Four-year trajectories of episodic memory decline in mid-late life by living arrangements: A cross-national comparison between China and England

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What is already known on this subject?

Cognitive decline and dementia risk have been associated with a range of social isolation markers, including older people's living arrangements. However, there is limited and conflicting evidence on the association between living arrangements and cognition in mid-late life. Most studies have largely focused on the effects of living alone in Western societies, but little is known about multigenerational living arrangements. Since living arrangements are largely determined by the societal, economic, and cultural context of a society, its impact on cognition may vary between Western and non-Western settings.

What this study adds?

This study measured gender-specific trajectories of episodic memory among middle-aged and older adults in China and England, and compared how episodic memory declined across specific living arrangements in the two countries. Living alone was associated with a faster memory decline among English women only. Co-residing with children/grandchildren in the absence of a partner was more detrimental than living alone among Chinese men and English women. Although older people's living arrangements are important for various ageing outcomes, these arrangements do not predict consistent differences in memory decline and appear to be context- and gender-specific.

Abstract

Background: There is mixed evidence on the association between living arrangements and mid-late life cognition, which may be due to distinct familial arrangements and preferences between populations. To address such heterogeneity, we assessed these associations in China and England.

Methods: Four-year trajectories of episodic memory scores (0-20, word-recall test) by living arrangements (living with partner only, living with partner and children/grandchildren, living with no partner but with children/grandchildren, and living alone) were estimated using latent growth curve modelling for men and women aged 50+ from China (N=12,801) and England (N=10,964).

Results: After adjusting for baseline socioeconomic, health behavioural, and health covariates, worse baseline memory was found in Chinese adults living with no partner but with children/grandchildren and in Chinese women living with partner and children/grandchildren, compared to those living with partner only. Better baseline memory was associated with living alone in English women. A faster memory decline was found in Chinese men living with no partner but with children/grandchildren (-0.122 word/year, 95% confidence interval [CI]: -0.213, -0.031), as well as in English women living with children/grandchildren with (-0.114, 95% CI: -0.180, -0.049) or without (-0.118, 95% CI: -0.209, -0.026) a partner and those living alone (-0.075, 95% CI: -0.127, -0.024). No differences at baseline nor over follow-up were found between English men in different living arrangements.

Conclusion: Overall, our findings did not confirm the protective effects of co-residence with children/grandchildren, nor the detrimental effects of living alone on mid-late life cognition in China and England.

Background

In 2014-2015 approximately 47 million people were living with dementia globally, among whom 10.5 million were from China,[1] and about 850,000 were from the UK.[2] As the number of people living with dementia is projected to soar to 132 million in 2050,[1] it is crucial to better understand cognitive decline and the role of modifiable risk factors. Although a review from the Alzheimer's Association[3] found unclear evidence on social engagement as a potential protective factor against cognitive decline, the *Lancet* Commission on Dementia Prevention, Intervention, and Care[4] and a recent meta-analysis[5] concluded that social isolation in late life is a modifiable risk factor for dementia and cognitive decline.

Social isolation in middle-aged and older adults is intertwined with their living arrangements.[6 7] Living arrangements have been found to be associated with a number of physical and mental health outcomes,[7-9] but cognition has received much less attention in the literature and the evidence is conflicting. A European-wide study of adults aged 65+ with a follow-up of 2-to-3 years reported protective effects of co-residing with partner against episodic memory decline in Sweden, the Netherlands, and Belgium but not in Southern European countries; no advantage was found for co-residing with adult children in any setting.[10] In contrast, a study from Wales showed that living alone was neither associated with cognition at baseline nor cognitive decline over two years among adults aged 65+.[11] A recent study from China showed that, compared to living alone, co-residing with children, either with or without a spouse, was associated with higher risk of cognitive impairment among older Chinese adults.[12]

As living arrangements are largely determined by the societal, economic, and cultural context of a society, its impact on cognition in mid-late life may well differ between societies, and thus contribute to the mixed findings. Testing this possibility demands cross-national

comparisons between societies with very different profiles such as China and England – two countries with distinct cultural norms towards household arrangements (e.g. filial piety still strongly regulates expectations and behaviours within Chinese families) and at different economic development stages. The rapid socioeconomic transition in China has changed older people's family arrangements voluntarily or involuntarily. For instance, some older adults may prefer not to live in a multigenerational setting as they increasingly value their own privacy and prefer to avoid intergenerational conflicts;[13] whereas others may be forced into living in an 'empty nest' as their children migrate for marriage and work.[14] In addition, the abovementioned meta-analysis[5] and the *Lancet* Commission report[4] heavily relied on studies conducted in Western countries. A direct comparison between China and England therefore would provide fresh insights.

Residential opportunities in later life are not only influenced by predominant family systems, but also by health and social care policies which present feasible options for the management of ageing in a given context.[15] Unlike England where assisted living and long-term care are generally available for the elderly, the lack of such services coupled with filial piety make home-based informal care the main form of care for Chinese elderly.[15] In England, the share of elderly people living in multigenerational households has dwindled over the last few decades due to the growing preference towards independent living.[16] Given the higher expectations towards multigenerational living in China than in England, multigenerational living may be more beneficial for cognition in China. Whereas living alone – often associated with being abandoned in China – could be considerably more detrimental in China than in England.

In this study, we compared four-year trajectories of episodic memory by living arrangements in China and England, using prospective data from two nationally representative cohort

studies – the China Health and Retirement Longitudinal Study (CHARLS) and England Longitudinal Study of Ageing (ELSA). We selected episodic memory because, as part of fluid intelligence, it is sensitive to ageing and starts to decline from middle age,[17] and has high diagnostic accuracy for identifying Alzheimer's disease.[18] Since women generally live longer than men, older women are more likely to live alone compared to their male counterparts in western countries. In China, however, they often live with their adult children. Therefore, gender differences in the association between living arrangements and episodic memory may be unique for each context.

