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Research Article

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Posted Date: November 23rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11265963/v1

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Additional Declarations: No competing interests reported.

Association Between Cognitive Trajectories and Dual Sensory Impairment Among Middle-Aged and Older Adults in China: A Nationally Representative Cohort Study

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Word count

Abstract: 332 words. Main text (Background to Conclusions): 3,766 words. Tables: 7. Figures: 3. References: 28.

Abstract

Background: Vision, hearing and cognitive impairment frequently coexist in later life, but most studies treat sensory impairment as the exposure and cognition as the outcome. Whether cognitive change predicts the onset of dual sensory impairment (DSI) is largely unknown. We examined whether cognitive trajectories predict prevalent and incident DSI in a nationally representative cohort of Chinese middle-aged and older adults.

Methods: We used four waves of the China Health and Retirement Longitudinal Study (2011, 2013, 2015 and 2018). The analytic cohort comprised 7,343 adults aged 45-85 years who were free of DSI in 2011 and had a valid DSI outcome in 2018. Cognition was measured with the 0-21 CHARLS composite score, and group-based trajectory modelling was used to identify cognitive trajectories. Logistic regression was used for DSI in 2018, and discrete-time complementary log-log models, with Cox models as a confirmatory analysis, for time to first DSI. Sensitivity analyses varied the sensory cut-off, the outcome definition and the analytic cohort.

Results: Three trajectories were identified: high-stable (n = 4,218, 57.4%), moderate-declining (n = 2,538, 34.6%) and low-declining (n = 587, 8.0%). Relative to the high-stable group, the fully adjusted odds ratio for DSI in 2018 was 1.73 (95% CI 1.38-2.16) for the moderate-declining group and 1.50 (95% CI 1.07-2.12) for the low-declining group. During follow-up, 1,032 participants (14.1%) developed DSI, with hazard ratios of 1.63 (95% CI 1.40-1.90) and 1.72 (95% CI 1.37-2.16) respectively. Seven-year cumulative incidence of first DSI rose from 9.6% in the high-stable group to 19.1% in the moderate-declining group and 24.2% in the low-declining group ($P < 0.001$). In the reverse direction, concurrent DSI was associated with lower cognitive scores in the same wave (beta = -0.73, SE 0.09; $P < 0.001$).

Conclusions: Declining cognitive trajectories predicted both prevalent and incident DSI, independently of sociodemographic, behavioural and comorbidity covariates. The findings are consistent with a bidirectional relationship between cognition and sensory function and suggest that adults with declining cognition are a reasonable target for combined vision and hearing screening.

Keywords

Dual sensory impairment; Cognitive trajectories; Group-based trajectory modelling; CHARLS; Cohort study; Ageing

Background

Population ageing is one of the most important medical and demographic challenges of our time[1]. In 2023, China had nearly 297 million people aged 60 years or older, and this number is projected to reach 402 million by 2040, about 28% of the population[2]. With population ageing, the prevalence of age-related vision impairment (VI), hearing impairment (HI), and dual sensory impairment (DSI, defined as concurrent VI and HI) is rising and has become a global public health concern. In 2020, more than 430 million people aged 50 years or older had vision impairment[3]; by 2050, an estimated 474 million people will have moderate or severe vision impairment and 360 million will have mild vision impairment[4]. The prevalence of clinically assessed DSI is approximately 5.5% and is projected to increase by 27.2% between 2025 and 2050[5]. Globally, more than 2.2 billion people have vision impairment and more than 1.5 billion live with hearing impairment[6].

Cognitive impairment is common among older adults worldwide[7], and China has the largest number of older adults with cognitive impairment, with a prevalence of 24.9% in 2018 and higher rates among women and people aged 80 years or older[8]. Sensory and cognitive impairment are closely related. Approximately 60% of people with DSI also have cognitive impairment[5]. Meta-analyses have shown that DSI increases the risk of dementia[9], longitudinal cohort studies have reported associations of DSI with cognitive decline and dementia risk[10], and cognitive function declines more steeply around the onset of new DSI[11].

Sensory impairment is partly modifiable, but treatment gaps remain large. In China, sensory impairment is common and is concentrated in rural areas[12,13]. Among middle-aged and older adults with hearing impairment, hearing aid use is associated with a lower risk of dementia[14]

and with better cognitive performance[15]. Timely sensory correction may slow cognitive decline and reduce the combined burden of the two conditions.

Almost all of this work runs in one direction: sensory impairment is treated as the exposure and cognition as the outcome. Whether cognitive change predicts later DSI has attracted far less attention. Part of the difficulty is measurement. A single cognitive score cannot separate people who are already low from people who are falling, whereas trajectory analysis can, and it has been used in CHARLS before to link depressive symptom trajectories to cardiovascular disease[18]. Trajectory methods have also been applied to cognition in this cohort[16,17], but we are not aware of any study that has used them to predict DSI. We therefore fitted group-based trajectory models to four waves of CHARLS data (2011, 2013, 2015 and 2018) and asked two questions: whether trajectory group predicts DSI in 2018, and whether it predicts the first onset of DSI during follow-up. Because the self-reported cut-off is a free parameter in this design, we also ran the analysis twice, once with impairment defined as poor ratings only and once with fair-or-poor ratings.

Methods

Study design and participants

We used four waves of the China Health and Retirement Longitudinal Study (CHARLS), collected in 2011, 2013, 2015, and 2018. CHARLS is a nationally representative cohort of community-dwelling adults aged 45 years and older in China[19]. The original study was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants provided written informed consent.

