The Impact of Social Integration on Cognitive Life Expectancy: A Comparative Study Across Racial and Nativity Groups in Elderly U.S. Populations

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Abstract

Background: Late-life social integration is associated with reduced dementia risk in the elderly in the United States, but its impacts on cognitive life expectancy across society are unexplored. Our study investigates associations between social integration and cognitive life expectancy across gender, race, and nativity groups, and assesses the potential role of social integration in explaining the Healthy Immigrant effect and the expansion and compression of morbidity.

Methods: Using Health and Retirement Study data (2004–2020), we used multistate life tables to estimate cognitive life expectancies by social integration, race, nativity, and gender. Cognitive status was assigned using the Langa–Weir algorithm. Social integration is measured by self-reported social ties to family and friends, and active engagement in work, family, and community activities.

Results: An increase from the lowest to the highest quartile of social integration is associated with an increase in total life expectancy of 6.8 years for US born Hispanic males, 6.3 years for foreign born Hispanic males, 8.3 years for non-Hispanic white males and 7.4 years for non-Hispanic black males. Similarly large associations are found for females and when measured in terms of cognitive health. In line with the Healthy Immigrant Effect, migrant Hispanic males and females have the highest life expectancies, though social integration is most strongly associated with cognitive health among non-Hispanic white males and females. Social integration has the

potential to both expand and compress cognitive morbidity, with social integration associated with lower risks of dementia and death across stages of cognitive impairment.

Conclusion: Social integration likely holds an important role in enhancing cognitive life expectancy. Though variations across groups may point to important social and cultural differences and inequalities, social integration appears to support cognitive health longevity across migrant and racial groups. Policies related to public health among the elderly population are warranted to bolster their social participation.

Introduction

Alzheimer's disease and other forms of dementia are characterized by progressively worsening memory, language deterioration, and diminished thinking capacity (1). In the United States, dementia poses a significant public health challenge, with recent estimates suggesting that clinical Alzheimer’s Disease and dementia more broadly affect between 5.3 and 6.1 million people (2,3). Post-2020, Alzheimer's disease, alongside COVID-19, has emerged as one of the top ten leading causes of death, with Alzheimer's occupying the seventh position (4). Population ageing is likely to drive prevalence higher, with projections suggesting the number of cases will double to 2050, when between 9.3 and 13.5 million Americans are projected to be living in clinical Alzheimer’s Disease or dementia (2,3).

Social factors are widely understood to influence cognitive health. Prior studies have identified that early-life education (5,6) and levels of social connections and integration

in later life (7–9) are among the key determinants influencing dementia risk, with their effects nuanced by factors such as societal inequality and cultural contexts (10). The specific protective impact of social integration in later life on the cognitive life expectancy of older adults though remains a question for further research. Given the intersection between socio-economic and cultural factors, particularly pertinent questions relate to the extent to which the protective effect of social integration varies across migrant and racial groups and helps to explain observed patterns of health and life expectancy across society.

Our study aims to examine associations between social integration and cognitive life expectancy across groups in society. Following Crittenden et al. (11), we define social integration by individual ties to family and friends and their active engagement in work, families and communities. In the vein of a growing body of scholarship (12,13), we develop a multistate life table model and apply it to the US Health and Retirement Study. Through this approach, we estimate prospective probabilities of transitioning between different states of cognitive function and cognitive life expectancy or the average number of years a person can expect to live in different states. We calculate these outputs by gender, race, nativity and the degree of social integration, providing a rich and nuanced analyses of how social integration supports cognitive health across the later life course.

Literature Review

Cognitive decline and social integration

Research points to important social influences and determinants of cognitive health. Crucially, elements like early-life education, late-life social engagement, and broader societal influences, including inequality and cultural norms, play pivotal roles in determining the incidence of dementia and the disparities in cognitive life expectancy among various demographic groups (5). Later-life social integration is associated with dementia incidence, where increased social participation and ties correlate with reduced dementia risk (7–9).

The relationship between cognitive health and social integration is thought to be underpinned by a set of key mechanisms (14). First, the development and maintenance of social connections are believed to enhance ‘cognitive reserve’ in older adults—the brain's capacity to preserve cognitive function and daily living skills amid neuropathological threats (15). Given that social interaction demands substantial cognitive engagement—necessitating the use of advanced cognitive skills such as planning, negotiation, and memory (16)—these activities potentially fortify older individuals' resistance to cognitive decline in later life (17).

Similarly, frequent social participation may foster brain health by mitigating the accumulation of neuropathology through the promotion of a healthy lifestyle (15,18). Social engagement can lead to improved health behaviors, including reduced alcohol and tobacco use (19), factors crucial for maintaining cardiovascular and cerebrovascular health (20). Importantly, compromised cardiovascular and cerebrovascular conditions are linked to an elevated risk of dementia (21).

Subsequently, stress resulting from significant social isolation—a state of minimal social integration—emerges as a risk factor for the morbidity and mortality associated with dementia (22–25). This stress activates the neuroendocrine response through the hypothalamic-pituitary-adrenal (HPA) axis, culminating in the adrenal cortex's secretion of glucocorticoids, including cortisol (26), that form the basis of the body's biological stress response (27).

Inequalities in cognitive life expectancy

Inequalities and cultural contexts act as moderating influences on how risk factors such as social integration and education impact dementia outcomes (10). These roles manifest through variations across gender, race, and nativity within the US population.

Research consistently indicates that immigrants to the US exhibit better overall health outcomes relative to their US-born counterparts. This is a pattern referred to as the 'healthy immigrant effect' (28) and is marked by, among other things, longer life expectancies among immigrants than native born populations. This health advantage extends to Hispanic Americans as a collective (US and foreign born), who are often found to experience longer lifespans even amidst socioeconomic disadvantages—a phenomenon often termed the 'Hispanic paradox' (29). Several theories have sought to explain the healthy immigrant effect, including 'salmon bias'—the tendency of unwell immigrants to return to their home countries (30), 'health selection'—the premise that only the healthiest individuals can withstand the migration journey (31), and a propensity among immigrants to adopt healthier lifestyles (32). The maintenance of

strong social ties in both origin and host countries is another potential factor that supports cognitive function among immigrants and racial minorities (33,34).

