hand, some contradictory findings were also reported: better cognition was associated with high parity (Phillips et al., 2023; Zhang and Fletcher, 2024), late parenthood (Read and Grundy, 2016; Weng and Yang, 2023), and longer reproductive period (Heys et al., 2011; Li et al., 2016). Having at least one child (Bordone and Weber, 2012; Phillips et al., 2023; Zhang and Fletcher, 2021) was linked to better cognition, but using UK biobank data, Zhang et al. (2023) found that mothers had worse cognitive function in some domains than childless women. This was also observed in a recent US study that having any child was associated with worse self-reported memory for women (Thomeer et al., 2024).

In contrast, the evidence on how employment history affects old-age cognition is more conclusive. Consistently undertaking high-skilled professional jobs was associated with higher numerical reasoning scores in the US (Kobayashi and Feldman, 2019), higher general cognitive function for older Americans and Mexicans and for older Indian women (Kobayashi et al., 2023), better cognition for European men (Greenberg and Burgard, 2021), and higher memory scores in South Africa (Yu et al., 2024). Other studies showed that sustained mid-life employment was associated with higher memory scores in South Africa (Yu et al., 2024) and Europe (Greenberg and Burgard, 2021) and lower dementia risks in the United States (Pacca et al., 2025), while part-time employment was beneficial for women's cognitive functioning in Europe (Bertogg and Leist, 2023). In China, Wang et al. (2024) found that compared with older adults in lifelong agricultural work, those in lifelong non-agricultural work had better global cognitive function and mental intactness and those who shifted from agricultural to non-agricultural work around age 30 also had better global cognitive function. These studies suggested that persistently being employed may constitute a source of financial stability and enhance social network, while high-skilled occupation may provide more cognitive stimulations, which may lead to better cognitive performance in later life.

In spite of the increasing recognition that an individual's multiple roles in midlife as a partner, a parent, and an employee, or the lack of these, are interacted in complex ways (Machů et al., 2022), to date there are only a few studies examining the effects of family-work history on later-life cognition. Ice et al. (2020) found that in Europe, compared with full-time working mothers, partnered mothers who mainly worked part-time had better cognitive function, while partnered mothers who were mainly unpaid caregivers or who did other unpaid activities had worse cognitive function. Mayeda et al. (2020) reported that American women who worked for pay in early adulthood and midlife experienced slower rates of later-life memory decline regardless of marital and parenthood status. Zhao and Gao (2023) showed that compared with urban working mothers with one child, urban multiparous or nulliparous women in China had worse cognition irrespective of employment status, and early exit from workforce was detrimental to both men's and women's cognition. Ice et al. (2020) and Mayeda et al. (2020) only

focused on older women and did not examine parity. Zhao and Gao (2023) focused on urban men and women in China whose midlife employment sector was not differentiated. Moreover, Zhao and Gao (2023) only examined inequalities in cognition cross-sectionally and did not explain how older adults' cognition score ranging from 0 to 12 was operationalised (cognition was one of the health outcomes they tested). In view of this, more research is needed to shed light on the effects of a more holistic and comprehensive family-work history on older adults' cognition, especially in non-Western settings.

2.2. The Chinese context

Although trends of later and less marriage and childbearing were observed in recent decades in China (Raymo et al., 2015), a recent study analysing data from the China Family Panel Studies (CFPS) showed that the family life course for China's 1930–39, 1940–49, and 1950-59 birth cohorts was marked by continuity despite change (Van Winkle and Wen, 2023). These birth cohorts were characterised by persistent high marriage rates (>95 %), low divorce rates (<2 %), low childless rates (<3 %), and young ages at first marriage (<23.25 years old) and first childbirth (<25 years old), albeit with declining average number of children (3.58 for 1930-39 birth cohort, 2.72 for 1940-49 birth cohort, and 2.01 for 1950-59 birth cohort) resulting from the one-child policy introduced in 1979 (Van Winkle and Wen, 2023).

The employment conditions of older birth cohorts in China were rigidly regulated by a few interrelated social institutions such as the household registration (*hukou*) system and urban work unit (*danwei*) system (Wu, 2019). Introduced in the 1950s, *hukou* system divided Chinese population into having agricultural (rural) or non-agricultural (urban) *hukou* status and imposed stringent restrictions on converting from rural to urban *hukou*, creating marked inequalities in terms of education opportunities, income, housing, childcare and healthcare services between rural and urban populations (Wu and Treiman, 2004). Rural citizens undertook agricultural jobs, while urbanites were affiliated with work units (e.g., government or public institutions, state-owned enterprises, collectively owned enterprises) with varying welfare benefits in the redistributive hierarchy, contributing to decades-long high labour force participation rates among men and women in China. The market-oriented economic reforms since the late 1970s gave rise to a large number of rural-to-urban migrants whose conversion to urban *hukou* holders became less insurmountable, the reshuffling of state-owned enterprises (e.g., massive layoffs from 1990s to mid-2000s), the development of private enterprises, and declining labour force participation among women (Song et al., 2025; Wu, 2019). Although researchers uncovered *hukou*-based health inequalities (e.g., depressive symptoms) in China (Song and Smith, 2021) and *hukou* status was strongly associated with employment sector in the pre-1978 period, there is a lack of evidence explicitly examining how older adults' major employment sector in midlife relates to later-life cognition in China.

In this study, our objective is to investigate how family-work history across partnership, fertility, and employment domains relates to inequality in later-life cognition cross-sectionally and longitudinally in China. We did not know *a priori* the number and nature of family-work trajectories that would be identified by sequence analysis using CHARLS data. However, informed by prior empirical work (Du et al., 2023; Heys et al., 2011; Ice et al., 2020; Li et al., 2016; Mayeda et al., 2020; Wang et al., 2024; Weng and Yang, 2023; Yang et al., 2022; Zhao and Gao, 2023) and the Chinese context (Song et al., 2025; Wu, 2019), we hypothesise that family-work history characterised by early marriage (presumably early transition to parenthood and high parity) and longer time spent in agricultural employment would be associated with poorer cognitive function in China.

3. Methods

3.1. Data and sample

Data were drawn from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative survey of community-dwelling adults aged 45 and above (Phillips et al., 2021; Wahrendorf et al., 2022; Zhao et al., 2014). Through multistage probability-proportional-to-size (PPS) sampling, the baseline wave of CHARLS fielded in 2011 had a response rate of 81 %, collecting demographic, socio-economic and health data from 17,708 participants who were regularly followed every two years (Zhao et al., 2013) with a special life-history wave conducted in 2014. At regular follow-up waves (2013, 2015, 2018, 2020), the response rates for longitudinal sample were above 86 % (Zhao et al., 2023). We used data from regular waves (2011, 2013, 2015, 2018, 2020) and the life history wave (2014) of CHARLS.