Eligible participants had a 2011 interview, valid age between 45 and 85 years, complete baseline demographic and health information, participation in all three follow-up waves, and cognitive

scores in all four waves. They also had to be free of dual sensory impairment (DSI) in 2011 and to have valid DSI status in 2018. The selection process is shown in Fig. 1.

Of 25,586 participants in the pooled sample, 7,878 were excluded because they had no 2011 interview. We then excluded 792 with missing or invalid age or age outside 45-85 years, 2,053 with missing baseline demographic or health information, 4,444 who did not complete all three follow-up waves, 2,559 with at least one missing cognitive score, and 517 with DSI or missing DSI status in 2011 (n = 504) or with missing DSI status in 2018 (n = 13). A total of 7,343 participants remained.

Cognitive function

At each wave, CHARLS assessed cognition with an adapted cognitive battery[19, 20]. We used the composite score, which ranges from 0 to 21, with higher values indicating better cognition. The score combines episodic memory, the average of immediate and delayed recall of ten words (0-10), and mental intactness from orientation, five consecutive subtractions of 7 from 100, and copying overlapping pentagons (0-11).

Dual sensory impairment

At each wave, participants rated distance vision, near vision, and hearing as excellent, very good, good, fair, or poor. Distance and near vision were rated with glasses or corrective lenses if used, and hearing was rated with a hearing aid if used. We defined vision impairment (VI) as a poor rating for distance or near vision, hearing impairment (HI) as a poor rating for hearing, and DSI as concurrent VI and HI. When a rating needed for classification was missing, the corresponding status was treated as missing.

Because sensory status was self-reported, the cut-off used to define impairment directly determines the prevalence and composition of the DSI groups. We conservatively restricted VI

and HI to ratings of poor, consistent with Ma[21] and with an English Longitudinal Study of Ageing analysis in which sensory impairment was defined as poor self-reported vision or hearing[22]; self-reported vision has also been shown to track measured visual acuity[23]. In our analytic cohort, the broader fair-or-poor cut-off used in several CHARLS-based studies[24] would classify 4,678 participants (63.7%) as having DSI in 2018 and 3,281 participants (44.7%) as already meeting the criterion in 2011, leaving little contrast between cognitive trajectory groups. We therefore used the conservative poor-only definition in the primary analyses and examined the broader definition in sensitivity analyses.

The primary outcome was DSI status in 2018. Time to first DSI was defined as the first follow-up wave (2013, 2015, or 2018) at which DSI was present; participants without DSI by 2018 were censored. In a sensitivity analysis, sustained DSI was defined as DSI at two consecutive waves (2013 and 2015, or 2015 and 2018).

Covariates

Baseline covariates included age (continuous), sex, residence (urban or rural), marital status (not married, married, other), education (below primary school, primary school, middle school, high school and above), ever smoking, ever drinking, and self-reported physician diagnoses of hypertension, dyslipidaemia, diabetes, chronic lung disease, and heart disease. We also adjusted for nighttime sleep duration and for activities of daily living (ADL), measured with six items and categorised as normal (0-1), mild impairment (2-3), or severe impairment (4-6).

Statistical analysis

Baseline characteristics were compared according to DSI status in 2018. Continuous variables were described as medians with interquartile ranges and compared with the Mann-Whitney U test; categorical variables were described as counts and percentages and compared with the chi-

square test, or Fisher exact test when expected cell counts were small. All tests were two-sided, and $P < 0.05$ was considered statistically significant. Analyses were performed in R 4.6.0 (gbmt package) and Python 3.12 (statsmodels, lifelines, and SciPy); survey weights were not applied.

Cognitive trajectory modelling

We used group-based trajectory modelling (GBTM) to identify subgroups of cognitive change across the four waves. Age at each wave was the time scale, and the 0-21 cognitive score was treated as a continuous outcome. Models with one to six trajectory groups were fitted using third-order polynomials in age. Model selection used the Bayesian information criterion (BIC), sample-size-adjusted BIC, entropy, average posterior probability (AvePP), odds of correct classification (OCC), and group size. Each participant was assigned to the trajectory group with the highest posterior probability. The gbmt package does not provide the Lo-Mendell-Rubin test or the bootstrap likelihood ratio test, so these statistics were not reported. The same modelling framework has been used to link trajectories of depressive symptoms to later cardiovascular disease in CHARLS[18].

Association between cognitive trajectories and DSI

Binary logistic regression was used to examine DSI in 2018. We fitted four models with increasing adjustment: Model 1 was unadjusted; Model 2 adjusted for sociodemographic variables; Model 3 additionally adjusted for health behaviours and comorbidities; Model 4 was fully adjusted for all covariates. Results are reported as odds ratios (OR) with 95% confidence intervals (CI).

Because DSI was only assessed at biennial visits, time to first DSI was analysed with discrete-time complementary log-log models on person-period data (20,860 records, 1,032 events). Cox proportional hazards models were fitted as a confirmatory analysis. The proportional hazards

assumption was checked with scaled Schoenfeld residuals and a trajectory-by-time interaction term. Kaplan-Meier curves were used to display cumulative incidence, and trajectory groups were compared with the log-rank test.

We also tested interactions between trajectory group and age at baseline (<65 vs. ≥65 years), sex, or nighttime sleep duration (≤6, >6 to ≤8, >8 h) in the fully adjusted models. Stratified hazard ratios were reported as exploratory evidence.