Whether health advantages for migrant and Hispanic Americans extends to cognitive health is a matter of debate. Some research indicates an elevated risk of cognitive decline among Latino and Hispanic Americans relative to US born non-Hispanic whites (35,36), while other studies find no significant differences (37). A recent study suggest white Americans spend a longer portion of their lives in good cognitive health than black and Latino Americans, before and after adjusting for education levels (38).

Teasing apart the effects of race and migration is important for understanding the risks of cognitive decline across society. Several studies do this by comparing cognitive functioning between US born and immigrant populations of the same minority group (38–42). Hill et al. , for example, compared immigrant and US born Mexican Americans, finding that men (but not women) who immigrated between the ages of 20 and 49 years had a slower rate of cognitive decline compared with US born Mexican Americans (41). Garcia et al. likewise find that after controlling for education, US born Latino Americans have lower cognitive functioning and higher risk cognitive impairment and dementia than immigrant Latino Americans (38). Other research finds that immigrant Latino and Hispanic Americans have a higher risk of living in a state of 'cognitively impaired not dementia' (CIND) than their US-born counterparts, yet they also enjoy a longer total life expectancy (40).

The literature points to important intersections between gender, race and nativity. Despite facing greater barriers to higher education (43), women generally are found to have a longer cognitively healthy life expectancy (with a gap of approximately 3 years) and a marginally longer life expectancy with dementia (with a gap of less than 1 year) compared to men (44–46). However, these gains are not experienced across racial and nativity groups. Some studies suggest that among Latina and Hispanic women, immigrant Americans, particularly those who migrate later in life, face a higher risk of cognitive impairment (40,47), while others point to inequalities between Latina and non-Latina women (42).

The influence of social integration on cognitive health expectancy remains underexplored, with its effects across different genders, races, and nativities yet to be clearly defined. While social integration is recognized for its role in extending lifespan and cognitive health (48,49), the extent to which it helps explain patterns across gender, racial and nativity groups remains an open question. While the role of social ties has been put forward as a potential factor to explain the health immigrant effect, this is challenged by research suggesting that Latino immigrants have weaker social ties than their US born counterparts (50).

Social integration and the expansion/compression of morbidity

The Expansion and Compression of Morbidity frameworks (51) are two theoretical models through which to examine changes in healthy life expectancy and the potential influence of social integration. Under the expansion framework (52), an increase in total

life expectancy is accompanied by an expansion in the average time people spend living in poor health. Conversely, the compression framework (53,54) posits that rising life expectancy results in a diminished proportion of life spent in poor health. These models traditionally examine morbidity in terms of chronic degenerative diseases or disabilities across cohorts, and particularly in respect of medical advancements (51,55). Recent scholarship has extended these frameworks to encompass cognitive health, offering new perspectives on the dynamics of morbidity and disability in cognitive domains (51,56,57).

Social integration can potentially help explain both an expansion and compression of cognitive impairment. Where the protective effects of social integration are focused on reducing mortality risks and delaying cognitive decline among cognitively normal populations, then we expect that social integration will contribute to a compression of cognitive morbidity. Where the protective effects are more focused towards providing support for people already in stages of cognitive impairment and protecting against mortality, we might expect an expansion of cognitive morbidity.

Social and cultural contexts may lead to differences in social integration across racial and nativity groups, and as a result, differences in whether integration contributes to an expansion or compression of morbidity. Wider family and kinship support networks in Latino culture (58) potentially provide a source of support for people across the cognitive life course. US-born non-Latino white Americans are more inclined to place their parents in nursing homes instead of providing in-person or at-home support than

Latino and black Americans (59), perhaps indicative of different cultural expectations with respect to familial duty and support (60,61). Despite providing professional services, nursing homes are marked by limited social interaction (62), with a reported median survival period of 25.8 months (63). The greater cultural predisposition towards familial support among Latino populations is also evident in the preference for proximity to and cohabitation with relatives (64,65). Elder Latinos are not only receptive to providing financial assistance to their adult children but are also actively engaged in household duties and caregiving for both children and dependent adults (64). This pattern of mutual support, particularly the care reciprocated by adult children, is more prevalent within Latino families, reflecting a distinct racial variation in the impact of social integration on health outcomes. While a source of strength in Latino culture and perhaps contributing to longer life expectancies, this familial support in later life may also contribute to longer life expectancies spent with cognitive impairment and an overall expansion of cognitive morbidity.

Research objectives and questions

In view of the existing evidence, we set out to analyze associations between social integration and cognitive functioning across gender, race and nativity groups and point to potential ways in which the relationship between integration and cognition can help to explain observed differences in cognitive life expectancy across groups. Our research questions are:

a. How does social integration's protective effect on cognitive life expectancy

differ by gender, race, and nativity, potentially leading to varied outcomes at higher social integration levels?

b. Do differences in social integration help explain the healthy immigrant effect and the Hispanic paradox and contribute to an expansion or compression of morbidity across racial and nativity groups?

Data and Methods

Data Source

Our research employed data from the Health and Retirement Study (HRS), a comprehensive national survey targeting non-institutionalized individuals aged over 50 and their spouses across the United States. The HRS has been collecting biennial responses since 1992 (66). For our analysis, we selected data from the 2004 to 2020 waves for two primary reasons. First, this period's nine waves of longitudinal survey data provided a robust sample size, allowing for detailed estimations of variations in cognitive life expectancies and mortality among the elderly, differentiated by gender, race, and social integration. Second, the consistency in measuring social integration was established starting from the 2004 wave (11), leading us to exclude earlier waves from our analysis. The final analytical sample comprised 24,345 unique respondents across 58,068 person-waves.

Assessment of Cognitive Health

Cognitive health was assessed using the Telephone Interview for Cognitive Status

(TICS-M), a tool designed for direct responses from the respondents. The TICS-M consists of three sections: first, it assesses processing speed by having respondents count backwards, with scores ranging from 0 to 2 points. Second, it measures working memory through the 'Serial Sevens' test, with a scoring potential of 0 to 5 points. Lastly, it evaluates memory performance by testing immediate and 5-minute delayed recall of 10 unrelated words or numbers, with scores varying from 0 to 20 points (67).