We selected respondents aged 50 to 85 in 2014 and interviewed in 2011, 2013, 2015, 2018, and 2020 (n = 8,913) who had complete information on partnership, fertility, and employment states from age 18 to 50 (n = 8,535). The cut-off point of age 50 was informed by previous studies (Ice et al., 2020; Mayeda et al., 2020; Zhao and Gao, 2023) and China's decades-long pension system (only applicable to urban workers: 60 for men, 55 for white-collar women, and 50 for blue-collar women) (Giles et al., 2023). We did not exclude rural respondents because agricultural employment (some agriculturally employed individuals potentially transitioned to non-agricultural employees in private sector following China's economic reforms in late 1970s) constituted a major employment sector in the Chinese context (Wang et al., 2024).

3.2. Variable

3.2.1. Dependent variable

Although the Harmonized Cognitive Assessment Protocols available only in CHARLS 2018 facilitated cross-cultural comparative studies (Zhang et al., 2024), in this study we relied on measures of cognition (immediate/delayed word recall and mental status) available in all waves of CHARLS that had been assessed by prior work (Cadar et al., 2023; Lei et al., 2014). Respondents' episodic memory score was usually constructed as the mean of their immediate and delayed word recall scores. However, immediate word recall tests were administered three times in 2018 and 2020 (Table S1 compares word recall questions across waves) so that respondents may score spuriously high in delayed recall test and thus in episodic memory due to practice effects (Weuve et al., 2015). In light of this, we included delayed word recall and episodic memory scores in our cross-sectional analysis, but for longitudinal analysis using data from CHARLS 2011 to 2020, we only used immediate word recall score in respondents' first attempt (range: 0–10, higher scores indicate better cognition) as our first measure of cognition.

Our second measure of cognition is based on some components of the mental status questions of the Telephone Interview of Cognitive Status (TICS) battery established to capture intactness of individuals (Lei et al., 2014). Across all CHARLS regular waves, mental status questions consistently contained the following items: serial 7 subtraction from 100 (up to five times), naming today's date (month, day, year, and season), the day of the week, and the ability to redraw a picture shown to him/her. Answers to these questions were summed up into a mental status score ranging from 0 to 11 with higher scores indicating better cognition.

3.2.2. Family-work trajectories and covariates

The classification of respondents' family-work trajectories is our key independent variable. We explained how we identified these trajectories in section 3.3. In longitudinal analysis, we adjusted for time-invariant or time-varying covariates (Read and Grundy, 2016) capturing respondents' demographics, socio-economic status, health behaviour and

physical or mental health (Agrigoroaei and Lachman, 2011). Our first time-invariant covariate was baseline age centred at 59 (the mean age of our sample, see Table 1) (Cadar et al., 2023; Thoma et al., 2025). As Thoma et al. (2025) noted, "in the cognitive aging literature, specifying time-since-baseline as the timescale while controlling for age at baseline is generally preferred because it separates cohort and period effects–estimated by between-person differences in baseline age–from aging effects, estimated by within-person change". Other time-invariant covariates included gender (women = ref), educational attainment (lower secondary or below, upper secondary, and tertiary), and respondents' Communist party membership reported in 2013 (no = ref). Party membership was related to career advancement and still conferred advantage in terms of income and occupational attainment after China's market transition (Wu, 2019). Quintile of household per capita wealth (lowest quintile = ref) and smoking status (no = ref) were taken from baseline wave because of substantial missing values in selected follow-up waves (Cho et al., 2023; Phillips et al., 2021) which may produce biased estimates in regression models in complete case analysis. Time-varying covariates were *hukou* (household registration) status (urban = ref), marital status (divorced/separated/widowed/single or married), drinking alcohol (no = ref), depressive symptomatology (no = ref, determined if respondents' depressive symptoms score ≥10 within a range of 0–30) (Wu et al., 2023), and the number of limitations in instrumental activities of daily living (IADLs which include doing housework, preparing meals, shopping, managing money, and taking medications, ranging from 0 to 5).

Table 1
Sample characteristics in CHARLS 2011 by six clusters of family-work trajectories (non-weighted).

	Married, 1 child, various types of employment (n = 1,332)	Married, ≥2 children, non-agriculturally employed in private sector (n = 488)	Married, ≥2 children, not in labour force (n = 505)	Married, ≥2 children, non-agriculturally employed in public sector (n = 763)	Late marriage, ≥2 children, agriculturally employed (n = 4,027)	Early marriage, ≥2 children, agriculturally employed (n = 1,420)	Total	p-value
	Mean (SD)/Freq. (%)	Mean (SD)/Freq. (%)	Mean (SD)/Freq. (%)	Mean (SD)/Freq. (%)	Mean (SD)/Freq. (%)	Mean (SD)/Freq. (%)		
Episodic memory	3.82 (1.76)	3.78 (1.63)	3.40 (1.66)	4.10 (1.64)	3.33 (1.61)	3.18 (1.55)	3.48 (1.66)	<0.001
Immediate word recall	4.31 (1.77)	4.25 (1.66)	3.90 (1.72)	4.61 (1.59)	3.80 (1.65)	3.65 (1.58)	3.96 (1.68)	<0.001
Delayed word recall	3.33 (2.06)	3.31 (1.87)	2.89 (1.89)	3.59 (1.97)	2.85 (1.87)	2.70 (1.83)	3.00 (1.92)	<0.001
Mental status	7.70 (3.00)	8.46 (2.52)	7.21 (2.99)	9.03 (2.26)	6.77 (3.12)	5.82 (3.16)	7.07 (3.14)	<0.001
Age	56.75 (7.67)	55.84 (7.45)	58.62 (7.79)	61.94 (7.95)	59.14 (7.64)	59.91 (7.06)	58.93 (7.73)	<0.001
Men	0.52 (0.50)	0.76 (0.43)	0.38 (0.49)	0.72 (0.45)	0.49 (0.50)	0.22 (0.41)	0.48 (0.50)	<0.001
Married	0.87 (0.34)	0.95 (0.21)	0.89 (0.32)	0.93 (0.26)	0.90 (0.30)	0.91 (0.28)	0.90 (0.30)	<0.001
Education								<0.001
Lower secondary or below	1,086 (81.53 %)	395 (80.94 %)	456 (90.30 %)	513 (67.23 %)	3,799 (94.34 %)	1,398 (98.45 %)	7,647 (89.60 %)	
Upper secondary	220 (16.52 %)	89 (18.24 %)	48 (9.50 %)	211 (27.65 %)	224 (5.56 %)	20 (1.41 %)	812 (9.51 %)	
Tertiary	26 (1.95 %)	4 (0.82 %)	1 (0.20 %)	39 (5.11 %)	4 (0.10 %)	2 (0.14 %)	76 (0.89 %)	
Rural hukou	0.69 (0.46)	0.77 (0.42)	0.78 (0.42)	0.27 (0.44)	0.96 (0.20)	0.98 (0.13)	0.84 (0.37)	<0.001
Communist party member	0.14 (0.35)	0.13 (0.34)	0.10 (0.29)	0.34 (0.47)	0.08 (0.27)	0.04 (0.19)	0.11 (0.31)	<0.001
Household per capita wealth quintile								<0.001
Lowest	195 (15.22 %)	69 (14.47 %)	84 (17.18 %)	102 (14.01 %)	842 (21.44 %)	368 (26.34 %)	1,660 (20 %)	
2nd	191 (14.91 %)	76 (15.93 %)	81 (16.56 %)	77 (10.58 %)	873 (22.23 %)	362 (25.91 %)	1,660 (20 %)	
3rd	222 (17.33 %)	88 (18.45 %)	111 (22.70 %)	100 (13.74 %)	847 (21.56 %)	293 (20.97 %)	1,661 (20.01 %)	
4th	246 (19.20 %)	115 (24.11 %)	108 (22.09 %)	164 (22.53 %)	809 (20.60 %)	217 (15.53 %)	1,659 (19.99 %)	
Highest	427 (33.33 %)	129 (27.04 %)	105 (21.47 %)	285 (39.15 %)	557 (14.18 %)	157 (11.24 %)	1,660 (20 %)	
Smoking	0.33 (0.47)	0.43 (0.50)	0.25 (0.43)	0.35 (0.48)	0.32 (0.47)	0.19 (0.39)	0.30 (0.46)	<0.001
Drinking alcohol	0.39 (0.49)	0.47 (0.50)	0.28 (0.45)	0.40 (0.49)	0.33 (0.47)	0.23 (0.42)	0.34 (0.47)	<0.001
Number of IADL limitations	0.31 (0.85)	0.17 (0.68)	0.43 (0.99)	0.17 (0.59)	0.40 (0.95)	0.54 (1.07)	0.38 (0.92)	<0.001