Methods

Study design

Nationally representative samples of middle-aged and older community-dwelling adults were selected from China (CHARLS: age≥45) and England (ELSA: age≥50). The baseline survey was conducted in 2011/2 for CHARLS and 2002/3 for ELSA, with a response rate of 81% and 70%, respectively.[19 20] Comprehensive information on sociodemographic, family, and health characteristics were collected at baseline and at biennial re-examinations in both studies.[19 20] Ethical approval was provided by the Ethical Review Committee of Peking University and London Multi-Centre Research Ethics Committee, respectively for CHARLS and ELSA. All CHARLS and ELSA participants provided written informed consent. Using data from the first three examinations (Waves 1-3 for CHARLS and ELSA), we analysed participants aged 50+ at baseline and with data on episodic memory at any wave (CHARLS N=12,801; ELSA N=10,964). At the end of the follow-up, 10,502 (82.0%) CHARLS and 7,229 (65.9%) ELSA participants remained in the cohorts.

Episodic memory

Both studies measured episodic memory using immediate and delayed recall of ten words at all waves. Participants were asked to recall as many words that were read out loud by the computer or the interviewer immediately after the ten-word list was read (immediate word recall) and after a short delay (delayed word recall). Episodic memory scores (0-20) comprised the total number of correctly repeated words in both recall tests. Details of the episodic memory tests in in each study are provided in Supplementary Methods.

Living arrangements

Baseline data on living arrangements were based on each household member and his/her relation to the participant in both CHARLS and ELSA. Co-residence with a spouse or partner was determined using the household grid in ELSA but ascertained by questions on marital status in CHARLS. Several types of living arrangements were derived including: 1) living with partner only (spouse or cohabiting partner), 2) living with partner, children and/or grandchildren, 3) living with no partner but with children and/or grandchildren, 4) other multigenerational living arrangements, and 5) living alone. We excluded participants who lived with siblings, other relatives or non-relatives at baseline (N=30 in CHARLS and N=187 in ELSA).

Covariates

All covariates were measured at baseline. Socioeconomic position (SEP) was captured by education, physical wealth, and ownership of current residence. Educational levels were grouped into low (CHARLS: ≤elementary school; ELSA: no qualifications), medium (CHARLS: lower secondary school; ELSA: NVQ1-NVQ3), or high (CHARLS: ≥upper secondary school; ELSA: ≥NVQ4). Physical wealth was captured by the total number of household assets (including electronics, vehicles, and valuables), and were categorised into study-specific tertiles. Health behaviours included smoking status and alcohol drinking

frequency in the past year. We also included several health variables, covering self-rated hearing, number of limitations in activities of daily living (ADLs, including bathing, dressing, eating, getting into/out of bed, and using the toilet), and self-reported doctor-diagnosis of cardiovascular disease, hypertension, and diabetes. Hearing could be a confounder as hearing loss is a risk factor for dementia[4] and it may also be associated with living arrangements (e.g., older adults with hearing problems may be more likely to live with others). Probable depression was determined by the 10-item Center for Epidemiological Depression (CES-D) scale[21] in CHARLS (score≥12) and the 8-item CES-D scale[22] in ELSA (score≥3). A detailed coding scheme of covariates is provided in Table S1.

Statistical analyses

Trajectories of episodic memory over the four-year follow-up in CHARLS and ELSA were estimated using latent growth curve modelling (LGCM) with two latent growth factors – the intercept (i.e. episodic memory scores at baseline) and the slope (i.e. rate of change in episodic memory scores per year of follow-up). Utilising episodic memory scores measured at three waves, a linear slope was estimated using factor loadings of 0, 2, and 4 for each wave, respectively, reflecting the time interval between waves. Both the intercept and slope factors were regressed on living arrangements separately for men and women, adjusting for age (centred at 60) and age squared (Model 1) to account for the possible non-linear age pattern of episodic memory, and additionally for SEP and health behaviours (Model 2) and health status (Model 3). In all models, the slope factor was additionally regressed on the number of word recall tests taken by the participants to take the possible practice effect of learning the cognition tests across waves into account.[10] Using the Model 3 results, four-year episodic memory trajectories were depicted by living arrangement categories with ageing-vector graphs[23] for every two years of age. We tested the gender interaction between living

arrangements and the intercept and slope, separately. We did not find any gender interaction in CHARLS (p for intercept=0.27, p for slope=0.46) but in ELSA there was gender interaction for the intercept ($p<0.05$) but not the slope ($p=0.76$). All analyses were performed using Mplus 7.4 (Muthén & Muthén, 2015), and unstandardised coefficients are reported.

Mplus handles missing outcome data using full information maximum likelihood (FIML) which yields valid estimates if missingness depends on observed data (i.e. missing at random), and is as effective as multiple imputation.[24] FIML was also used to deal with missingness on the covariates included in Models 2 and 3 by estimating their variances and covariances.[25] The comparative fit index (CFI)>0.95, Tucker-Lewis index (TFI)>0.95, and root mean squared error of approximation (RMSEA)<0.06 indicate good model fit.[26] These model fit indices showed that we had reasonable goodness of model fit in CHARLS and ELSA datasets (Table S2).

We carried out several sensitivity analyses. First, to quantify the possible impact of changes in living arrangements during follow-up, we conducted a sensitivity analysis in participants with stable living arrangements across the three waves. Second, analyses were carried out among participants with no cognitive impairments – excluding those at the bottom age- and sex-specific quintile of global cognition. Global cognition measures were derived using data on episodic memory, time orientation and executive function in line with a previous CHARLS and ELSA study[27]. Third, analyses were restricted to participants with episodic memory scores across all three waves.