We use assessments of respondents' cognitive health using the Langa-Weir algorithm (68), applied to the results obtained from the TICS-M test. This algorithm uses thresholds established and validated against the Aging, Demographics, and Memory Study (ADAMS), which is a comprehensive neuropsychological study based on a subset of HRS respondents. For non-proxy interviews, the Langa-Weir algorithm categorizes cognitive health as follows: scores between 12 to 27 on the TICS-M indicate 'cognitive normal' (CN), scores from 7 to 11 suggest 'cognitively impaired not dementia' (CIND), and scores from 0 to 6 denote 'dementia'.

For interviews completed by a proxy (usually a family member), the LW algorithm employs responses related to 'instrumental activities of daily living' (IADLs), 'memory evaluation', and 'cognitive status evaluation', with scoring systems ranging from 0 to 5, 0 to 4, and 0 to 2, respectively. Based on this, cognitive health classifications for proxy respondents are determined: scores from 0 to 2 indicate CN, 3 to 5 suggest CIND, and 6 to 11 indicate dementia. This method of classifying cognitive health for proxy respondents is comparable to that for non-proxy respondents, and the reliability and

validity of this classification approach have been confirmed through multiple studies, establishing it as a reliable instrument for research into cognitive health. (40,69–71).

Measuring Social Integration

Social integration was evaluated across seven domains: 1. retirement, 2. volunteer activities, 3. attendance at religious services, 4. marital status, 5. involvement in social and community activities, 6. contact with children and 7. contact with friends. Respondents received 1 point for active participation in each domain, according to established criteria for social activity or social tie engagement (7,11,72). For instance, employed respondents received 1 point, while retirees were assigned 0 points. Similarly, in the volunteering domain, those who volunteered at least one hour per week earned a point. Marital status contributed to the score, with partnered respondents receiving 1 point. Involvement in social and community activities, attendance at religious services and interactions with children and friends were also quantified: regular involvement for at least once per week merited a point, while less frequent participation did not. The overall social integration score for each wave was calculated as the sum of the scores from seven domains of social activities and ties, with scores ranging from zero to seven.

Three of the seven domains of social integration were collected in the Health and Retirement Study's Psychosocial and Lifestyle questionnaire, or the 'Leave-Behind' questionnaire. These are questionnaires that interviewers left with respondents to self-complete. Respondents only complete the Leave-Behind questionnaire once every four years, or every second survey wave, with a rotating half-sample completing the survey

every two years. There have also been some changes in the questionnaire over time. In the involvement in social and community activities domain, respondents were asked about their involvement in a wider set of activities from 2008 onwards, including care for a sick or disabled adult, activities and volunteer work with children, charity work, attendance at an educational or training course, going to a sport, social or other club and attendance at political, community or other non-religious groups. As described below, we use multiple imputation to fill in missing data, protect against non-random completion, particularly of the Leave-Behind questionnaire and maximise the available data where questions have changed over time.

Other Variables and Stratification

The other key variables we utilize in this study are age, gender, race, migrant status, a Hispanic flag and education. We combine race, the Hispanic flag and migrant status into a single variable with five categories, i.e. 'US-born Hispanic', 'Foreign born Hispanic', 'US-born white non-Hispanic', 'US-born black non-Hispanic' and an other category. We further differentiate respondents in each of these categories by whether they are male or female and report results for each category. Education is a key control variable, representing respondents' highest level of education. It is a categorical variable comprised of five categories, 1. College graduate and above, 2. Some college, 3. High school graduate, 4. General Education Development (GED) and 5. Less than high school.

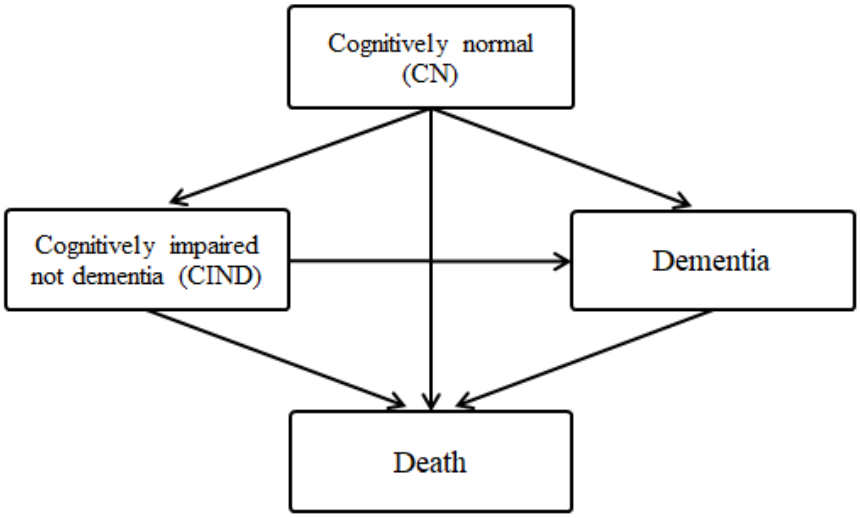
Multistate analysis

Multistate analysis is used to create life course trajectories of cognitive health. With growing and diverse applications particularly in public health but also more broadly, multistate analysis conceives of, and measures, population cohorts living and transitioning between different states of being. In public health research, the illness-death model is the most well-known and widely used multistate model, in which populations can live and shift between states of good and poor health and death (73,74). As others have done, the illness-death model can be readily adapted to focus specifically on cognitive health (75–77). In building on traditional survival (event history) and life table analyses, multistate analysis allows for the calculation of healthy life expectancies, the average lengths of time that population cohorts can expect to live in good and poor health, providing useful and policy-relevant outputs on the quantity and quality of life. The scholarly value of these outputs lies in the fact they are created from complete life trajectories – right up until death – based on data provided both by individuals who have died and those still living at the time they were last observed. Multistate analysis thus overcomes the problem of right censoring, maximizing the use of available data and minimizing potential bias that might arise, for example, from only being able to use data on those who have already died.