Notes: Data source: CHARLS 2011 and 2014. CHARLS = China Health and Retirement Longitudinal Study. SD = standard deviation. IADL = instrumental activities of daily living. Respondents' Communist party membership is taken from CHARLS 2013 because it was not asked in 2011.

3.3. Analytical strategy

First, we conducted sequence analysis (Abbott and Tsay, 2000) to map each respondent's unique family-work history from age 18 to 50. We kept the number of family-work states parsimonious by specifying two categories for partnership (married or non-married with the latter category corresponding to single, divorced, or widowed), three categories for fertility (no child, 1 child, and ≥2 children), and four categories for employment ("agriculturally employed" which included self-employed and family business, "non-agriculturally employed in public sector" such as government or public institutions or state- or collectively controlled firms, "non-agriculturally employed in private sector" which incorporated self-employed and others, and "not in labour force" which included education, army service, home, unemployed, retired, and others). We did not break down non-married to single, divorced, and widowed because 96 % of our study sample stayed in marriage by age 50 (Fig. S1). Our choice of differentiating no child, 1 child, and ≥2 children was informed by Van Winkle and Wen (2023) as 64 % of our study sample were born between 1950 and 1964 whose birth cohorts on average had no more than 2 children. Alternatively we tested the classification of no child, 1–2 children, and ≥3 children but this approach did not yield substantively meaningful cluster solutions (results not shown). Respondents' any work episode lasting no less than 6 months was recorded. When synthesizing information from these three domains, we opted for the extended/expanded alphabet approach (Arpino et al., 2023; Emery and Berchtold, 2023) and constructed 24 (2 × 3 × 4) possible combinations/elements for each respondent's family-work state at each age. In this way, there was one family-work sequence per each respondent running from age 18 to 50 which contained the timing, duration, and transitions between family-work states. We did not use the multi-channel approach whose strong assumption (the state observed at a given position in a given domain is independent from the states occurring at the same position in other domains) may not hold (Ritschard et al., 2023) given the intersectionality of family and work.

Because gendered family-work history (Uccheddu et al., 2022) and gender differences in old-age cognition are not the major objective of our study, we did not use gender-stratified sample for sequence and subsequent analyses. Three operations (insertion, deletion, and substitution) are generally adopted when determining the effort/costs needed to transform one sequence into another (i.e., to calculate the pairwise distance/dissimilarity between two sequences). Our respondents' sequences were of equal length (32 years, i.e., 33 yearly records) and the timing of transitions mattered (e.g., the timing of parenthood) so we followed Lesnard (2014) and calculated dynamic Hamming distance (Lesnard, 2010), a variant of Optimal Matching which only used substitution for operation, to map inter-sequence dissimilarity and derived a symmetric matrix. When classifying respondents with similar sequences into a finite number of clusters, we conducted hierarchical cluster analysis using Ward's linkage and turned to Calinski-Harabasz pseudo-F statistics (higher is better, i.e., larger between-cluster variation and smaller within-cluster variation) (Halpin, 2016), dendrograms, chronograms, and index plots (Halpin, 2017) to aid in determining the optimal number of clusters. The Calinski-Harabasz cluster-stopping index examined the sum of squared distances within the partitions (i.e., n + 1 clusters) and compared it to that in the unpartitioned data (i.e., n clusters), taking into account the number of clusters and number of cases (Halpin, 2016). Sequence analysis and hierarchical cluster analysis were conducted using the Stata package *sadi* (Halpin, 2017).

Then, we described our sample's characteristics (cognition and socio-demographics) by various family-work trajectories in 2011 and tested differences in characteristics across all family-work trajectories using one-way analysis of variance (ANOVA) or Pearson χ^2 tests depending on the nature of variables (continuous or categorical). Next, for cross-sectional analysis we specifically tested whether means in episodic memory, immediate word recall, delayed word recall, and mental status scores in 2011 differed between each pair of family-work trajectories using Bonferroni correction to address the increased risk of Type I error when conducting multiple testing.

Last, for longitudinal analysis we built linear mixed-effects models using maximum likelihood estimation to explore the effects of family-work trajectories on immediate recall and mental status from 2011 to 2020. We added random intercepts for family-work trajectories (random slopes were tested but dropped due to no improvement in model fit), specified unstructured covariance, and interacted time with family-work trajectories. We used time as our choice of timescale (Thoma et al., 2025) which was defined as years since baseline wave (i.e., CHARLS, 2011). We also interacted time with all covariates but only kept the significant interactions (Yu et al., 2024) which varied across models depending on which outcome was tested and illustrated the effects of family-work trajectories using margins plots. Longitudinal weight for our study sample consecutively interviewed in all six waves of CHARLS (five regular waves plus a special life-history wave) was not available from the CHARLS team. All analyses were conducted using Stata 18.