Sensitivity analyses

We repeated the main analyses after excluding participants with any VI or HI in 2011 (n = 4,880) and after restricting the cohort to participants free of DSI in both 2011 and 2013 (n = 6,905). We also used sustained DSI as the outcome (215 events), replaced trajectory groups with single baseline cognitive scores, and fitted random-intercept linear mixed models with concurrent DSI as a time-varying exposure as a reverse-direction check. Missing data were handled by the exclusion criteria above; no multiple imputation was performed. Finally, we repeated the main analyses after redefining VI and HI as fair or poor ratings, both in the full analytic cohort and after additionally excluding participants who met the broader criterion at baseline.

Results

Participant characteristics and cognitive trajectories

The analysis included 7,343 participants. Those with DSI in 2018 were older than those without DSI (median 60 vs. 57 years), more often female (61.2% vs. 50.2%) and rural (74.1% vs. 62.3%), and had lower educational attainment. They also had higher proportions of hypertension, lung disease, and heart disease, more ADL impairment, and shorter nighttime sleep. Differences were not significant for dyslipidaemia, diabetes, or marital status (Table 1).

Cognitive trajectory distributions differed by DSI status. The moderate-declining trajectory was present in 49.7% of participants with DSI versus 33.4% of those without, and the low-declining trajectory in 13.2% versus 7.6%.

The selected model contained a high-stable trajectory (n = 4,218, 57.4%), a moderate-declining trajectory (n = 2,538, 34.6%), and a low-declining trajectory (n = 587, 8.0%). Mean scores changed from 13.80 to 13.47 in the high-stable group, from 9.65 to 5.85 in the moderate-declining group, and from 4.39 to 1.48 in the low-declining group between 2011 and 2018 (Fig. 2).

Cognitive trajectory and DSI in 2018

Both declining trajectories carried higher odds of DSI in 2018 than the high-stable trajectory in unadjusted models (moderate-declining OR 2.37, 95% CI 1.95-2.88; low-declining OR 2.78, 95% CI 2.08-3.71). Adjustment for sociodemographic variables and health covariates attenuated the estimates. In the fully adjusted model, the ORs were 1.73 (95% CI 1.38-2.16) for the moderate-declining group and 1.50 (95% CI 1.07-2.12) for the low-declining group (Table 2).

Cognitive trajectory and incident DSI

During follow-up, 1,032 participants (14.1%) developed DSI. Fully adjusted Cox models gave hazard ratios of 1.63 (95% CI 1.40-1.90) for the moderate-declining group and 1.72 (95% CI 1.37-2.16) for the low-declining group (Table 3). Discrete-time complementary log-log models produced nearly identical estimates (Table 4).

The 7-year cumulative incidence of first DSI was 9.6% in the high-stable group, 19.1% in the moderate-declining group, and 24.2% in the low-declining group (Fig. 3). The overall log-rank test was significant ($P < 0.001$). Pairwise comparisons were significant for high-stable versus each declining group (both $P < 0.001$) and between the two declining groups ($P = 0.004$).

Effect modification

Interaction terms between trajectory group and baseline age (P = 0.060), sex (P = 0.123), and nighttime sleep duration (P = 0.450) were not statistically significant. Stratified fully adjusted hazard ratios followed the same direction across strata. The associations appeared stronger in participants aged 65 years or older, in men, and in those sleeping more than 8 h per night. For example, the low-declining hazard ratio was 2.23 (95% CI 1.43-3.47) at age 65 or older, 2.03 (95% CI 1.29-3.19) in men, and 3.25 (95% CI 1.50-7.04) with more than 8 h of sleep. We regard these subgroup estimates as exploratory (Table 5).

Sensitivity analyses

Sensitivity analyses are shown in Table 6. After excluding participants with any VI or HI in 2011 (n = 4,880), fully adjusted ORs for DSI in 2018 were 1.60 (95% CI 1.14-2.25) for the moderate-declining group and 1.98 (95% CI 1.20-3.26) for the low-declining group. Hazard ratios for first DSI were 1.60 (95% CI 1.28-2.00) and 2.08 (95% CI 1.50-2.88).

Among 6,905 participants free of DSI in 2011 and 2013, hazard ratios for first DSI after 2013 were 1.51 (95% CI 1.24-1.84) for the moderate-declining group and 1.37 (95% CI 1.01-1.85) for the low-declining group. In this restricted cohort, the logistic estimate for the low-declining group attenuated and was no longer significant (OR 1.23, 95% CI 0.82-1.85).

With sustained DSI as the outcome (215 events), fully adjusted ORs were 1.66 (95% CI 1.18-2.35) for the moderate-declining group and 2.04 (95% CI 1.25-3.34) for the low-declining group.

When trajectory groups were replaced by a single baseline cognitive measurement, the associations weakened. The lowest quartile of baseline cognition was not significantly associated with DSI in 2018 (OR 1.19, 95% CI 0.97-1.47; P = 0.099). Each standard deviation increase in baseline cognition gave an OR of 0.90 (95% CI 0.81-0.99).

In random-intercept linear mixed models across 29,372 observations, concurrent DSI was associated with lower cognitive scores in the same wave (β = -0.73, SE 0.09; $P < 0.001$) after full adjustment (Table 7).