Results

Episodic memory decreased across waves in CHARLS, but slightly increased in ELSA (Table 1) possibly owing to biases from attrition and practice effects. Additional analyses showed improvements in predicted memory scores with each additional word recall test taken

over the four-year period, especially for younger participants (Figure S1). Participants with better baseline memory were more likely to be followed up in ELSA (Table S3). In China, it was most common to be living with partner and children/grandchildren, followed by living with partner only. These were also the two most prevalent arrangements in England but followed an inverse order. The proportion of adults living alone was much higher in England than in China. Living in other multigenerational settings was rare in both China (<5%) and England (<2%); subsequent results for this category are therefore not reported.

Table 1. Study characteristics of the CHARLS and ELSA analytic samples by gender

	CHARLS (N=12,801)		ELSA (N=10,964)	
	Men (N=6,315)	**Women (N=6,486)**	**Men (N=4,992)**	**Women (N= 5,972)**
Mean episodic memory scores (0-20, SD)				
Wave 1	6.9±3.3	6.6±3.5	9.1±3.5	9.6±3.6
Wave 2	6.8±3.4	6.3±3.7	9.5±3.5	10.1±3.7
Wave 3	6.1±3.5	5.7±3.7	9.7±3.6	10.2±3.8
Mean age (years, SD)	61.9±8.1	61.7±8.3	64.8±10.0	65.4±10.6
Living arrangements (%)				
Living with partner only	30.5	28.3	57.5	47.8
Living with partner and children/grandchildren	50.5	45.1	20.6	13.6
Living with no partner but with children/grandchildren	8.2	15.4	2.3	5.9
Living in other multigenerational setting	4.4	3.7	1.1	1.1
Living alone	6.4	7.6	18.6	31.6
Educational level (%)				
Low	62.6	81.3	36.3	47.4
Medium	22.5	11.4	35.6	35.3
High	14.9	7.3	28.1	17.3
Physical wealth tertiles (%)				
Low	43.7	45.1	40.4	47.7
Medium	33.0	32.5	43.5	38.3
High	23.4	22.4	16.1	14.0
Does not own current residence (%)	9.9	11.4	18.7	21.4
Not married or cohabitating (%)	15.3	23.7	23.7	40.1
Smoking status (%)				
Never smoker	26.7	91.2	25.9	43.5
Past smoker	17.3	2.3	56.9	38.4
Current smoker	56.1	6.5	17.2	18.1
Alcohol drinking frequency (%)				
Never	51.2	90.5	7.9	14.8
Less than once a month	11.2	4.8	12.8	24.9
1-3 times a month†/1-2 times a month‡	5.6	1.5	9.1	11.5
1-3 times a week†/1-2 times a week‡	7.2	1.1	34.3	26.9
4-6 times a week†/3-6 times a week‡	1.8	0.3	30.1	18.7
Almost daily or more	23.0	1.7	5.8	3.2
Mean number of limitations in activities of daily living (0-5, SD)	0.3±0.8	0.4±1.0	0.4±1.0	0.4±1.0
Self-rated hearing (%)				
Excellent or very good	14.0	12.6	41.8	54.6
Fair	29.5	29.4	31.1	28.8
Poor or very poor	56.5	58.0	27.1	16.6
Probable depression^ (%)	23.0	36.2	20.1	28.4
Self-reported cardiovascular disease (%)	14.7	18.5	26.3	20.5
Self-reported hypertension (%)	27.1	31.7	36.9	38.8
Self-reported diabetes (%)	6.2	8.1	8.9	6.1

†For CHARLS

‡For ELSA

^Probable depressive cases were defined as CES-D 10 scores ≥ 12 in CHARLS and CES-D 8 scores ≥3 in ELSA.

SD: standard deviation

Although English adults had better episodic memory at baseline than their Chinese counterparts, their age-related declines in episodic memory were stronger (Tables 2-3). Compared to Chinese men living with partner only, those living with partner and children/grandchildren and those living alone had worse episodic memory at baseline (intercept in Table 2). However, only Chinese men living with no partner but with children/grandchildren had a faster memory decline (slope in Model 1: -0.115 word/year, 95% confidence interval [CI]: -0.205, -0.024) than the reference group. Differences in baseline episodic memory for Chinese men living alone were explained by SEP and health behaviours. Nevertheless, these factors along with health status did not diminish baseline differences for Chinese men living with partner and children/grandchildren; nor prospective differences for Chinese men living with no partner but with children/grandchildren. Among English men, only those living alone had poorer episodic memory at baseline (Model 1: -0.470 word, 95% CI: -0.664, -0.276) and a faster decline (-0.086 word/year, 95% CI: -0.149, -0.023) than the reference group; but these differences were explained by SEP and health behaviours. Overall, fully-adjusted memory trajectories were generally similar across living arrangement categories for men in England (Figure S2) and in China (Figure 1), with the exception of the widening gap in episodic memory between Chinese men living with no partner but with children/grandchildren and those living with partner only over the follow-up.