4. Results

4.1. Family-work history

We explained how we conducted sequence analysis and hierarchical cluster analysis in section 3.3. When determining the optimal number of clusters (i.e., family-work trajectories), Table S1 shows that a six-cluster solution yielded the highest Calinski-Harabasz pseudo-F statistics so fit our data best. We used dendrograms (Fig. S2a) and chronograms (Fig. 1 and Fig. S2b–S2f where time 1 indicates age 18) to compare five-, six-, seven-, eight-, nine-, and ten-cluster solutions. In tandem with statistical justification, we believed the six-cluster solution was also substantively meaningful in the Chinese context, distinguishing older adults whose midlife was spent in various employment sectors (agricultural employment, non-agricultural employment in private sector, non-agricultural employment in public sector, and not in the labour force) and differentiating rural older adults who married earlier or later. To capture the distinct characteristics of older adults belonging to each family-work trajectory, we named these six trajectories as follows: "Group 1 (n = 1,332): married, 1 child, various employment states", "Group 2 (n = 488): married, ≥2 children, non-agriculturally employed in private sector", "Group 3 (n = 505): married, ≥2 children, not in labour force", "Group 4 (n = 763): married, ≥2 children, non-agriculturally employed in public sector", "Group 5 (n = 4,027): late marriage, ≥2 children, agriculturally employed", and "Group 6 (n = 1,420): early marriage, ≥2 children, agriculturally employed". It shall be noted that being assigned to a specific trajectory did not necessarily mean respondents kept that family-work state until age 50 (e.g., some respondents in Group 5 who were mainly agriculturally employed in midlife switched to non-agricultural employment in private sector in their late 40s). In other words, this six-cluster classification underlined the advantage of using sequence analysis to document individuals' decades-long employment profile rather than simply taking their employment status at age 45 or 50. We also drew index plots (Fig. S2g) to illustrate individuals' full-length sequences in each family-work trajectory because chronograms (Fig. 1) emphasised the composition of various family-work states in each year in each family-work trajectory.

4.2. Sample characteristics by family-work trajectories

Table 1 shows our sample's characteristics in 2011 by six distinct family-work trajectories. The average age of respondents was about 59 years old and the gender composition was balanced (48 % men). About 90 % of respondents were married with lower secondary or below education and 84 % of them had rural *hukou*. There are differences in all characteristics across these six family-work trajectories. For example, those in the "married, ≥2 children, non-agriculturally employed in

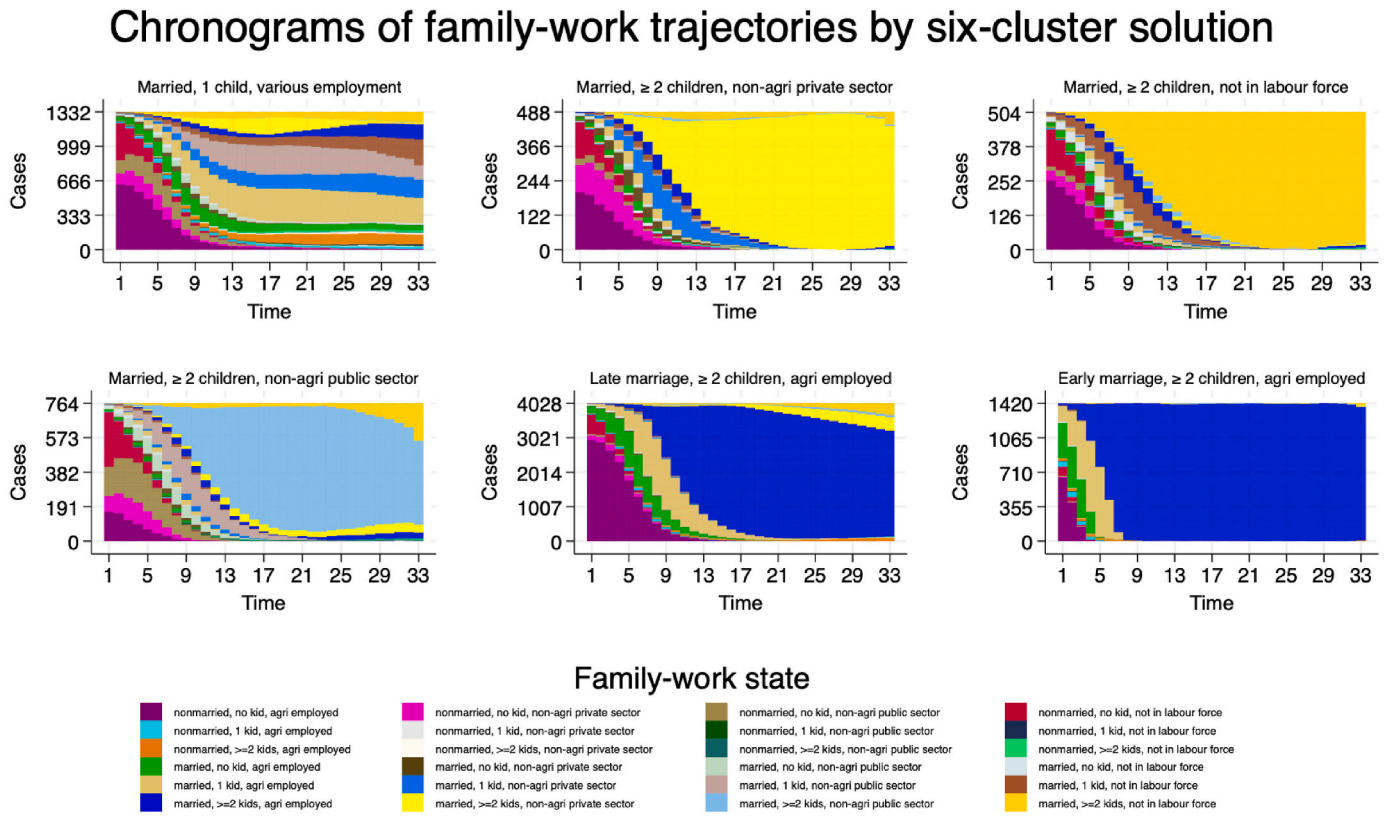

Fig. 1. Chronograms for family-work trajectories by six-cluster solution for study sample aged 50 and above in CHARLS 2014 (n = 8,535).

public sector" trajectory were oldest, having the highest proportions of tertiary degree holders, urban *hukou* holders, and Communist party members and more likely to be the wealthiest. They also had highest scores on episodic memory, immediate recall, delayed recall, and mental status, while those in the "early marriage, ≥2 children, agriculturally employed" trajectory had lowest scores on any of these four cognition measures.