When VI and HI were redefined using the fair-or-poor cut-off, 4,678 participants (63.7%) had DSI in 2018 and 6,008 (81.8%) developed DSI during follow-up. In the full cohort, the moderate-declining group retained higher odds of DSI in 2018 (OR 1.29, 95% CI 1.14-1.46) and a higher hazard of first DSI (HR 1.15, 95% CI 1.08-1.23), whereas estimates for the low-declining group attenuated and were no longer significant (OR 1.00, 95% CI 0.81-1.24; HR 1.06, 95% CI 0.96-1.19). After additionally excluding 3,281 participants who already met the broader criterion in 2011 (n = 4,062), the moderate-declining association persisted (OR 1.31, 95% CI 1.12-1.54; HR 1.19, 95% CI 1.09-1.31), while the low-declining estimates remained close to unity. Under the broader definition, most participants were classified as having DSI, which reduced the contrast between trajectory groups and probably explains the attenuated low-declining estimates.

Discussion

In this nationally representative cohort of 7,343 Chinese adults, cognitive trajectories that were already declining at baseline predicted DSI seven years later. Taking the high-stable group as the reference, the moderate-declining group had higher odds of DSI in 2018 (OR 1.73, 95% CI 1.38-2.16) and a higher hazard of first DSI (HR 1.63, 95% CI 1.40-1.90); the equivalent estimates for the low-declining group were 1.50 (95% CI 1.07-2.12) and 1.72 (95% CI 1.37-2.16). The literature on this pair of conditions runs overwhelmingly in one direction. Concurrent and cumulative sensory impairment predict cognitive decline and dementia in meta-analyses[9], in global projections[5] and in cohort studies[10], which is why the reverse direction has gone

largely untested. Our estimates supply it, and to our knowledge no previous study has used cognitive trajectories to predict DSI in a nationally representative Chinese sample. Read alongside the finding that cognition declines more steeply around the onset of new DSI[11], the two directions agree, and the simplest reading is that cognition and sensory function deteriorate together and that each accelerates the other.

The association probably has more than one source. Vascular pathology, neuroinflammation and protein accumulation affect the ageing brain and the sensory organs at the same time, so some of the overlap is likely to be structural; cumulative sensory impairment has already been linked to faster cognitive decline and incident dementia in Chinese cohorts[6]. A second possibility is that declining cognition changes what people notice and report. Registering that reading or conversation has become difficult requires attention and memory, and people with lower cognitive function seek care less often and are less likely to obtain hearing aids or glasses, so losses that begin as mild may drift into impairment. The reverse pathway is also plausible: untreated hearing and vision loss narrow social contact and environmental stimulation, and both have been associated with steeper cognitive decline[16,17,25,26]. We do not see these accounts as competing; a shared vulnerability, in which one underlying process drives decline in both domains, fits our data equally well. One caveat deserves emphasis. Because DSI was self-reported, an unknown part of the association may lie in reporting behaviour, and this is the main reason we stop short of a causal reading.

The two declining groups did not behave identically. Cumulative incidence of first DSI rose from 9.6% in the high-stable group to 19.1% in the moderate-declining group and 24.2% in the low-declining group, and it was the low-declining group that carried the highest hazard. The logistic estimates, by contrast, were similar for the two groups, and those for the low-declining

group moved more across sensitivity analyses, which is unsurprising given that it contains only 587 people. A three-group solution of this kind, with groups separated by level as well as slope, is what other CHARLS analyses have also reported[16,17]. We found no evidence that age, sex or nighttime sleep modified the association (P = 0.060, 0.123 and 0.450), although the stratified estimates were larger among participants aged 65 years or older, among men, and among those sleeping more than 8 h. We would not build on these strata. Some of them are small, and we did not adjust for multiple testing.

We probed the result in several ways, and it survived most of them. Estimates barely moved when we excluded participants who already had VI or HI in 2011, when we restricted the cohort to those free of DSI in 2011 and 2013, and when we required DSI to persist across two consecutive waves. Replacing the trajectory with a single baseline cognitive score weakened the association, which we take as evidence that the direction of change, and not merely the starting level, is what matters. In the opposite direction, concurrent DSI went with lower cognitive scores in the same wave (beta = -0.73, SE 0.09), in line with earlier reports[11]. The wider fair-or-poor definition was less informative. It classified 63.7% of the cohort as having DSI in 2018 and 81.8% during follow-up, and it left little variation between trajectory groups. Even so, the moderate-declining association held under it (OR 1.29, 95% CI 1.14-1.46; HR 1.15, 95% CI 1.08-1.23) and after we removed participants who already met the criterion at baseline (OR 1.31, 95% CI 1.12-1.54; HR 1.19, 95% CI 1.09-1.31), whereas the low-declining estimates fell towards the null. With most of the cohort classified as impaired, that group loses the contrast against which it is measured, and we read the attenuation as a property of the definition rather than as a failure of the association.

Where does this leave practice? If cognitive trajectories mark people who are about to develop DSI, they offer a way of finding those people before either condition has set in, and in China the potential yield is large: sensory impairment is common, and the treatment gap is widest in rural areas[12,13]. What correction achieves is less certain. Trials of sensory rehabilitation with cognitive endpoints remain scarce[27]; the supporting evidence is mostly observational, including a pooled analysis of seven cohorts linking hearing aid use to lower dementia risk[14] and studies in Chinese older adults reporting slower cognitive decline among hearing aid users[15]. Whether rehabilitation also lowers the incidence of DSI is untested, and we would not want our results read as evidence that it does. Screening is a more modest proposal. Cognition, vision and hearing can all be checked in a primary care visit at little cost, and patients whose cognitive scores are falling are a sensible group to prioritise for it. Managing their vision and hearing as separate problems, as often happens now, is likely to miss the point.