The first step in multistate analysis is the articulation of a multistate space. This is a visual model depicting the states in which individuals live and the transitions they make between states. The multistate space used in this study is depicted in Figure 1. There are three states of cognitive health, ‘cognitively normal’ (CN), ‘cognitively impaired not dementia’ (CIND) and ‘dementia’ and a state of ‘death’. Our model treats cognitive

impairment as progressive and uni-directional. Over discrete periods of time (in our case, two years to align with HRS survey waves), people can shift to states of progressively greater impairment but not backwards. Individuals initially classified as 'cognitive normal' (CN) can transition to any of four states: remaining CN, progressing to CIND, dementia, or death. Those starting in CIND have three possible outcomes: persisting in CIND, advancing to dementia, or death. Lastly, individuals initially with dementia face two prospects: continuing in the dementia state or death.

Figure 1 Multistate cognitive health space



Predicting transition probabilities

Binary logistic regression models are used to predict the probabilities of making each of the six possible transitions between cognitive states. The risk of transition across age is modelled with several functional forms. Following O'Donnell, the main results we present utilise linear splines, in which transition risks are assumed to change linearly between pre-specified knots (78). We specify knots at ages 65, 75, 85 and 95. Results

using two different functional forms (piecewise constant and polynomial functions) are provided in the Appendix.

The main regression equations take the following form:

1. $$log\left(\frac{P_{t,t+2}^{ij}}{1-P_{t,t+2}^{ij}}\right) = \beta_{0i} + \beta_1.age_t + \beta_2.\max(0, age_t - k) + \beta_3.S + \beta_4.S.R + \beta_5.S.R.SI_t + \beta_6.E$$

Here, P_{ij}^{t} represents the probability of transitioning from cognitive state *i* to state *j* between time *t* and *t+2* years; age is the age of the respondent at time t; k is the set of knots used for the linear spline, taking on values of 65, 75, 85 and 95; S and E are the respondent's gender and highest level of education respectively; R is the indicator of the respondent's race and migrant status; SI is the respondent's social integration scores; and the β terms are the regression coefficients to be estimated by the models. The models include interactions between gender, migrant-race and social integration, allowing us to calculate separate transition probabilities for each combination of variables and based on the hypothesis that race and social integration jointly influence these transitions.

The regression results are used to create a set of age-specific transition probabilities. These represent the probabilities that individuals at each age will transition between one state and another over the next two years. Transition probabilities are estimated for each two-year interval between the age of 50 and death for each gender-race-migrant

group and at different levels of social integration. The levels of social integration are based on age-specific quartiles. We calculate average social integration scores across all survey respondents in five year age groups (e.g. 50-54, 55-59, 60-64,…,95+). The lowest social integration quartile represents individuals with scores in the lowest 25 percent of scores for their age group, while the highest quartile represents individuals with the highest 25 percent of scores and so on. This allows us to compare cognitive transitions and life expectancies for individuals across the spectrum of social integration.

There are six sets of age-specific probabilities for each gender, racial and nativity group and social integration quartile. These represent the six types of cognitive health transition that individuals are conceived to make in the multistate space: CN to CIND, CN to dementia, CN to death, CIND to dementia, CIND to death and dementia to death. Additionally, we calculate three probabilities of remaining in the same state: individuals with CN remaining CN, those with CIND remaining CIND, and individuals with dementia staying in the dementia state. These are calculated as the remainder after subtracting all outbound transitions. The probability of remaining in the CN state, for example, is calculated as one minus the sum of probabilities of transitioning to CIND, dementia and death.

Multistate Life Tables

Cognitive life expectancies are calculated by applying the transition probabilities to a multistate life table. We start with a synthetic cohort of 100 cognitively normal individuals at age 50 (the life table radix) for each gender-migrant-race group and social

integration quartile. The transition probabilities for people aged 50 are organised into a matrix and multiplied by the starting population to estimate the number of people living in each cognitive state after two years. We repeat this matrix multiplication for each two-year interval between age 50 and 110, thereby generating life course trajectories that track the number of people in each cognitive state every two years. The calculation of the number of 'survivors' takes the form:

$$2. \qquad \mathbf{l}_{x+2} = \mathbf{l}_x \cdot \mathbf{P}_x$$

Where $\mathbf{l}_{x+2}$ represents the survivorship matrix, whose elements ${}^{ij}l_{x+2}$ denote the number of individuals who started in cognitive state *i* and are now in state *j* at age $x + 2$. $\mathbf{P}_x$ is the transition probability matrix, whose elements were calculated from the regression models.

The next step is the calculation of the number of person-years lived in each state. Assuming that individuals transition between states halfway through the two-year year interval, we can approximate person-years as two multiplied by the average of the numbers of people at the start and end of the interval:

$$3. \qquad {}_2\mathbf{L}_x = 2 \cdot \frac{1}{2} \cdot (\mathbf{l}_x + \mathbf{l}_{x+2})$$

Life expectancy, in terms of the average number of years spent in each state after the age of 50 is calculated by:

$$4. \qquad {}^{i}\boldsymbol{e_{50}} = \frac{\sum_{50}^{\infty} {}^{i}\boldsymbol{L}}{\boldsymbol{l_{50}}}$$

Total life expectancy is derived from the sum of life expectancies across all cognitive health states, excluding the death state, and is calculated by:

$$5. \quad {}^{Total}e_{50} = {}^{CN}e_{50} + {}^{CIND}e_{50} + {}^{Dementia}e_{50}$$

Cognitive life expectancies are calculated for gender, racial and nativity groups across quartiles of social integration. The estimated life expectancies represent those for hypothetical cohorts of individuals who remain in the same social integration quartile throughout their later life. We estimate the potential contribution of social integration to the compression and/or expansion of morbidity by calculating the share of total life expectancy spent in states of cognitive decline for different quartiles of social integration. A negative association between social integration and the proportion of time spent with cognitive impairment indicates a compression of morbidity, while a positive association indicates an expansion.