4.3. Family-work history and cognition

We examined how family-work history affected CHARLS respondents' cognition cross-sectionally (Table 2) and longitudinally (Table 3). Table 2 presents results from pairwise comparisons with Bonferroni correction of means in episodic memory, immediate word recall, delayed word recall, and mental status in 2011 among six clusters of family-work trajectories. We found that those in the "married, ≥2 children, non-agriculturally employed in public sector" trajectory had higher episodic memory score (diff = 0.28, $p < 0.01$) than those in the "married, 1 child, various types of employment" trajectory, 0.33 point higher ($p < 0.01$) than those in the "married, ≥2 children, non-agriculturally employed in private sector" trajectory, 0.70 point higher ($p < 0.001$) than those in the "married, ≥2 children, not in labour force" trajectory, 0.77 point higher ($p < 0.001$) than those in the "late marriage, ≥2 children, agriculturally employed" trajectory, and 0.92 point higher ($p < 0.001$) than those in the "early marriage, ≥2 children, agriculturally employed" trajectory). In contrast, those in the "early marriage, ≥2 children, agriculturally employed" trajectory had lower episodic memory scores than those in the "married, 1 child, various types of employment" trajectory (diff = 0.64, $p < 0.001$) and those in the "married, ≥2 children, non-agriculturally employed in private sector" trajectory (diff = 0.59, $p < 0.001$). Respondents in this trajectory also scored lower than those in the "married, ≥2 children, not in labour force" trajectory and the "late marriage, ≥2 children, agriculturally employed" trajectory, although the differences were not significant. Similarly, the cognitive advantage for those in the "married, ≥2 children, non-agriculturally employed in public sector" trajectory and the cognitive disadvantage for those in the "early marriage, ≥2 children, agriculturally employed" trajectory were also found in immediate word recall, delayed word recall, and mental status scores.

Across other four trajectories of family-work trajectories in Table 2, those in the "late marriage, ≥2 children, agriculturally employed" underperformed in episodic memory than those in the "married, 1 child, various employment states" trajectory (diff = 0.50, $p < 0.001$) and those in the "married, ≥2 children, non-agriculturally employed in private sector" (diff = 0.45, $p < 0.001$)". Meanwhile, those in the "married, ≥2 children, not in labour force" trajectory scored lower in episodic memory than those in the "married, 1 child, various employment states" trajectory (diff = 0.42, $p < 0.001$) and those in the "married, ≥2 children, non-agriculturally employed in private sector" (diff = 0.37, $p < 0.05$). We found similar gradients in immediate word recall, delayed word recall, and mental status scores.

Table 3 shows selected results from fully adjusted linear mixed-effects models examining how family-work trajectories affected immediate word recall and mental status longitudinally from 2011 to 2020 (full results are shown in Table S2b). Margins plots for these effects are shown in Fig. 2. Chronologically, there was an annual decline in immediate recall score (b = −0.15, 95 % confidence interval (CI): −0.16 to −0.13, $p < 0.001$) for the reference group (those aged 59 in the "early marriage, ≥2 children, agriculturally employed" trajectory who did not have depressive symptomatology) over this nine-year period. We tried only keeping one interaction term (family-work trajectories × time) in regression models and the coefficient for time became −0.141 (results not shown), very similar to that in Table 3 (−0.146 if we kept three decimal places). Compared with respondents in the "early marriage, ≥2 children, agriculturally employed" trajectory, several trajectories started off with higher baseline immediate word recall scores (for the "married, 1 child, various types of employment" trajectory: b = 0.22, 95 % CI: 0.11 to 0.34, $p < 0.001$; for the "married, ≥2 children, non-agriculturally

Table 2
Pairwise comparisons with Bonferroni correction of means in episodic memory, immediate word recall, delayed word recall, and mental status between six clusters of family-work trajectories in CHARLS 2011 (n = 8,535).

Differences in means between row cluster and column cluster	Married, 1 child, various types of employment (n = 1,332)	Married, ≥2 children, non-agriculturally employed in private sector (n = 488)	Married, ≥2 children, not in labour force (n = 505)	Married, ≥2 children, non-agriculturally employed in public sector (n = 763)	Late marriage, ≥2 children, agriculturally employed (n = 4,027)
Episodic memory					
Married, ≥2 children, non-agriculturally employed in private sector (n = 488)	−0.05 (0.09)				
Married, ≥2 children, not in labour force (n = 505)	−0.42*** (0.09)	−0.37* (0.11)			
Married, ≥2 children, non-agriculturally employed in public sector (n = 763)	0.28** (0.08)	0.33** (0.10)	0.70*** (0.10)		
Late marriage, ≥2 children, agriculturally employed (n = 4,027)	−0.50*** (0.06)	−0.45*** (0.09)	−0.08 (0.08)	−0.77*** (0.07)	
Early marriage, ≥2 children, agriculturally employed (n = 1,420)	−0.64*** (0.07)	−0.59*** (0.09)	−0.22 (0.09)	−0.92*** (0.08)	−0.15 (0.05)
Immediate recall					
Married, ≥2 children, non-agriculturally employed in private sector (n = 488)	−0.07 (0.10)				
Married, ≥2 children, not in labour force (n = 505)	−0.41*** (0.10)	−0.34* (0.11)			
Married, ≥2 children, non-agriculturally employed in public sector (n = 763)	0.29** (0.08)	0.36** (0.10)	0.70*** (0.10)		
Late marriage, ≥2 children, agriculturally employed (n = 4,027)	−0.51*** (0.06)	−0.45*** (0.09)	−0.10 (0.08)	−0.81*** (0.07)	
Early marriage, ≥2 children, agriculturally employed (n = 1,420)	−0.66*** (0.07)	−0.59*** (0.09)	−0.25 (0.09)	−0.95*** (0.08)	−0.15 (0.06)
Delayed recall					
Married, ≥2 children, non-agriculturally employed in private sector (n = 488)	−0.02 (0.11)				
Married, ≥2 children, not in labour force (n = 505)	−0.44*** (0.11)	−0.42* (0.13)			
Married, ≥2 children, non-agriculturally employed in public sector (n = 763)	0.26 (0.09)	0.28 (0.12)	0.70*** (0.12)		
Late marriage, ≥2 children, agriculturally employed (n = 4,027)	−0.47*** (0.06)	−0.46*** (0.10)	−0.04 (0.10)	−0.73*** (0.08)	
Early marriage, ≥2 children, agriculturally employed (n = 1,420)	−0.63*** (0.08)	−0.61*** (0.11)	−0.19 (0.11)	−0.89*** (0.09)	−0.15 (0.06)
Mental status					
Married, ≥2 children, non-agriculturally employed in private sector (n = 488)	0.76*** (0.17)				
Married, ≥2 children, not in labour force (n = 505)	−0.49* (0.16)	−1.25*** (0.20)			
Married, ≥2 children, non-agriculturally employed in public sector (n = 763)	1.33*** (0.14)	0.57* (0.18)	1.82*** (0.18)		
Late marriage, ≥2 children, agriculturally employed (n = 4,027)	−0.93*** (0.10)	−1.69*** (0.15)	−0.44* (0.15)	−2.26*** (0.12)	
Early marriage, ≥2 children, agriculturally employed (n = 1,420)	−1.88*** (0.12)	−2.64*** (0.16)	−1.39*** (0.16)	−3.21*** (0.14)	−0.95*** (0.09)

Notes: Data source: CHARLS 2011, 2013, 2014, 2015, 2018, and 2020. CHARLS = China Health and Retirement Longitudinal Study. Numbers in cells are the differences in means followed by standard errors in parentheses. *p < 0.05, **p < 0.01, ***p < 0.001.

employed in private sector" trajectory: b = 0.17, 95 % CI: 0.01 to 0.33, p < 0.05; for the "married, ≥2 children, non-agriculturally employed in public sector" trajectory: b = 0.40, 95 % CI: 0.25 to 0.54, p < 0.001). In the meantime, compared with respondents in the "early marriage, ≥2 children, agriculturally employed" trajectory, protective effects against the decline in immediate word recall were found for the "married, ≥2 children, not in labour force" trajectory (b = 0.04, 95 % CI: 0.01 to 0.06, p < 0.01), the "married, ≥2 children, non-agriculturally employed in public sector" trajectory (b = 0.04, 95 % CI: 0.03 to 0.06, p < 0.001), and the "late marriage, ≥2 children, agriculturally employed" trajectory (b = 0.02, 95 % CI: 0.00 to 0.03, p < 0.05).