Table 2. Study-specific linear growth model of episodic memory scores (0-20) by living arrangements in men

	Model 1*		Model 2†		Model 3‡	
	Intercept b (95% CI)	**Slope b (95% CI)**	**Intercept b (95% CI)**	**Slope b (95% CI)**	**Intercept b (95% CI)**	**Slope b (95% CI)**
CHARLS						
Mean	7.494 (7.365, 7.624)	-0.499 (-0.609, -0.390)	6.740 (6.470, 7.010)	-0.427 (-0.556, -0.297)	7.188 (6.872, 7.504)	-0.407 (-0.548, -0.266)
Variance	3.734 (3.241, 4.227)	0.068 (0.004, 0.133)	2.872 (2.411, 3.334)	0.071 (0.010, 0.132)	2.706 (2.250, 3.162)	0.073 (0.013, 0.134)
Baseline age, centred	-0.083 (-0.095, -0.071)	-0.010 (-0.014, -0.007)	-0.033 (-0.045, -0.021)	-0.008 (-0.012, -0.004)	-0.031 (-0.043, -0.018)	-0.008 (-0.012, -0.004)
Baseline age, squared	-0.002 (-0.003, -0.001)	0.000 (-0.001, 0.000)	-0.003 (-0.004, -0.003)	0.000 (-0.001, 0.000)	-0.003 (-0.004, -0.002)	0.000 (-0.001, 0.000)
Living with partner only	Ref	Ref	Ref	Ref	Ref	Ref
Living with partner and children/grandchildren	-0.230 (-0.383, -0.076)	-0.013 (-0.062, 0.037)	-0.309 (-0.459, -0.159)	-0.008 (-0.058, 0.043)	-0.257 (-0.406, -0.108)	-0.012 (-0.062, 0.039)
Living with no partner but with children/grandchildren	-0.210 (-0.494, 0.074)	-0.115 (-0.205, -0.024)	-0.126 (-0.400, 0.149)	-0.108 (-0.199, -0.017)	0.011 (-0.262, 0.283)	-0.122 (-0.213, -0.031)
Living alone	-0.561 (-0.858, -0.264)	-0.049 (-0.146, 0.049)	-0.225 (-0.510, 0.061)	-0.028 (-0.125, 0.069)	-0.168 (-0.450, 0.115)	-0.033 (-0.130, 0.064)
ELSA						
Mean	10.065 (9.959, 10.172)	-1.333 (-1.715, -0.952)	8.395 (8.117, 8.672)	-1.095 (-1.459, -0.732)	8.809 (8.515, 9.103)	-1.130 (-1.493, -0.767)
Variance	4.848 (4.362, 5.334)	0.069 (0.005, 0.132)	3.952 (3.501, 4.403)	0.072 (0.012, 0.132)	3.833 (3.387, 4.279)	0.071 (0.011, 0.131)
Baseline age, centred	-0.154 (-0.167, -0.142)	-0.006 (-0.010, -0.002)	-0.119 (-0.131, -0.107)	-0.006 (-0.010, -0.002)	-0.114 (-0.126, -0.101)	-0.006 (-0.011, -0.002)
Baseline age, squared	0.000 (-0.001, 0.001)	0.000 (0.000, 0.000)	0.000 (-0.001, 0.000)	0.000 (0.000, 0.000)	0.000 (-0.001, 0.000)	0.000 (0.000, 0.000)
Living with partner only	Ref	Ref	Ref	Ref	Ref	Ref
Living with partner and children/grandchildren	-0.184 (-0.382, 0.013)	-0.049 (-0.111, 0.013)	-0.067 (-0.255, 0.121)	-0.046 (-0.108, 0.015)	-0.056 (-0.242, 0.141)	-0.048 (-0.109, 0.014)
Living with no partner but with children/grandchildren	-0.333 (-0.815, 0.150)	-0.032 (-0.180, 0.116)	0.233 (-0.227, 0.693)	0.008 (-0.140, 0.156)	0.300 (-0.158, 0.778)	0.027 (-0.122, 0.175)
Living alone	-0.470 (-0.664, -0.276)	-0.086 (-0.149, -0.023)	0.052 (-0.139, 0.244)	-0.050 (-0.115, 0.015)	0.072 (-0.120, 0.309)	-0.041 (-0.107, 0.024)

b represents unstandardised coefficients.

Ref: reference category

*Adjusted for age and age squared. The slope was additionally adjusted for the number of episodic memory tests taken over the four-year period.

†Adjusted for Model 1 covariates plus educational level, physical wealth, current residence ownership, smoking status and alcohol drinking frequency.

‡Adjusted for Model 2 covariates plus number of limitations in ADLs, self-rated hearing, probable depression, and self-reported doctor-diagnosis of cardiovascular disease, hypertension, and diabetes, in turn.

Contrary to the results for men, living arrangements were more influential in episodic memory decline for women in England than in China (Table 3). Chinese women co-residing with children/grandchildren, regardless of the presence of their partner, had worse baseline episodic memory than the reference group after full adjustment. Memory decline did not differ between living arrangement categories in Chinese women except those living with no partner but with children/grandchildren (Model 1: -0.084 word/year, 95% CI: -0.154, -0.013). This difference in slope was fully explained by SEP and health behaviours. Only English women living with no partner but with children/grandchildren had poorer episodic memory at baseline than the reference group, but this difference was explained by SEP and health behaviours. Despite weak baseline differences among English women, significant differences in the rate of decline emerged over the four years of follow-up, which remained strong after controlling for all covariates. Specifically, English women co-residing with children/grandchildren, both with (Model 3: -0.114 word/year, 95% CI: -0.180, -0.049) or without a partner (-0.118 word/year, 95% CI: -0.209, -0.026), as well as those living alone (-0.075 word/year, 95% CI: -0.127, -0.024) had faster memory declines than the reference group. In conclusion, fully adjusted four-year memory trajectories did not substantially differ by living arrangements for Chinese women (Figure S3); but slightly diverged between English women co-residing with children/grandchildren, either with or without a partner, and those living with their partner only (Figure 2). Trajectories for English women living alone converged with those living with their partner only.