We also estimate the potential contribution of social integration to the 'Healthy Immigrant Effect', and differences in cognitive life expectancy across racial and nativity groups generally. We do this by comparing estimates of actual life expectancies with those that would prevail if those groups had the same social integration levels as the US-born non-Hispanic white population. We do this by calculating average age-specific integration levels of the white population and then applying the transition probabilities for each racial and nativity group as if they had these integration levels.

Evidence that social integration helps explain differences in cognitive life expectancy is revealed where the resulting cognitive life expectancies estimates are substantially different from actual life expectancy estimates for different racial and nativity groups.

Multiple imputation and bootstrap resampling

We use multiple imputation to correct for missing data and bootstrap resampling to generate confidence intervals around our estimates. We use an approach recommended by Schomaker & Heumann (2018), referred to as the 'MI Boot (pooled sample)' method (79). With this approach, we create 25 survey datasets with missing data imputed through multiple imputation. The imputation is carried out using chained equations in Stata 18 (80). For each of the 25 datasets, we create 96 bootstrapped estimates of the regression parameters, giving us 2,400 sets of parameters in total. We estimate transition probabilities and the multistate life table outputs, including cognitive life expectancy, with each set. This gives us a simulated sampling distribution, from which we calculate 95 percent confidence intervals.

We run the models with different variants of the imputation strategy to test its impact on the results. In the main results reported below, we impute social integration scores in person-waves even where the respondent did not complete a Leave Behind questionnaire. This helps to adjust for observable bias in whether or not respondents complete and return the questionnaire. In the Appendix, we show results where we a) perform no imputation and b) impute missing items only in survey waves in which respondents have at least partially completed the Leave Behind questionnaire.

Results

Sample Characteristics

Table 1 displays the number of person-waves and average social integration scores by the characteristics of HRS participants who completed a Leave Behind survey between 2004 to 2020. The data, segmented for both females and males, shows that the proportion of dementia cases increases with age and decreases with education and social integration. The proportion of person-waves spent in the cognitively normal (CN) state is substantially higher among US-born white non-Hispanics (84 percent) than for other groups (e.g. 66 percent for US born non-Hispanic blacks and 70 percent for US and foreign-born Hispanics). There are few racial-migrant differences in average social integration scores among cognitively normal respondents. However, scores are generally significantly lower for whites among those in the cognitively impaired and dementia states. Foreign-born Hispanic respondents in the CIND and dementia states report somewhat higher integration scores than other groups. We observe more than 5,700 progressive transitions between cognitive states over two-year intervals between waves and almost 2,600 deaths. The proportion of observations where respondents died during the subsequent two-year interval was six times higher among people in the dementia state (18 percent) than those in the cognitively normal state (3 percent).

Table 1 Number of person-waves and average social integration by cognitive function and characteristics of the sample

	Person-waves			Average Social Integration score (95% confidence interval)		
	CN	CIND	Dementia	CN	CIND	Dementia
a. Males						
Age group						
<70	7,925	1,037	159	3.4 (3.4, 3.5)	2.9 (2.8, 3.0)	2.4 (2.1, 2.6)
70-79	6,092	1,055	213	3.3 (3.3, 3.4)	2.8 (2.7, 2.9)	2.4 (2.2, 2.7)
80-89	3,859	1,228	327	3.2 (3.1, 3.2)	2.7 (2.6, 2.8)	2.1 (1.9, 2.3)
90+	871	541	226	2.7 (2.6, 2.8)	2.2 (2.0, 2.4)	1.8 (1.6, 2.1)
Nativity and race						
US-born Hispanic	748	253	<100	3.2 (3.1, 3.3)	2.7 (2.4, 2.9)	2.2 (1.8, 2.7)
Foreign Born Hispanic	1,037	364	<100	3.2 (3.1, 3.3)	3.0 (2.8, 3.2)	2.4 (2.0, 2.8)
US-born white	13,780	2,157	455	3.3 (3.3, 3.4)	2.6 (2.5, 2.7)	1.9 (1.8, 2.1)
US-born black	1,824	815	253	3.2 (3.2, 3.3)	2.8 (2.6, 2.9)	2.4 (2.2, 2.7)
Other	1,358	272	<100	3.3 (3.2, 3.4)	2.8 (2.6, 3.0)	2.1 (1.7, 2.6)
Highest education						
College	6,120	398	<100	2.9 (2.8, 3.0)	2.6 (2.5, 2.7)	2.1 (2.0, 2.3)
Some college	4,705	675	109	2.9 (2.8, 3.0)	2.7 (2.5, 3.0)	2.2 (1.7, 2.7)
High school	4,964	1,125	182	3.1 (3.1, 3.2)	2.7 (2.6, 2.8)	2.1 (1.8, 2.4)
GED	988	241	<100	3.3 (3.2, 3.3)	2.8 (2.6, 2.9)	2.1 (1.8, 2.5)
Less than high school	1,970	1,422	511	3.6 (3.6, 3.7)	3.0 (2.8, 3.2)	2.3 (1.9, 2.8)
Inter-wave transitions						
CIND	1,791			2.9 (2.8, 3.0)		
Dementia	205	449		2.9 (2.6, 3.1)	2.4 (2.2, 2.6)	
Death	688	388	176	2.8 (2.6, 2.9)	2.3 (2.1, 2.5)	1.7 (1.4, 2.0)
b. Females						
Age group						
50-59	12,671	1,530	208	3.7 (3.6, 3.7)	3.1 (3.0, 3.2)	2.6 (2.3, 2.9)
60-69	8,554	1,340	277	3.4 (3.4, 3.4)	2.9 (2.8, 3.0)	2.4 (2.1, 2.7)
70-79	5,263	1,489	422	3.1 (3.0, 3.1)	2.6 (2.5, 2.7)	2.0 (1.8, 2.2)
80+	1,482	835	461	2.5 (2.4, 2.6)	2.0 (1.9, 2.2)	1.5 (1.4, 1.7)
Nativity and race						
US-born Hispanic	1,089	332	118	3.4 (3.3, 3.5)	2.9 (2.7, 3.1)	2.2 (1.9, 2.6)
Foreign Born Hispanic	1,619	576	145	3.4 (3.3, 3.5)	3.0 (2.8, 3.2)	2.3 (2.0, 2.7)
US-born white	19,596	2,497	603	3.4 (3.4, 3.5)	2.6 (2.5, 2.7)	1.7 (1.6, 1.9)
US-born black	3,727	1,422	391	3.5 (3.4, 3.5)	2.8 (2.7, 2.9)	2.2 (2.0, 2.4)
Other	1,941	367	111	3.4 (3.3, 3.5)	2.8 (2.6, 3.0)	2.1 (1.7, 2.4)
Highest education						
College	6,904	341	<100	2.9 (2.8, 3.0)	2.5 (2.5, 2.6)	2.0 (1.9, 2.2)
Some college	7,795	869	165	3.1 (3.0, 3.2)	2.7 (2.4, 2.9)	1.6 (1.1, 2.1)
High school	8,893	1,687	356	3.3 (3.2, 3.3)	2.8 (2.7, 2.9)	1.9 (1.7, 2.1)
GED	1,329	271	<100	3.5 (3.5, 3.5)	3.0 (2.9, 3.1)	2.2 (1.9, 2.5)
Less than high school	3,049	2,026	724	3.8 (3.7, 3.8)	2.9 (2.7, 3.1)	2.4 (1.9, 3.0)
Inter-wave transitions						
CIND	2,333			3.0 (2.9, 3.0)		
Dementia	259	677		2.7 (2.4, 3.0)	2.4 (2.2, 2.6)	
Death	726	381	237	2.5 (2.3, 2.6)	1.9 (1.7, 2.1)	1.5 (1.3, 1.8)
Total person-waves	46,717	9,055	2,293	3.4 (3.4, 3.4)	2.7 (2.7, 2.8)	2.1 (2.0, 2.2)
Total respondents	20,691	6,708	1,921	3.3 (3.3, 3.3)	2.9 (2.8, 2.9)	2.3 (2.2, 3.3)