Table 3 shows that there was also an annual decline in mental status

Table 3
Selected results from linear mixed-effects models exploring the effects of family-work history on CHARLS respondents' **immediate word recall and mental status scores** from 2011 to 2020 (n = 8,535).

	Immediate recall		Mental status	
	coef.	95 % CI	coef.	95 % CI
Fixed-effects portion				
Family-work trajectories				
Early marriage, ≥2 children, agriculturally employed	ref	ref	ref	ref
Married, 1 child, various types of employment	0.22***	[0.11,0.34]	0.63***	[0.43,0.83]
Married, ≥2 children, non-agriculturally employed in private sector	0.17*	[0.01,0.33]	0.93***	[0.66,1.21]
Married, ≥2 children, not in labour force	0.04	[-0.11,0.19]	0.74***	[0.48,1.00]
Married, ≥2 children, non-agriculturally employed in public sector	0.40***	[0.25,0.54]	1.45***	[1.20,1.71]
Late marriage, ≥2 children, agriculturally employed	0.05	[-0.04,0.14]	0.39***	[0.23,0.55]
Time	−0.15***	[-0.16,-0.13]	−0.13***	[-0.15,-0.11]
Family-work trajectories × Time				
Early marriage, ≥2 children, agriculturally employed × Time	ref	ref	ref	ref
Married, 1 child, various types of employment × Time	0.01	[-0.00,0.03]	0.02	[-0.00,0.04]
Married, ≥2 children, non-agriculturally employed in private sector × Time	0.01	[-0.01,0.03]	−0.01	[-0.04,0.02]
Married, ≥2 children, not in labour force × Time	0.04**	[0.01,0.06]	0.01	[-0.02,0.04]
Married, ≥2 children, non-agriculturally employed in public sector × Time	0.04***	[0.03,0.06]	−0.00	[-0.03,0.02]
Late marriage, ≥2 children, agriculturally employed × Time	0.02*	[0.00,0.03]	−0.00	[-0.02,0.01]
Random-effects portion				
Variance (constant)	0.83	[0.79,0.87]	3.99	[3.85,4.14]
Variance (residual)	1.99	[1.96,2.02]	3.64	[3.58,3.70]
Observations	36,669		38,494	

Notes: Data source: CHARLS 2011, 2013, 2014, 2015, 2018, and 2020. CHARLS = China Health and Retirement Longitudinal Study. CI = confidence interval. For immediate call, the models adjusted for gender, baseline age centred at 59, baseline age centred at 59 × time, *hukou* status, marital status, educational attainment, Communist party membership, quintile of household per capita wealth, smoking, drinking alcohol, depressive symptomatology, depressive symptomatology × time, and number of limitations in instrumental activities of daily living. For mental status, the models adjusted for gender, gender × time, baseline age centred at 59, *hukou* status, marital status, educational attainment, Communist party membership, quintile of household per capita wealth, smoking, drinking alcohol, depressive symptomatology, depressive symptomatology × time, and number of limitations in instrumental activities of daily living. *p < 0.05, **p < 0.01, ***p < 0.001.

score (b = −0.13, 95 % CI: −0.15 to −0.11, p < 0.001) for the reference group (women in the "early marriage, ≥2 children, agriculturally employed" trajectory with no depressive symptomatology) over this nine-year period. We tried only keeping one interaction term (family-work trajectories × time) in regression models and the coefficient for time became −0.128 (results not shown), very similar to that in Table 3 (−0.131 if we kept three decimal places). Compared with respondents in the "early marriage, ≥2 children, agriculturally employed" trajectory, respondents in all other five family-work trajectories had higher baseline mental status scores. All interaction terms between family-work trajectories and time were insignificant, suggesting that the rate of decline in respondents' mental status was similar across various family-work trajectories. Table S2c and Fig. S2h show results for respondents' delayed recall and episodic memory from linear mixed-effects models with significant interaction terms between time and covariates (gender and baseline age). Models only keeping one interaction term (family-work trajectories × time) gave very similar coefficients for time (for delayed recall: b = 0.12, 95 % CI: 0.10 to 0.13, p < 0.001; for episodic memory: b = −0.00, 95 % CI: −0.01 to 0.01, p > 0.05) compared with results in Table S2c. These annual changes (increases in delayed recall and stability in episodic memory) for the reference group (respondents in the "early marriage, ≥2 children, agriculturally employed" trajectory) may be biased because of practice effects when immediate recall tests were administered three times in CHARLS 2018 and 2020.

4.4. Sensitivity analyses

We conducted a series of sensitivity analyses to check the robustness of our findings in Tables 2 and 3. In the main analysis, we included as many respondents as possible aged 50 and above in CHARLS 2014 who had complete family-work information from age 18 to 50 (n = 8,535). In the first sensitivity analysis, we changed sample to respondents aged 50+ in 2011 (n = 7,432) and repeated all analyses (sequence, cluster, and cross-sectional and longitudinal analysis). We found that a six-cluster solution remained optimal (Table S3a) and it yielded the same classification of family-work trajectories (Figure S3a and Figure S3b). Results from pairwise comparisons (Table S3b) and linear mixed-effects models (Table S3c, Fig. S3c, Table S3d, and Fig. S3d) were similar to those in Tables 2 and 3.

Second, we excluded CHARLS 2020 data (fielded in July and August in 2020) to reduce potential bias caused by COVID-19 related measures such as social distancing that may affect older adults' cognition. We obtained a less selective study sample comprising respondents interviewed in 2011, 2013, 2014, 2015, and 2018 (n = 9,329) and repeated all analyses (sequence, cluster, cross-sectional and longitudinal analysis). A six-cluster solution still remained optimal (Table S4a) and it yielded the same classification of family-work trajectories (Figure S4a and Figure S4b). Results from pairwise comparisons (Table S4b) and linear mixed-effects models (Table S4c, Fig. S4c, Table S4d, and Fig. S4d) were similar to those in Tables 2 and 3. We found protective effects against the decline in immediate recall for all other five trajectories (all interaction terms were significant in Table S4c), implying that disadvantage in immediate recall for those in the "early marriage, ≥2 children, agriculturally employed" trajectory became more pronounced over time in a less selective sample.