Sensitivity analysis of participants in stable living arrangements over time (CHARLS N=5,152; ELSA N=5,666, Table S4) provided a similar pattern of results, but faster declines in episodic memory were no longer observed for English women co-residing with children/grandchildren and with or without a partner due to small sample sizes (Tables S5-6). The associations between living arrangements and episodic memory trajectories were similar

in CHARLS after excluding participants with cognitive impairment at baseline; however, most of the associations in ELSA were weaker, except for English men living with their partner and children/grandchildren whose memory decline became faster (Table S7). The results also remained largely unchanged after excluding participants with doctor-diagnosed cognitive disorders (e.g. Parkinson's disease, Alzheimer's disease, and dementia) at baseline (Table S8). Among participants with complete episodic memory measurements over time, the associations became weaker in both studies (Table S9), but more so in English men and women due to more selective attrition in ELSA (Table S3).

Table 3. Study-specific linear growth model of episodic memory scores (0-20) by living arrangements in women

	Model 1*		Model 2†		Model 3‡	
	Intercept b (95% CI)	**Slope b (95% CI)**	**Intercept b (95% CI)**	**Slope b (95% CI)**	**Intercept b (95% CI)**	**Slope b (95% CI)**
CHARLS						
Mean	7.055 (6.920, 7.189)	-0.730 (-0.842, -0.617)	6.246 (5.912, 6.580)	-0.736 (-0.882, -0.591)	6.955 (6.580, 7.330)	-0.793 (-0.950, -0.637)
Variance	4.593 (4.079, 5.108)	0.072 (0.005, 0.138)	3.383 (2.907, 3.859)	0.068 (0.006, 0.131)	3.211 (2.740, 3.683)	0.065 (0.004, 0.127)
Baseline age, centred	-0.100 (-0.112, -0.088)	-0.014 (-0.018, -0.010)	-0.051 (-0.063, -0.039)	-0.012 (-0.016, -0.008)	-0.046 (-0.058, -0.034)	-0.013 (-0.017, -0.009)
Baseline age, squared	-0.001 (-0.002, 0.000)	0.000 (0.000, 0.000)	-0.003 (-0.004, -0.002)	0.000 (0.000, 0.000)	-0.003 (-0.004, -0.002)	0.000 (0.000, 0.000)
Living with partner only	Ref	Ref	Ref	Ref	Ref	Ref
Living with partner and children/grandchildren	-0.303 (-0.471, -0.135)	-0.051 (-0.103, 0.001)	-0.369 (-0.531, -0.207)	-0.044 (-0.096, 0.009)	-0.332 (-0.493, -0.171)	-0.044 (-0.096, 0.009)
Living with no partner but with children/grandchildren	-0.407 (-0.629, -0.184)	-0.084 (-0.154, -0.013)	-0.409 (-0.621, -0.196)	-0.065 (-0.135, 0.006)	-0.336 (-0.548, -0.125)	-0.065 (-0.136, 0.005)
Living alone	-0.119 (-0.420, 0.181)	0.004 (-0.092, 0.101)	0.027 (-0.258, 0.312)	0.008 (-0.088, 0.104)	-0.012 (-0.295, 0.271)	0.013 (-0.082, 0.109)
ELSA						
Mean	10.624 (10.523, 10.724)	-1.282 (-1.641, -0.924)	9.462 (9.257, 9.666)	-1.142 (-1.477, -0.807)	9.800 (9.579, 10.021)	-1.187 (-1.521, -0.853)
Variance	5.004 (4.551, 5.457)	0.076 (0.018, 0.135)	4.145 (3.723, 4.567)	0.102 (0.046, 0.157)	3.979 (3.560, 4.397)	0.093 (0.037, 0.148)
Baseline age, centred	-0.131 (-0.142, -0.119)	-0.007 (-0.011, -0.003)	-0.094 (-0.105, -0.082)	-0.007 (-0.010, -0.003)	-0.090 (-0.101, -0.078)	-0.007 (-0.010, -0.003)
Baseline age, squared	-0.002 (-0.002, -0.001)	0.000 (0.000, 0.000)	-0.002 (-0.002, -0.001)	0.000 (0.000, 0.000)	-0.002 (-0.002, -0.001)	0.000 (0.000, 0.000)
Living with partner only	Ref	Ref	Ref	Ref	Ref	Ref
Living with partner and children/grandchildren	-0.031 (-0.244, 0.183)	-0.108 (-0.173, -0.042)	0.101 (-0.102, 0.304)	-0.113 (-0.178, -0.047)	0.118 (-0.083, 0.319)	-0.114 (-0.180, -0.049)
Living with no partner but with children/grandchildren	-0.593 (-0.883, -0.303)	-0.109 (-0.200, -0.018)	-0.102 (-0.380, 0.177)	-0.109 (-0.201, -0.018)	-0.012 (-0.289, 0.266)	-0.118 (-0.209, -0.026)
Living alone	-0.059 (-0.222, 0.103)	-0.073 (-0.123, -0.022)	0.236 (0.078, 0.395)	-0.073 (-0.125, -0.022)	0.266 (0.108, 0.424)	-0.075 (-0.127, -0.024)

b represents unstandardised coefficients.

Ref: reference category

*Adjusted for age and age squared. The slope was additionally adjusted for the number of episodic memory tests taken over the four-year period.

†Adjusted for Model 1 covariates plus educational level, physical wealth, current residence ownership, smoking status and alcohol drinking frequency.

‡Adjusted for Model 2 covariates plus number of limitations in ADLs, self-rated hearing, probable depression, and self-reported doctor-diagnosis of cardiovascular disease, hypertension, and diabetes, in turn.

Discussion

This cross-national investigation found worse baseline episodic memory in Chinese adults with multigenerational living than their partnered counterparts, but such associations were not observed in England. A faster rate of episodic memory decline was associated with living with no partner but with children/grandchildren in Chinese men, and with co-residing with children/grandchildren regardless of the presence of partner in English women. No relationship between living alone and episodic memory trajectories was found in Chinese adults nor in English men. Slightly better episodic memory at baseline, however, was observed in English women living alone than those living with partner only and their trajectories converged after the four-year period.