Notes: CN = cognitively normal; CIND = cognitively impaired not dementia; GED = General Educational Development

Source: Health and Retirement Study (HRS), United States, 2004-2020

Regression Results

The findings from the regression analysis show that social integration is negatively associated with cognitive decline across most, if not all groups. The results are shown in Tables 2 and 3. Table 2 shows the results for transitions out of the Cognitively Normal state. Table 3 shows the results for the other transitions. All results are reported in terms of odds ratios. An additional social tie is associated with a significant 31 percent ([1.00 - .72] × 100) reduction in the odds of transitioning from the CN state to dementia among US-born Hispanic females, a 31 percent reduction in the odds of dying and an 8 percent reduction in the odds of transitioning to CIND (Table 2). The odds of progressing to dementia and death from CIND and dementia are also lower with increasing social integration for US and foreign-born Hispanics, and generally significantly so (Table 3). Social integration is most significantly associated with a slowing in progression among US-born non-Hispanic white males and females. The magnitude of the associations is generally similar for non-white groups, suggesting that the lack of statistical significance, particularly in transitions from dementia to death, is generally the result of relatively small sample sizes.

Table 2 Logistic regression results predicting transitions from Cognitively Normal to CIND, Dementia and Death

	Transition from Cognitively Normal to:		
	CIND	Dementia	Death
	Odds ratios (95% confidence intervals)		
Age	1.01 (1.01, 1.02)***	1.03 (1.01, 1.06)***	1.07 (1.06, 1.09)***
Knot 65	1.04 (1.03, 1.06)***	1.04 (1.00, 1.08)**	1.00 (.97, 1.02)
Knot 75	1.01 (1.00, 1.03)*	1.02 (.98, 1.06)	1.00 (.98, 1.02)
Knot 85	.95 (.93, .98)***	.97 (.92, 1.02)	1.04 (1.01, 1.08)**
Knot 95	.94 (.78, 1.13)	1.02 (.79, 1.33)	1.05 (.89, 1.24)
Female	1.06 (.70, 1.6)	1.61 (.65, 4.02)	.90 (.40, 2.05)
Gender, race & nativity [baseline: US born Hispanic]			
Males			
Migrant Hispanic	.95 (.63, 1.44)	.39 (.13, 1.14)*	.62 (.26, 1.50)
US born white	.72 (.51, 1.01)*	.57 (.28, 1.17)	1.58 (.88, 2.85)
US born black	1.62 (1.13, 2.32)***	1.09 (.49, 2.43)	1.66 (.87, 3.13)
Other	1.19 (.79, 1.78)	.73 (.27, 1.96)	1.29 (.63, 2.64)
Females			
Migrant Hispanic	.88 (.62, 1.24)	.71 (.30, 1.68)	.55 (.24, 1.25)
US born white	.60 (.45, .79)***	.41 (.21, 0.79)***	1.39 (.76, 2.53)
US born black	1.63 (1.21, 2.20)***	.81 (.39, 1.68)	1.35 (.70, 2.59)
Other	.63 (.44, .90)**	.58 (.26, 1.31)	.92 (.43, 1.97)
Social integration by gender, race, nativity			
Males			
US born Hispanic	.91 (.82, 1.01)*	.90 (.71, 1.13)	.76 (.61, .94)**
Migrant Hispanic	.92 (.84, 1.00)*	.95 (.72, 1.25)	.77 (.60, 1.00)**
US born white	.90 (.87, .93)***	.83 (.77, .91)***	.73 (.70, .77)***
US born black	.89 (.85, .94)***	.84 (.72, .98)**	.77 (.69, .85)***
Other	.84 (.77, .92)***	.77 (.58, 1.02)*	.73 (.62, .86)***
Females			
US born Hispanic	.92 (.84, 1.00)**	.69 (.53, .91)***	.69 (.54, .88)***
Migrant Hispanic	.94 (.88, 1.01)	.74 (.60, .91)***	.72 (.56, .92)***
US born white	.86 (.83, .88)***	.73 (.67, .80)***	.68 (.65, .71)***
US born black	.87 (.84, .91)***	.81 (.72, .92)***	.72 (.65, .79)***
Other	.96 (.88, 1.03)	.78 (.64, .96)**	.67 (.56, .81)***
Highest education [baseline: High school]			
No high school	1.95 (1.85, 2.07)***	2.10 (1.82, 2.43)***	1.30 (1.18, 1.44)***
GED	1.16 (1.06, 1.27)***	1.38 (1.09, 1.75)***	1.18 (1.01, 1.38)**
Some college	.71 (.67, .75)***	.78 (.66, .91)***	1.06 (.97, 1.15)
College and above	.43 (.40, .46)***	.64 (.54, .77)***	.81 (.73, .89)***
F	193***	45***	119***

Significance levels: *** p < .01; ** p < .05; * p < .1.