The limitations are worth stating plainly. Vision and hearing were self-rated, not measured by visual acuity testing or audiometry, and self-assessment and audiometry are known to disagree[28]; severity in particular is poorly captured this way. Our cut-off is also stricter than most CHARLS work, which counts fair as well as poor ratings. Restricting impairment to poor ratings picks out people with marked difficulty, but it costs comparability, and it fails when applied loosely: under the fair-or-poor rule 63.7% of our cohort would have had DSI in 2018 and 81.8% during follow-up, leaving too little variation between trajectory groups for the contrast to be informative. The low-declining estimate weakened under that rule, and we read this as a loss of contrast rather than as evidence against an association, though we accept that part of it may reflect the cut-off itself. Two further qualifications concern the exposure. Trajectory groups are a latent construct, so their number follows from modelling choices, and the small low-declining

group (n = 587) makes its estimates the least stable in the paper. On the outcome side, DSI was recorded only at biennial waves, so transient impairment would be missed, and device use was not modelled separately. Selection is a further concern. Requiring complete cognitive scores and all three follow-up waves, and restricting age to 45-85 years, is likely to have removed the frailest participants, and we did not apply survey weights. As in any observational analysis of this kind, residual confounding by depression, genetic risk or social support cannot be ruled out, and follow-up ended in 2018, so reverse causation is not fully excluded, even though excluding baseline DSI and the reverse-direction mixed model point the same way. Objective sensory measurement, longer follow-up and harmonised cross-national cohorts would settle several of these questions.

Conclusions

Among 7,343 Chinese adults aged 45-85 years who had no DSI at baseline, those on a moderately or steeply declining cognitive trajectory were more likely to have DSI in 2018 and to develop it during follow-up, and the estimates were little changed by adjustment for sociodemographic, behavioural and comorbidity covariates. The findings held in each sensitivity analysis, and a mixed model with concurrent DSI as the exposure pointed the other way as well, which is what a bidirectional process would look like. If this holds, trajectory information could be used to select adults for combined vision and hearing screening. Only a trial of sensory rehabilitation with cognitive and sensory endpoints can show whether the pathway can be interrupted.

List of abbreviations

ADL: activities of daily living

AvePP: average posterior probability

BIC: Bayesian information criterion

CHARLS: China Health and Retirement Longitudinal Study

CI: confidence interval

DSI: dual sensory impairment

GBTM: group-based trajectory modelling

HI: hearing impairment

HR: hazard ratio

OCC: odds of correct classification

OR: odds ratio

SE: standard error

VI: vision impairment

Declarations

Ethics approval and consent to participate

All procedures performed in this study were in accordance with the Declaration of Helsinki. The CHARLS study was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015), and all participants provided written informed consent. [Ethical approval for the present secondary analysis was obtained from <institution>; approval number <number>.]

Consent for publication

Not applicable.

Availability of data and materials

The CHARLS data are publicly available from the China Health and Retirement Longitudinal Study (http://charls.pku.edu.cn). The analysis code is available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

[<funder>; grant number <number>.] The funders had no role in the design of the study, in the collection, analysis and interpretation of data, or in the writing of the manuscript.

Authors' contributions

[<initials>] designed the study. [<initials>] performed the statistical analysis. [<initials>] and [<initials>] drafted the manuscript. All authors read and approved the final manuscript.

Acknowledgements

This analysis uses data from the China Health and Retirement Longitudinal Study (CHARLS). We thank the CHARLS team and the participants for making the data available.