Potential mechanisms linking living arrangements to cognition

The conceptual framework by Berkman and colleagues[28] theorises that social networks provide individuals with opportunities for social support, social influences, social engagement, and access to resources and material goods. These mechanisms impact health through health behaviours, psychological factors (e.g. self-efficacy and coping effectiveness), and physiological processes (e.g. hypothalamic-pituitary-adrenal axis responses to stress and cardiopulmonary fitness). This framework has been extended to social networks and dementia risk.[29] Living with others, whether partners or other generations, under one roof implies guaranteed social networks that provide different types of social interaction and support, which in turn link to better cognition and slower cognitive decline via the aforementioned pathways.[10 29] Living with others also brings more access to resources and material goods into the household, which could be protective against cognitive decline via lower levels of stress and stress response, depression, cardiovascular risk factors (e.g. lifestyle, hypertension, hyperlipidaemia, diabetes), as well as via better access to health care.[29-31] In addition, living

with other persons may also have protective effects on cognition as it reduces anxiety and loneliness older adults may face.[10] Social ties, on the other hand, could also bring more interpersonal conflicts (e.g. demands for assistance and criticisms) and unfavourable changes in behaviours resulting in increased psychological distress which thus compromise one's health.[32]

Multigenerational living arrangements

The worse baseline episodic memory associated with co-residing with children/grandchildren we found in China is partially in line with a European-wide cross-sectional study, in which co-residing with children was linked to worse immediate recall in men aged 60+ and worse delayed recall in women aged 60+.[33] Reverse causation may explain some of these associations – older Chinese adults with worse cognition may be more likely to live with their children/grandchildren for help and care. Comparing our longitudinal findings on co-residing with children/grandchildren and additionally with or without a partner, the faster decline in episodic memory was driven by co-residing with children/grandchildren in Chinese men, whereas for English women it was both the absence of the partner and the co-residence with children/grandchildren. These findings contradict those from a European-wide study which reported no association between co-residing with adult children and episodic memory decline,[10] but is consistent with a longitudinal study from China.[12] Our cross-sectional and longitudinal findings as a whole suggest that the theorised protective effects of living with children/grandchildren do not exist or are offset by its detrimental effects.

It is possible that caring for grandchildren gives the grandparents a purpose for living and a cognitive challenge, which in turn may slow down their cognitive decline.[34] Caregiving to grandchildren has been shown to be protective against cognitive decline in Italian adults aged 65+.[35] Caregiving to grandchildren nevertheless conceptually is not the same as co-residing

with grandchildren; co-residing with grandchildren likely brings a heavier burden which may undermine the grandparent's cognition. This explanation may underlie the faster decline of episodic memory we found in Chinese men and English women co-residing with children/grandchildren.

Since home-based informal care is the main form of elderly care in China, the elderly who experience considerable health declines are most likely to live at home with their partner and/or adult children. Whereas in England they could have assisted living or be institutionalised since such services are generally accessible. Consequently, the same living arrangement may have different meanings in China and England, which may explain some country discrepancies and warrants cautious interpretation.

Living alone

Both Chinese and English adults living alone, compared to those living with partner only, tended to have lower levels of SEP (Tables S10-11). The better episodic memory at baseline in English women living alone may support the hypothesis that older adults' good health and cognitive capacity enable them to live independently in the community.[9 36] In addition, as showed by a study of Spanish women aged 65+,[37] older adults living alone are possibly not as socially isolated as is often believed and they may actively seek contact with relatives and friends. This finding also supports the notion that being alone and feeling lonely are conceptually distinct phenomena – living alone is the objective physical separation from others, whereas loneliness is the subjective state of feeling alone or separated from others.[38] Due to the faster decline over time, the slight advantage in episodic memory that English women living alone had at baseline disappeared after the four years of follow-up. This faster decline, however, supports the hypothesis that the presence of a partner is important in protecting one's cognition.[10] Even if older adults living alone actively engage with relatives or

friends; the social support, person-to-person contact, and access to resources and material goods brought by relatives/friends are less beneficial than those provided by partners as people age.

Living alone was not associated with episodic memory trajectories in China. There has been a shift in China that older urban-dwelling Chinese adults favour to live by themselves but close to their children in the same community/neighbourhood.[39] Older Chinese living alone thus may have an adult child living nearby who supports them, or they actively engage with their relatives and friends who live nearby. According to a Singaporean study, older adults living alone were not particularly disadvantaged compared to those living with spouse and/or children in their social and economic wellbeing.[40] This may explain our findings in China given their similarity in cultural norms for family arrangements.

Strengths and limitations

To our best knowledge, this is the first study examining how episodic memory trajectories differed by living arrangements in mid- to late life from two countries with distinctive cultural norms, using longitudinal data from two large nationally representative cohort studies. The comparability of our data from China and England is maximised by the similarity between CHARLS and ELSA, both of which are sister studies of the Health and Retirement Study. We used latent growth curve modelling that allowed us to assess the cross-sectional and longitudinal associations between living arrangements and episodic memory simultaneously. Moreover, missing data was dealt with by FIML, which makes our results valid under the missing at random assumption.

Although our main findings were supported by the sensitivity analysis results, we were unable to assess whether episodic memory decline differed in those who experienced transitions into living alone or co-residing with children/grandchildren during the follow-up. Since

multigenerational living was uncommon in England, we could not further explore the role of specific generations residing in the household in episodic memory decline. Due to the differences in elderly care between China and England, our sample from China could consist of more unhealthy older adults living at home, perhaps diluting differences in episodic memory trajectories between living arrangement categories in China. Although both CHALRS and ELSA excluded institutionalised older adults from the sample recruitment, this exclusion may also explain the larger re-test effects in ELSA than in CHARLS as long-term care is much more prevalent in England than in China. The word recall test – a brief and limited test for episodic memory – may not be sufficiently sensitive to age-related changes and thus leads to underestimated differences in the rate of episodic memory decline by living arrangements. We controlled for socioeconomic position, health behaviours, and health conditions that may lead to higher risk of dementia, but we did not test whether these factors are mediators linking living arrangements with episodic memory decline, or touch upon other possible psychological or physiologic pathways, which need to be addressed in future research. Due to data restrictions, we were only able to examine trajectories over four years; further research with longer follow-up are therefore also required.