Notes: GED = General Educational Development

Source: authors' calculations from Health and Retirement Study (HRS 2004-2020)

Table 3 Logistic regression results predicting transitions from Cognitive Impairment and Dementia to Dementia and Death

Transition from:	CIND		Dementia
To:	Dementia	Death	Death
	Odds ratios (95% confidence intervals)		
Age	1.03 (1.01, 1.04)***	1.06 (1.04, 1.08)***	1.12 (1.07, 1.17)***
Knot 65	1.03 (1.00, 1.06)**	.97 (.93, 1.01)	.95 (.89, 1.01)*
Knot 75	1.00 (.97, 1.02)	1.06 (1.02, 1.09)***	1.00 (.96, 1.04)
Knot 85	.96 (.93, .99)***	1.00 (.97, 1.03)	1.02 (.99, 1.05)
Knot 95	.99 (.89, 1.11)	1.04 (.94, 1.15)	1.04 (.97, 1.12)
Female	.95 (.53, 1.72)	.48 (.20, 1.13)*	.44 (.20, .94)**
Gender, race & nativity [baseline: US born Hispanic]			
Males			
Migrant Hispanic	.71 (.38, 1.34)	.73 (.30, 1.75)	.41 (.17, 1.01)*
US born white	.59 (.36, .97)**	1.39 (.73, 2.65)	1.22 (.65, 2.28)
US born black	.95 (.56, 1.59)	1.03 (.52, 2.03)	.75 (.38, 1.45)
Other	.87 (.45, 1.71)	.88 (.38, 2.03)	.97 (.45, 2.09)
Females			
Migrant Hispanic	1.06 (.66, 1.70)	.85 (.37, 2.00)	.99 (.50, 1.94)
US born white	.72 (.49, 1.07)	2.00 (1.05, 3.82)**	1.68 (1.01, 2.8)**
US born black	1.02 (.67, 1.53)	2.10 (1.08, 4.08)**	1.21 (.70, 2.09)
Other	1.18 (.69, 2.02)	1.42 (.62, 3.23)	1.19 (.61, 2.31)
Social integration by gender, race, nativity			
Males			
US born Hispanic	.84 (.70, 1.01)*	.80 (.62, 1.04)*	.85 (.64, 1.13)
Migrant Hispanic	.80 (.67, .96)**	.78 (.61, .98)**	.99 (.72, 1.38)
US born white	.85 (.79, .92)***	.77 (.72, .83)***	.81 (.73, .90)***
US born black	.87 (.79, .95)***	.78 (.70, .88)***	.84 (.72, .97)**
Other	.79 (.64, .97)**	.83 (.66, 1.04)	.77 (.57, 1.03)*
Females			
US born Hispanic	.89 (.76, 1.04)	.73 (.53, .99)**	.84 (.65, 1.09)
Migrant Hispanic	.78 (.69, .89)***	.72 (.55, .94)**	.83 (.63, 1.09)
US born white	.89 (.84, .95)***	.77 (.71, .83)***	.88 (.81, 0.96)***
US born black	.86 (.80, .93)***	.70 (.62, .79)***	.87 (.76, 1.01)*
Other	.73 (.61, .87)***	.71 (.56, .90)***	.88 (.67, 1.16)
Highest education [baseline: High school]			
No high school	1.53 (1.40, 1.68)***	.95 (.85, 1.06)	.85 (.75, .95)***
GED	1.24 (1.04, 1.48)**	.96 (.78, 1.18)	.95 (.75, 1.20)
Some college	.84 (.74, .95)***	1.09 (.96, 1.23)	.99 (.85, 1.16)
College and above	1.01 (.86, 1.17)	.92 (.79, 1.08)	1.27 (1.06, 1.51)**
F	31***	52***	32***

Significance levels: *** p < .01; ** p < .05; * p < 0.1.

Source: authors' calculations from Health and Retirement Study (HRS 2004-2020)

Life Table Estimates

Social integration is associated with increased total and cognitive survivorship. Survivorship curves are shown in the Appendix, with survivorship in the Cognitively Normal state shown in Figure S1 and survivorship in any state shown in Figure S2. We estimate, for example, that 52 percent of US-born Hispanic males who have remained in the lowest social integration quartile will still be in the Cognitively Normal state at age 60, 22 percent of at age 70 and 4 percent at age 80 (Figure S1a). This compares with 63 percent at age 60, 35 percent at age 70 and 12 per cent at age 80 among US-born Hispanic males in the highest social integration quartile. A shift in social integration from the lowest to the highest quartile is therefore associated with an 8 percentage point increase in the probability of US-born Hispanic males being in the Cognitively Normal state at age 80. This increase is similar for US-born Hispanic females (9 points) and migrant Hispanic males (8 points) and females (7 points), higher than for US-born non-Hispanic black males (4 points) and females (6 points) and substantially lower than the increase for white males (14 points) and females (24 points).

Social integration is associated with an increase in total and cognitively healthy life expectancy for all groups. Table 4 presents estimates of remaining life expectancy from age 50 within each cognitive state for males and females respondents and for the four key nativity and race groups. These estimates are segmented by levels of social integration quartiles, which are projected to remain consistent throughout the individuals' life course.