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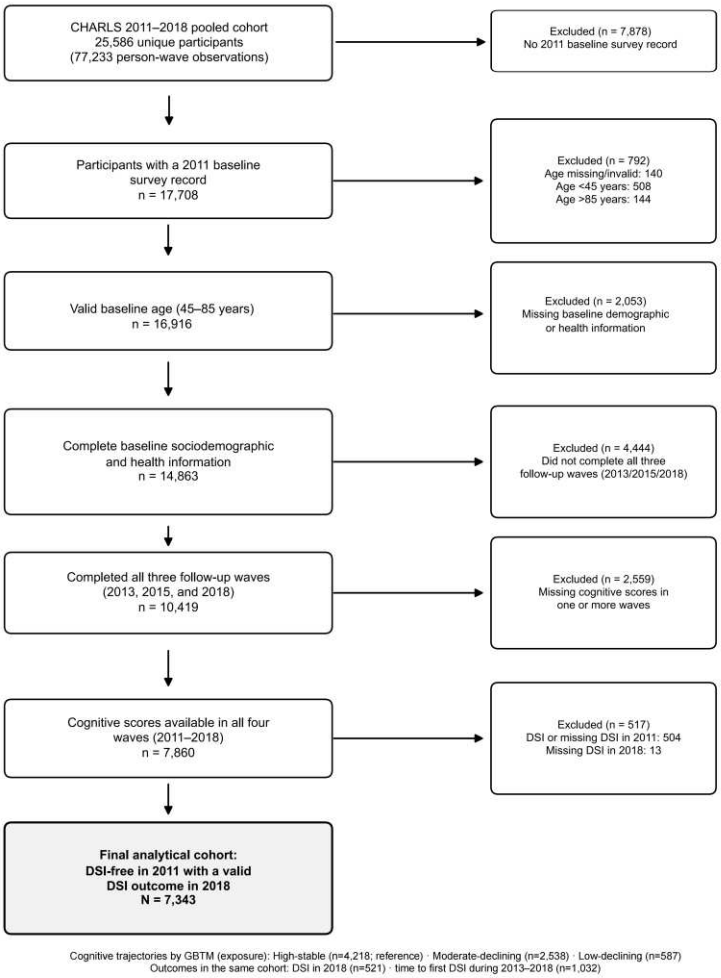
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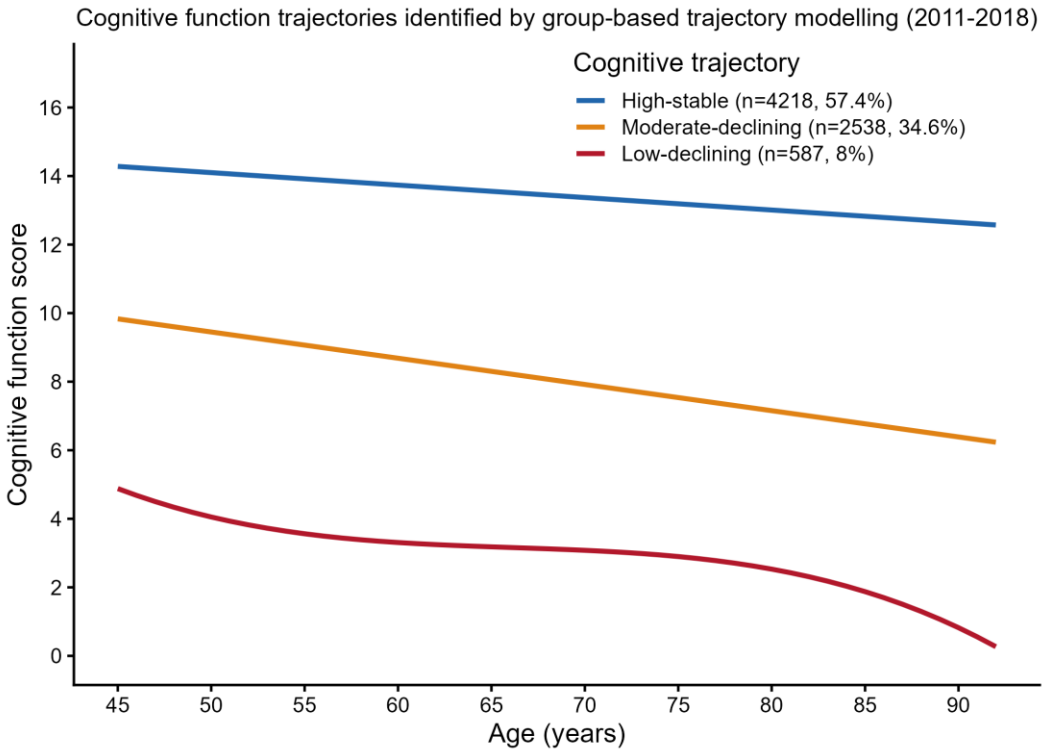
Figure legends

Fig. 1 Participant selection. Starting from 25,586 participants in the pooled 2011-2018 CHARLS waves, we excluded 7,878 who had no 2011 interview, then 792 with missing, invalid or out-of-range age (45-85 years), 2,053 with incomplete baseline demographic or health information, 4,444 who missed one or more follow-up waves, and 2,559 with a missing cognitive score in any wave. A final 517 were dropped for DSI or unknown DSI status in 2011 (n = 504) or unknown DSI status in 2018 (n = 13). The analytic cohort therefore comprised 7,343 participants who were free of DSI in 2011 and had a valid DSI outcome in 2018.



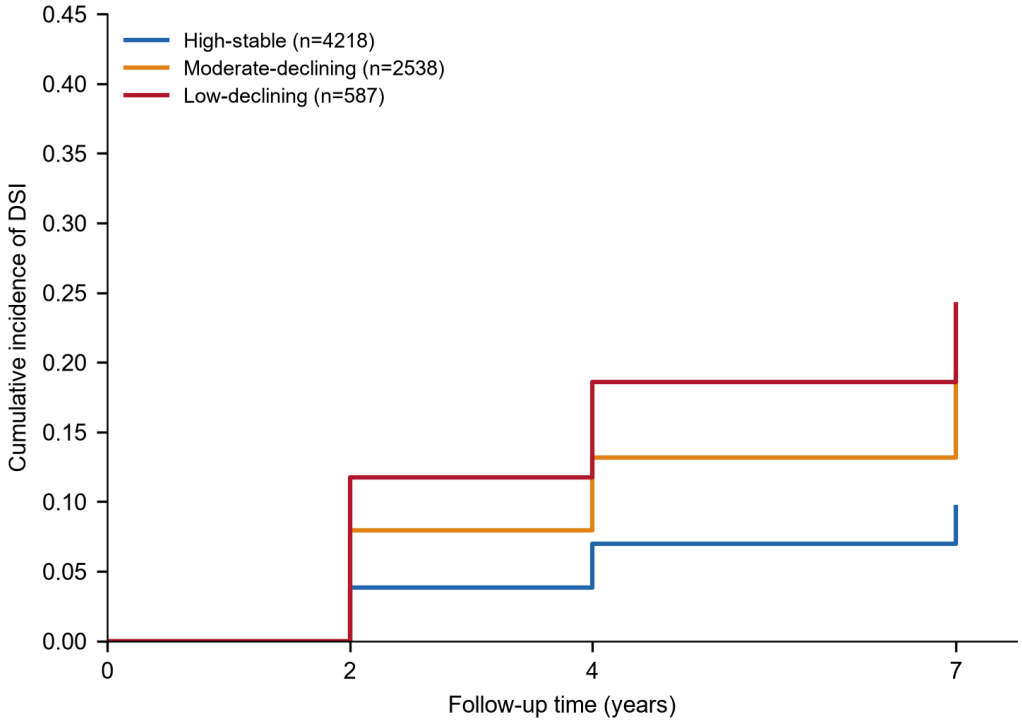
483

484 Fig. 2 Cognitive trajectories fitted by group-based trajectory modelling, plotted against age.
485 Scores are on the 0-21 cognitive scale and are estimated from the 2011, 2013, 2015 and 2018
486 waves. The three groups are high-stable (n = 4,218, 57.4%), moderate-declining (n = 2,538,
487 34.6%) and low-declining (n = 587, 8.0%).