In summary, multigenerational living was associated with poorer baseline episodic memory in China but not in England, and it appeared to accelerate cognitive decline in Chinese men and English women. The cognitive advantage among English women living alone disappeared as they aged. These results contest the hypothesised protective effects of multigenerational living and the detrimental effects of living alone on cognition in both China in England.

Figure legends

Figure 1. Vector graphs of the 4-year episodic memory trajectories by living arrangements for every two years of age in CHARLS men

Note: Figure is based on LGCM Model 3. Black lines indicate statistically significant differences in rates of episodic memory decline (slope); grey lines indicate statistically non-significant slope differences.

Figure 2. Vector graphs of the 4-year episodic memory trajectories by living arrangements for every two years of age in ELSA women

Note: Figure is based on LGCM Model 3. Black lines indicate statistically significant differences in rates of episodic memory decline (slope); grey lines indicate statistically non-significant slope differences.

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Contributors

YH and MR, as joint first authors, conceived the study, developed the harmonised variables, conducted the scientific literature search, prepared the data for analysis, analysed the data, interpreted the results, and prepared the first and final drafts of the manuscript. MB and PM made substantial contributions to the analysis and interpretation of data and results, and critically reviewed the first and final drafts of the manuscript for important intellectual content. All authors agreed on the submission of this manuscript.

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Competing interests

None declared.

Patient consent for publication

Not required.

Ethics approval

Ethical approval was provided by the Ethical Review Committee of Peking University (IRB00001052-11015) and London Multi-Centre Research Ethics Committee (MREC/01/2/91), respectively for CHARLS and ELSA.

Data availability statement

Data from the China Health and Retirement Longitudinal Study and the English Longitudinal Study of Ageing are available in a public, open access repository (CHARLS: http://charls.pku.edu.cn/pages/data/111/en.html, ELSA: https://beta.ukdataservice.ac.uk/datacatalogue/series/series?id=200011).

References

1. Prince M, Wimo A, Guerchet M, et al. World Alzheimer report 2015—the global impact of dementia: an analysis of prevalence, incidence, cost and trends. London: Alzheimer's Disease International, 2015.
2. Prince M, Knapp M, Guerchet M, et al. Dementia UK. 2nd ed. London: Alzheimer's Society 2014.
3. Baumgart M, Snyder HM, Carrillo MC, et al. Summary of the evidence on modifiable risk factors for cognitive decline and dementia: A population-based perspective. *Alzheimers & Dementia* 2015;11(6):718-26. doi: 10.1016/j.jalz.2015.05.016
4. Livingston G, Sommerlad A, Orgeta V, et al. Dementia prevention, intervention, and care. *Lancet* 2017;390(10113):2673-734. doi: 10.1016/S0140-6736(17)31363-6
5. Evans IEM, Martyr A, Collins R, et al. Social Isolation and Cognitive Function in Later Life: A Systematic Review and Meta-Analysis. *J Alzheimers Dis* 2019;70:S119-S44. doi: 10.3233/Jad-180501
6. Wang H, Chen K, Pan YF, et al. Associations and Impact Factors between Living Arrangements and Functional Disability among Older Chinese Adults. *Plos One* 2013;8(1) doi: 10.1371/journal.pone.0053879
7. Hughes ME, Waite LJ. Health in household context: living arrangements and health in late middle age. *J Health Soc Behav* 2002;43(1):1-21. doi: 10.2307/3090242
8. Weissman JD, Russell D. Relationships Between Living Arrangements and Health Status Among Older Adults in the United States, 2009-2014: Findings From the National Health Interview Survey. *Journal of Applied Gerontology* 2018;37(1):7-25. doi: 10.1177/0733464816655439
9. Hu YY, Leinonen T, van Hedel K, et al. The relationship between living arrangements and higher use of hospital care at middle and older ages: to what extent do observed and

unobserved individual characteristics explain this association? *BMC public health* 2019;19 doi: 10.1186/S12889-019-7296-X

10. Mazzuco S, Meggiolaro S, Ongaro F, et al. Living arrangement and cognitive decline among older people in Europe. *Ageing Soc* 2017;37(6):1111-33. doi: 10.1017/S0144686x16000374
11. Evans IEM, Llewellyn DJ, Matthews FE, et al. Living alone and cognitive function in later life. *Arch Gerontol Geriat* 2019;81:222-33. doi: 10.1016/j.archger.2018.12.014
12. Zhou Z, Mao FZ, Ma JP, et al. A Longitudinal Analysis of the Association Between Living Arrangements and Health Among Older Adults in China. *Res Aging* 2018;40(1):72-97. doi: 10.1177/0164027516680854
13. Chen T. Living arrangement preferences and realities for elderly Chinese: implications for subjective wellbeing. *Ageing and Society* 2018:1-25. doi: 10.1017/S0144686X18000041
14. Lei XY, Strauss J, Tian M, et al. Living arrangements of the elderly in China: evidence from the CHARLS national baseline. *China Econ J* 2015;8(3):191-+. doi: 10.1080/17538963.2015.1102473
15. Reher D, Requena M. Living Alone in Later Life: A Global Perspective. *Population and Development Review* 2018;44(3):427-54. doi: 10.1111/padr.12149
16. Grundy E. Co-residence of mid-life children with their elderly parents in England and Wales: Changes between 1981 and 1991. *Pop Stud-J Demog* 2000;54(2):193-206. doi: 10.1080/713779085
17. Celsis P. Age-related cognitive decline, mild cognitive impairment or preclinical Alzheimer's disease? *Ann Med* 2000;32(1):6-14. doi: 10.3109/07853890008995904
18. Weissberger GH, Strong JV, Stefanidis KB, et al. Diagnostic Accuracy of Memory Measures in Alzheimer's Dementia and Mild Cognitive Impairment: a Systematic