Third, instead of changing our study sample and redoing sequence analysis, we summed up immediate recall and mental status scores to a total cognition score (range: 0–21) and repeated the cross-sectional and longitudinal analysis (Table S5a, Table S5b, and Fig. S5). The results were similar to those in Tables 2 and 3.

Fourth, missing values on the dependent variables and covariates (there was no missing value on family-work history) led to respondents being dropped from models because of listwise deletion, which may bias our estimates. In our long format data, among various other missing patterns, 86 % of records had no missing values, 4 % of records only had missing values in immediate recall, and 4 % of records only had missing

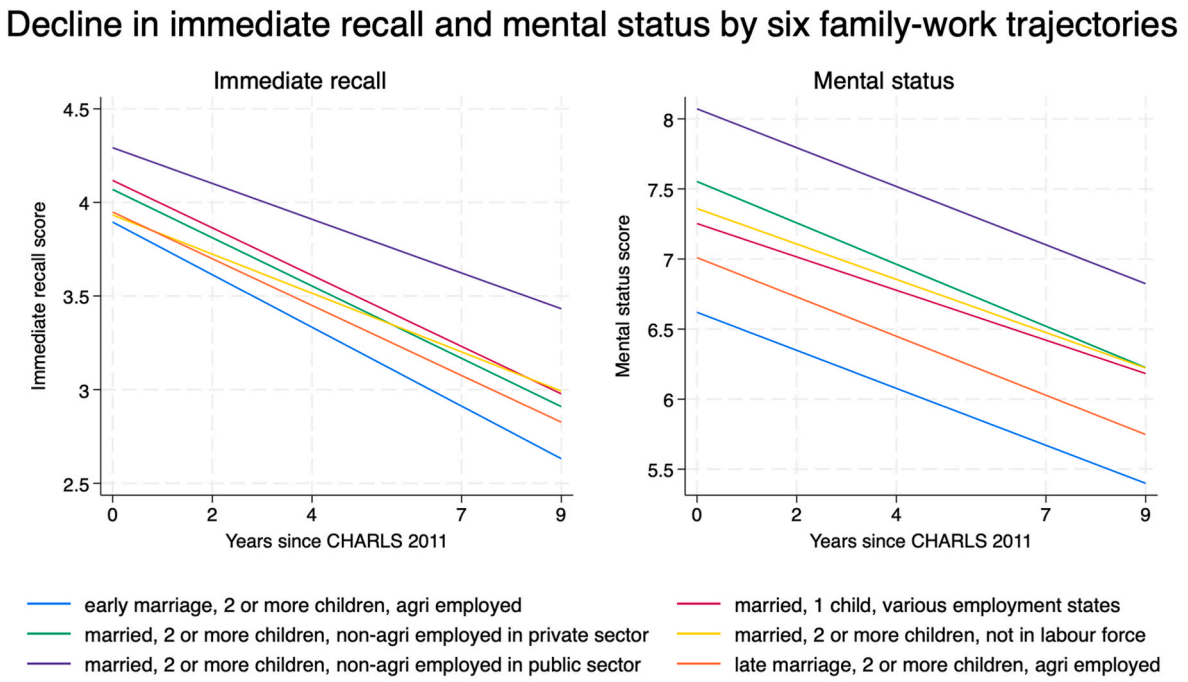

Fig. 2. Margins plots for the effects of family-work history on CHARLS respondents' immediate recall and mental status from 2011 to 2020.

values in immediate recall, mental status, and depressive symptomatology. Assuming missing at random (MAR), we imputed our data 10 times using multiple imputation by chained equations (MICE), re-estimated linear mixed-effects models, and obtained marginal effects using the Stata command *mimrgns* (Klein, 2022). The results (Table S6 and Fig. S6) were similar to those in Table 3 and Fig. 2.

Then, time-varying covariates we adjusted for (marital status, *hukou* status, IADLs, drinking alcohol, and depressive symptomatology) may be mediators rather than confounders. We did another sensitivity analysis by estimating models without these time-varying covariates. The results (Table S7 and Fig. S7) were similar to those in Table 3 and Fig. 2.

Next, to gain more insights into cohort effects, we replaced baseline age with respondents' birth cohort classified into 4 groups: "1960–1964 (ref)", "1955–1959″, "1950–1954″, and "1949 or before" and re-estimated linear mixed-effects models. We found that earlier birth cohorts were associated with lower immediate recall and mental status scores, but faster decline was only found in immediate recall (Table S8 and Fig. S8).

Last, although multiple observation points per individual are needed for estimating linear mixed-effects models, we acknowledge the selective nature of our sample due to attrition across waves and our other choices (age 50+ in 2014 and having complete information in family-work states from age 18 to 50). In the second sensitivity analysis, we chose a less selective sample by not using CHARLS 2020 data. Here, we also necessarily compared respondents' characteristics in CHARLS 2011 between excluded respondents and our study sample (Table S9). We found that those excluded respondents were slightly younger, more likely to have urban *hukou* status, more educated, wealthier, less likely to be in marriage, and had more limitations in instrumental activities of daily living. These differences shall be noted when interpreting the key findings of our study.

5. Discussion

In this study using CHARLS data, we conducted sequence analysis and identified six statistically justifiable and context-attuned family-work trajectories running from age 18 to 50 for Chinese older adults born in or before 1964. Building on this, we examined inequalities in cognition among older adults in various trajectories cross-sectionally and longitudinally.

Regardless of cognition outcomes tested (immediate recall, delayed recall, episodic memory, or mental status), older adults in the "early marriage, ≥2 children, agriculturally employed" family-work trajectory had lowest cognitive function in CHARLS 2011, supporting our hypothesis. Given the short gap between marriage and first childbirth in China illustrated in Fig. 1, this result is consistent with prior studies that early parenthood was associated with poorer cognition in later life (Fu et al., 2023; Gemmill and Weiss, 2021; Read and Grundy, 2016; Thomeer et al., 2024; Weng and Yang, 2023; Zhang, 2022). Moreover, older adults agriculturally employed throughout their midlife undertook low-skilled jobs according to the International Standard Classification of Occupations 2008 (ISCO-08) (International Labour Office, 2012). At baseline they underperformed than those in the "married, ≥2 children, non-agriculturally employed in public sector" trajectory who probably held managerial or professional positions, echoing findings that high-skilled professional occupation in midlife was beneficial for later-life cognition (Greenberg and Burgard, 2021; Kobayashi and Feldman, 2019; Kobayashi et al., 2023; Wang et al., 2024; Yu et al., 2024). These inequalities were also found in longitudinal analysis. Compared with older adults in the "early marriage, ≥2 children, agriculturally employed" trajectory, slower declines in immediate recall were found for those in the "late marriage, ≥2 children, agriculturally employed", "married, ≥2 children, not in labour force", and "married, ≥2 children, non-agriculturally employed in public sector" trajectories, once again supporting our hypothesis.