488

489 Fig. 3 Cumulative incidence of first DSI over 7 years of follow-up, by cognitive trajectory group.
490 Kaplan-Meier curves are shown for the high-stable, moderate-declining and low-declining
491 groups. The log-rank test was significant overall ($P < 0.001$). Pairwise comparisons were
492 significant between the high-stable group and each declining group (both $P < 0.001$) and between
493 the two declining groups ($P = 0.004$).


High-stable (n=4218)
Moderate-declining (n=2538)
Low-declining (n=587)
Cumulative incidence of DSI
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
2
4
7
Follow-up time (years)

494

Tables

Table 1. Baseline characteristics of participants by DSI status in 2018

Characteristic	Overall (N=7,343)	No DSI in 2018 (N=6,822)	DSI in 2018 (N=521)	p-value
Age, median (Q1, Q3)	57.00 (50.00, 62.00)	57.00 (50.00, 62.00)	60.00 (54.00, 65.00)	<0.001
Gender				
Female	3,741 (50.9%)	3,422 (50.2%)	319 (61.2%)	
Male	3,602 (49.1%)	3,400 (49.8%)	202 (38.8%)	<0.001
Residence				
Urban	2,704 (36.8%)	2,569 (37.7%)	135 (25.9%)	
Rural	4,639 (63.2%)	4,253 (62.3%)	386 (74.1%)	<0.001
Marital status				
Not married	33 (0.4%)	31 (0.5%)	2 (0.4%)	
Married	6,702 (91.3%)	6,237 (91.4%)	465 (89.3%)	
Others	608 (8.3%)	554 (8.1%)	54 (10.4%)	0.197
Education				
Below primary school	2,940 (40.0%)	2,644 (38.8%)	296 (56.8%)	
Primary school	1,764 (24.0%)	1,648 (24.2%)	116 (22.3%)	
Middle school	1,706 (23.2%)	1,632 (23.9%)	74 (14.2%)	
High school and above	933 (12.7%)	898 (13.2%)	35 (6.7%)	<0.001
Smoking status				
No	4,419 (60.2%)	4,079 (59.8%)	340 (65.3%)	
Yes	2,924 (39.8%)	2,743 (40.2%)	181 (34.7%)	0.014
Drinking status				
No	4,402 (59.9%)	4,059 (59.5%)	343 (65.8%)	
Yes	2,941 (40.1%)	2,763 (40.5%)	178 (34.2%)	0.004
Hypertension				
No	5,590 (76.1%)	5,216 (76.5%)	374 (71.8%)	
Yes	1,753 (23.9%)	1,606 (23.5%)	147 (28.2%)	0.016
Dyslipidemia				
No	6,594 (89.8%)	6,131 (89.9%)	463 (88.9%)	
Yes	749 (10.2%)	691 (10.1%)	58 (11.1%)	0.466
Diabetes				

No	6,917 (94.2%)	6,432 (94.3%)	485 (93.1%)	
Yes	426 (5.8%)	390 (5.7%)	36 (6.9%)	0.262
Lung disease				
No	6,728 (91.6%)	6,266 (91.8%)	462 (88.7%)	
Yes	615 (8.4%)	556 (8.2%)	59 (11.3%)	0.012
Heart disease				
No	6,513 (88.7%)	6,071 (89.0%)	442 (84.8%)	
Yes	830 (11.3%)	751 (11.0%)	79 (15.2%)	0.004
ADL score				
Normal ADL function	6,991 (95.2%)	6,519 (95.6%)	472 (90.6%)	
Mild ADL impairment	256 (3.5%)	225 (3.3%)	31 (6.0%)	
Severe ADL impairment	96 (1.3%)	78 (1.1%)	18 (3.5%)	<0.001
Trajectory of cognitive function				
High-stable	4,218 (57.4%)	4,025 (59.0%)	193 (37.0%)	
Moderate-declining	2,538 (34.6%)	2,279 (33.4%)	259 (49.7%)	
Low-declining	587 (8.0%)	518 (7.6%)	69 (13.2%)	<0.001
Sleep time, median (Q1, Q3)	7.00 (5.00, 8.00)	7.00 (5.00, 8.00)	6.00 (5.00, 8.00)	<0.001

Values are medians (Q1, Q3) for continuous variables and n (%) for categorical variables. P values from the Mann-Whitney U test, chi-square test, or Fisher exact test. ADL, activities of daily living; DSI, dual sensory impairment.