Review and Meta-Analysis. *Neuropsychol Rev* 2017;27(4):354-88. doi: 10.1007/s11065-017-9360-6

19. Zhao Y, Hu Y, Smith JP, et al. Cohort profile: the China Health and Retirement Longitudinal Study (CHARLS). *International journal of epidemiology* 2014;43(1):61-8. doi: 10.1093/ije/dys203
20. Steptoe A, Breeze E, Banks J, et al. Cohort Profile: The English Longitudinal Study of Ageing. *International journal of epidemiology* 2013;42(6):1640-48. doi: 10.1093/ije/dys168
21. Andresen EM, Malmgren JA, Carter WB, et al. Screening for Depression in Well Older Adults - Evaluation of a Short-Form of the Ces-D. *Am J Prev Med* 1994;10(2):77-84. doi: 10.1016/S0749-3797(18)30622-6
22. Turvey CL, Wallace RB, Herzog R. A revised CES-D measure of depressive symptoms and a DSM-based measure of major depressive episodes in the elderly. *Int Psychogeriatr* 1999;11(2):139-48. doi: 10.1017/S1041610299005694
23. Mirowsky J, Kim JY. Graphing age trajectories - Vector graphs, synthetic and virtual cohort projections, and cross-sectional profiles of depression. *Sociol Method Res* 2007;35(4):497-541. doi: 10.1177/0049124106296015
24. Graham JW. Missing Data Analysis: Making It Work in the Real World. *Annu Rev Psychol* 2009;60:549-76. doi: 10.1146/annurev.psych.58.110405.085530
25. Mplus Website. Missing on x's. (16/08/2019). https://www.statmodel.com/download/Missing%20on%20x's.pdf.
26. Hu LT, Bentler PM. Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives. *Struct Equ Modeling* 1999;6(1):1-55. doi: 10.1080/10705519909540118

27. Ma Y, Liang L, Zheng F, et al. Association Between Sleep Duration and Cognitive Decline. *JAMA Netw Open* 2020;3(9):e2013573. doi: 10.1001/jamanetworkopen.2020.13573

28. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57. doi: 10.1016/S0277-9536(00)00065-4

29. Fratiglioni L, Paillard-Borg S, Winblad B. An active and socially integrated lifestyle in late life might protect against dementia. *Lancet Neurol* 2004;3(6):343-53. doi: 10.1016/S1474-4422(04)00767-7

30. Matthews KA, Gallo LC, Taylor SE. Are psychosocial factors mediators of socioeconomic status and health connections? A progress report and blueprint for the future. *Annals of the New York Academy of Sciences* 2010;1186:146-73. doi: 10.1111/j.1749-6632.2009.05332.x

31. Adler NE, Newman K. Socioeconomic disparities in health: pathways and policies. *Health affairs (Project Hope)* 2002;21(2):60-76. doi: 10.1377/hlthaff.21.2.60

32. Seeman TE, Crimmins E. Social environment effects on health and aging - Integrating epidemiologic and demographic approaches and perspectives. *Ann Ny Acad Sci* 2001;954:88-117. doi: 10.1111/j.1749-6632.2001.tb02749.x.

33. Bordone V, Weber D. Number of children and cognitive abilities in later life. *Vienna Yearbook of Population Research* 2012;10:95-126. doi: 10.1553/populationyearbook2012s95

34. Boyle PA, Buchman AS, Barnes LL, et al. Effect of a Purpose in Life on Risk of Incident Alzheimer Disease and Mild Cognitive Impairment in Community-Dwelling Older Persons. *Arch Gen Psychiat* 2010;67(3):304-10. doi: 10.1001/archgenpsychiatry.2009.208

35. Trevisan C, Pamio MV, Curreri C, et al. The effect of childcare activities on cognitive status and depression in older adults: gender differences in a 4.4-year longitudinal study. *Int J Geriatr Psych* 2018;33(2):348-57. doi: 10.1002/gps.4750

36. Young H, Grundy E. Living arrangements, health and well-being. In: Stillwell J, Coast E, Kneale D, eds. Fertility, Living Arrangements, Care and Mobility. Dordrecht: Springer 2009:127–50.

37. Zunzunegui MV, Alvarado BE, Del Ser T, et al. Social networks, social integration, and social engagement determine cognitive decline in community-dwelling Spanish older adults. *J Gerontol B-Psychol* 2003;58(2):S93-S100. doi: 10.1093/geronb/58.2.S93

38. Cacioppo JT, Hughes ME, Waite LJ, et al. Loneliness as a specific risk factor for depressive symptoms: cross-sectional and longitudinal analyses. *Psychol Aging* 2006;21(1):140-51. doi: 10.1037/0882-7974.21.1.140

39. Meng DJ, Xu GH, He L, et al. What determines the preference for future living arrangements of middle-aged and older people in urban China? *Plos One* 2017;12(7) doi: 10.1371/journal.pone.0180764

40. Gubhaju B, Ostbye T, Chan A. Living arrangements of community-dwelling older Singaporeans: predictors and consequences. *Ageing Soc* 2018;38(6):1174-98. doi: 10.1017/S0144686x16001495