There are a number of reasons behind these inequalities in cognition. Among pre-1964 birth cohorts in China, agriculturally employed rural older adults' early transition to parenthood impeded their educational attainment (Weng and Yang, 2023) which is critical for old-age cognition (Zhang et al., 2024) and their high parity depleted socio-economic resources (rural residents were less affected by China's one-child policy introduced in late 1970s) (Yang et al., 2022; Zhao and Gao, 2023). China's *hukou* system (Wu and Treiman, 2004) created decades-long segregated internal labour market with rural residents having lower income, fewer social welfare in terms of health insurance and pension benefits, more exposure to higher levels of pesticides/herbicides and ultraviolet radiation, and less support from adult children emigrating to

urban areas for better economic opportunities (Song and Smith, 2019; Wang et al., 2024), all of which contributed to their poorer cognition in old age (Kezios et al., 2022; Peng et al., 2023).

Compared with those agriculturally employed and those in private sector, urban residents employed in public sector topped the redistributive hierarchy with more job stability, higher income, broader social network, and generous entitlements to social welfare (Wu, 2019) so they may reap cognitive gains. Moreover, they may benefit from greater workplace cognitive stimulations in relation to data (high to low: synthesizing, coordinating, analysing, compiling, computing, copying, comparing), people (high to low: mentoring, negotiating, instructing, supervising, diverting, persuading, speaking, serving, and taking instructions), and things (high to low: setting up, prevision work, operating, driving, manipulating, tending, feeding, and handling) (Andel et al., 2014). Additionally, although weak ties to employment in midlife were often associated with poorer old-age cognition (Ice et al., 2020; Machů et al., 2022; Mayeda et al., 2020; Zhao and Gao, 2023), our analysis not using gender-stratified sample revealed an exception in China where older adults primarily not in the labour force in their midlife had better old-age cognition than those agriculturally employed. The majority of respondents belonging to the "married, ≥2 children, not in labour force" trajectory reported retired as early as in their late 30s (results not shown) who were likely to be laid-off employees from state-owned enterprises in the 1990s and 2000s (Song et al., 2025) whose sustained limited access to social welfare may have still bestowed cognitive advantage on them over rural residents.

Our findings lend support to cumulative dis/advantage (CAD) (Dannefer, 2003, 2020) and cumulative inequality (CI) (Ferraro and Shippee, 2009) theories. We illustrated how institutional factors embedded in China's unique historical context (e.g., *hukou* system and the rigid duality of urban/rural labour market) shaped individuals' demographic processes and occupational developments (i.e., family-work trajectories) over their life course which related to later-life cognition. In particular, we showed that the intersection of early marriage, early parenthood (presumably high parity) and sustained agricultural employment in midlife predicted lower initial immediate recall and mental status scores and a faster decline in immediate recall. Exposures in these intertwined domains (partnership, fertility, and employment) may act concertedly to influence old-age cognition via risk factors such as education, depression, chronic conditions, health behaviour, air pollution, and social network.

Since retrospective family-work trajectories in midlife could not be altered in old age, a question that surfaces is whether there are some remedies to support persistently agriculturally employed older adults with cognitive disadvantage. One option may be promoting leisure and physical activities as well as social engagement which may compensate for long-term cognitive disadvantage conferred by working in less cognitively stimulating occupations (Andel et al., 2014; Stern et al., 2020). Moreover, China's New Cooperative Medical Scheme (NCMS) and New Rural Pension Scheme (NRPS) implemented just before 2010 improved rural older adults' cognitive function (Cheng et al., 2015, 2018), which underscored the importance of refining social welfare to support cognitively vulnerable populations.

In this study, we only traced respondents' employment history from age 18 to 50 but the urban-rural differences in employment/retirement may extend well beyond age 50. Giles et al. (2023) found that the rates of retirement (defined as no longer engaged in any wage or self-employed activities, including both agricultural and non-agricultural work) were higher among urban *hukou* older adults than among rural *hukou* residents in China and the gap widened with age (in the 50–54 age group: 30 % vs 16 %; in the 55–59 age group: 44 % vs 22 %; in the 60–64 age group: 71 % vs 26 %). The fact that rural residents continued to work until advanced ages because of limited access to generous pensions and poor economic resources (usually undertaking low-skilled jobs in unfavourable working conditions) calls for improvement in retirement policy and broader social welfare to promote equity in later life.

The main limitation of our observational study is that causality could not be claimed. One of the endogeneity issues is that early-life (childhood or adolescence) cognitive abilities or socioeconomic status, observed or non-observed, may influence both family-work history and later-life cognition so more robust causal inference methods are needed (Cheng et al., 2025; Schwartz and Glymour, 2023). That said, to some extent early-life disadvantages may have been proxied by respondents' timing of marriage and parenthood as well as labour force participation and their first job's employment sector that had been captured in our sequence analysis so not considering early-life factors may not alter our substantive findings.

Despite the limitation noted above, the contribution of our study is threefold. First, we addressed the research gap by unmasking the link between family-work history and later-life cognition in China, a nation among LMICs underrepresented in prior work. Second, we extended the literature by explicitly considering employment sector, identifying six statistically justifiable and context-attuned family-work trajectories in China, and probing inequalities in cognition cross-sectionally and longitudinally. Third, we cautioned that how immediate word recall questions were administered in CHARLS 2018 and 2020 was prone to practice effects so researchers operationalising cognition as delayed word recall and episodic memory scores in these two waves may obtain biased results. Another issue is that the word lists used were identical in CHARLS 2011, 2013, and 2015 but they changed in CHARLS 2018 and were modified again in 2020 (Table S1). A weighted equipercentile equating method could be used to adjust for alterations to the administration and content of recall tests over time (Guo et al., 2025; Wu et al., 2024) but it relies on the assumption that respondents in the calibration sample with a common age range and similar educational levels across waves have equal underlying cognitive abilities so that the weighted percentile ranks of the recall scores are comparable. Overall, our research revealed that China's pre-1964 birth cohorts' midlife employment sector played a major role in contributing to later-life disparities in cognitive function. Future work may peruse gendered family-work history and its effects on gender differences in old-age cognition in the Chinese context.

CRediT authorship contribution statement

Jiawei Wu: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Guillaume Marois:** Writing – review & editing, Supervision, Methodology.

Ethic approval

None required. This study conducts secondary data analysis without collecting new data from participants.

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2025.118318.

Data availability

This study uses data from the China Health and Retirement Longitudinal Study (CHARLS) (http://charls.pku.edu.cn) and harmonized CHARLS data (https://g2aging.org/) both of which are publicly accessible upon registration. Code-related inquiries shall be directed to the authors.

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