Table 2. Association between cognitive trajectory groups and DSI in 2018 (binary logistic regression)

Model	Moderate-declining vs High-stable: OR (95% CI)	P	Low-declining vs High-stable: OR (95% CI)	P
M1	2.37 (1.95-2.88)	<0.001	2.78 (2.08-3.71)	<0.001
M2	1.73 (1.39-2.17)	<0.001	1.56 (1.11-2.19)	0.010
M3	1.76 (1.40-2.19)	<0.001	1.60 (1.14-2.24)	0.007
M4	1.73 (1.38-2.16)	<0.001	1.50 (1.07-2.12)	0.020

OR, odds ratio; CI, confidence interval. Model 1, unadjusted; Model 2, adjusted for age, sex, residence, marital status, and education; Model 3, additionally adjusted for smoking, drinking, hypertension, dyslipidaemia, diabetes, chronic lung disease, and heart disease; Model 4, fully adjusted, additionally including nighttime sleep duration and ADL impairment. Reference group, high-stable trajectory.

Table 3. Association between cognitive trajectory groups and first DSI during follow-up (Cox proportional hazards models)

Model	Moderate-declining vs High-stable: HR (95% CI)	P	Low-declining vs High-stable: HR (95% CI)	P
M1	2.10 (1.84-2.39)	<0.001	2.77 (2.29-3.35)	<0.001
M2	1.63 (1.40-1.90)	<0.001	1.77 (1.41-2.22)	<0.001
M3	1.65 (1.41-1.92)	<0.001	1.81 (1.45-2.27)	<0.001
M4	1.63 (1.40-1.90)	<0.001	1.72 (1.37-2.16)	<0.001

HR, hazard ratio; CI, confidence interval. Model 1, unadjusted; Model 2, adjusted for age, sex, residence, marital status, and education; Model 3, additionally adjusted for smoking, drinking, hypertension, dyslipidaemia, diabetes, chronic lung disease, and heart disease; Model 4, fully adjusted, additionally including nighttime sleep duration and ADL impairment. Reference group, high-stable trajectory.

Table 4. Association between cognitive trajectory groups and first DSI during follow-up (discrete-time complementary log-log models)

Model	Moderate-declining vs High-stable: HR (95% CI)	P	Low-declining vs High-stable: HR (95% CI)	P
M3	1.65 (1.42-1.92)	<0.001	1.81 (1.45-2.27)	<0.001
M4	1.63 (1.40-1.90)	<0.001	1.72 (1.37-2.17)	<0.001

HR, hazard ratio; CI, confidence interval. Models M3 and M4 as defined in Table 2.

Table 5. Stratified associations between cognitive trajectory groups and first DSI, with tests for interaction

Subgroup	n	Events	Moderate vs high: HR (95% CI)	P	Low vs high: HR (95% CI)	P	P for interaction
Age group (baseline)							0.060
<65	5987	771	1.69 (1.42-2.00)	<0.001	1.51 (1.14-2.00)	0.004	
>=65	1356	261	1.52 (1.09-2.11)	0.013	2.23 (1.43-3.47)	<0.001	
Sex							0.123
Female	3741	601	1.38 (1.11-1.70)	0.003	1.52 (1.16-2.01)	0.003	
Male	3602	431	1.91 (1.54-2.38)	<0.001	2.03 (1.29-3.19)	0.002	
Night-time sleep (baseline)							0.450
<=6 h	3572	581	1.74 (1.42-2.14)	<0.001	1.75 (1.28-2.38)	<0.001	
6-8 h	3206	367	1.34 (1.04-1.72)	0.024	1.42 (0.96-2.09)	0.077	
>8 h	565	84	2.18 (1.20-3.96)	0.010	3.25 (1.50-7.04)	0.003	

HR, hazard ratio; CI, confidence interval. Estimates from fully adjusted discrete-time complementary log-log models. P for interaction from trajectory group by subgroup interaction terms.

Table 6. Sensitivity analyses of the association between cognitive trajectories and DSI

Sensitivity scenario	N	Events	Moderate vs high: OR/HR (95% CI)	P	Low vs high: OR/HR (95% CI)	P
1. No VI or HI at 2011; logistic, DSI in 2018	4880	220	1.60 (1.14-2.25)	0.007	1.98 (1.20-3.26)	0.008
1. No VI or HI at 2011; survival, first DSI	4880	489	1.60 (1.28-2.00)	<0.001	2.08 (1.50-2.88)	<0.001
2. DSI-free at 2011 and 2013; logistic, DSI in 2018	6905	384	1.60 (1.24-2.07)	<0.001	1.23 (0.82-1.85)	0.323
2. DSI-free at 2011 and 2013; survival, first DSI	6905	599	1.51 (1.24-1.84)	<0.001	1.37 (1.01-1.85)	0.046

after 2013						
3. Sustained DSI (>=2 consecutive waves); logistic	7343	215	1.66 (1.18-2.35)	0.004	2.04 (1.25-3.34)	0.005

OR from binary logistic regression for DSI in 2018; HR from Cox models for first DSI. All models fully adjusted. VI, vision impairment; HI, hearing impairment.

Table 7. Reverse-direction analysis: random-intercept linear mixed models of concurrent DSI and cognitive score

Model	Beta (SE)	t-value	P-value	AIC	BIC
M1	-1.250 (0.095)	-13.13	<0.001	159119.5	159144.4
M2	-0.813 (0.091)	-8.90	<0.001	154320.8	154412
M3	-0.793 (0.091)	-8.69	<0.001	154310.6	154459.8
M4	-0.726 (0.091)	-7.94	<0.001	154202.4	154376.5

Beta is the change in the 0-21 cognitive score per wave for participants with concurrent DSI versus no DSI; 29,372 person-wave observations. Models M1-M4 as defined in Table 2. AIC and BIC computed as -2*logLik + k*ln(N).