Notable disparities are evident in total life expectancy based on social integration. At age 50, males and females in the highest quartile of social integration can expect to live 6.3-9.0 years longer on average than people in the lowest quartile. The difference is greatest for US-born non-Hispanic white males (8.3 years) and females (9.0 years) and smaller but still substantial and significant for foreign born Hispanic males (6.3 years) and females (8.6 years). The association between social integration and cognitively healthy life expectancy is also higher for white males and females. A shift from the lowest to the highest quartile of social integration is associated with an increase in the number of years spent in the cognitively normal state of 4.6 years for non-Hispanic white males and 7.0 years for females. The change in social integration is associated with a smaller increase in cognitively normal life expectancy among foreign-born Hispanics (2.9 years for males and 2.6 years for females) and a larger increase in the time spent in the CIND state (4.1 years for males and 6.0 years for females).

Social integration does not help to explain the migrant health advantage or other gender, racial and migrant disparities in total and cognitive life expectancy. Figure 2 shows the results where we compare actual cognitive life expectancy in each migrant-racial group against what their life expectancy might have been were they to have the same level of social integration as the US-born non-Hispanic white population. In line with the healthy migrant effect, migrant Hispanic males (30.0 years) and females (32.5 years) have the highest total remaining life expectancy at age 50 under their actual levels of social integration. If migrant Hispanic males and females had the same social integration profile as US-born non-Hispanic white males and females, total and

cognitively healthy remaining life expectancy would be essentially unchanged (30.1 years for males and 32.8 years for females). The same is true for US-born Hispanic males and females and US-born non-Hispanic black males and females: estimates of cognitive life expectancy are unaffected by relative levels of social integration. Thus, while social integration is associated with longer total and cognitively healthy life expectancies, particularly for white males and females, what differences there are in social integration between groups does not explain the overall life expectancy advantage experienced by Hispanic migrants, nor the advantage experienced in cognitive life expectancy experienced by non-Hispanic whites.

Table 4 Estimated remaining life expectancies at age 50 by cognitive status, gender, nativity, race and social integration

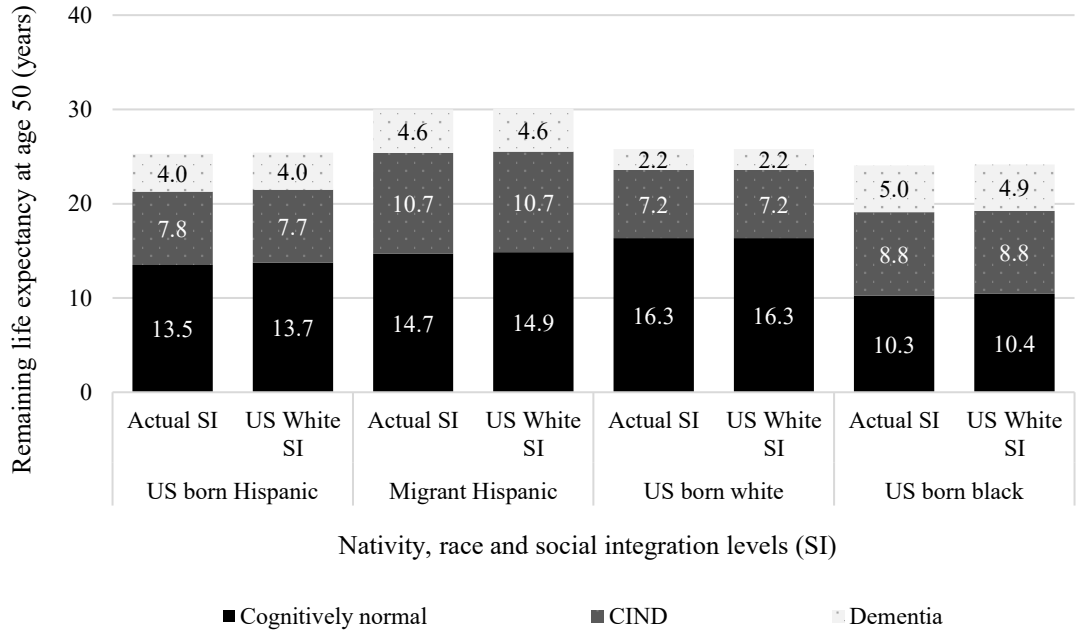
Gender, nativity and race	SI quartile[a]	Total	Cognitively Normal	CIND	Dementia
			Years (95% confidence interval)		
a. Males					
US born Hispanic	1. Low	23.9 (22.7, 25.3)	12.5 (11.4, 13.7)	7.4 (6.4, 8.5)	4.1 (3.3, 5.0)
	2.	26.3 (24.8, 27.8)	13.6 (12.5, 14.7)	8.4 (7.2, 9.6)	4.3 (3.4, 5.5)
	3.	28.1 (26.0, 30.4)	14.6 (13.2, 16.1)	9.1 (7.4, 10.9)	4.5 (3.1, 6.1)
	4. High	30.7 (27.2, 34.3)	15.8 (13.6, 18.1)	10.2 (7.5, 13.2)	4.8 (2.8, 7.6)
	High – Low	6.8 (3.1, 10.3)	3.3 (.9, 5.9)	2.7 (-.1, 5.8)	0.7 (-1.5, 3.5)
Migrant Hispanic	1. Low	28.5 (27.1, 30.2)	13.7 (12.6, 14.8)	10.0 (8.9, 11.2)	4.9 (3.8, 6.1)
	2.	30.7 (29.1, 32.4)	14.7 (13.7, 15.6)	11.4 (10.2, 12.7)	4.6 (3.6, 5.9)
	3.	32.4 (30.3, 34.6)	15.6 (14.3, 16.9)	12.4 (10.8, 14.2)	4.4 (3.2, 6.0)
	4. High	34.8 (31.5, 38.2)	16.6 (14.7, 18.7)	14.1 (11.3, 17.3)	4.1 (2.4, 6.7)
	High – Low	6.3 (2.6, 10.0)	2.9 (.7, 5.3)	4.1 (1.0, 7.4)	-0.7 (-2.9, 2.0)
US born white	1. Low	23.4 (22.9, 23.9)	14.5 (14.0, 15.0)	6.7 (6.3, 7.1)	2.2 (2.0, 2.5)
	2.	26.2 (25.7, 26.8)	16.0 (15.6, 16.5)	7.7 (7.3, 8.2)	2.5 (2.2, 2.7)
	3.	28.5 (27.9, 29.2)	17.4 (16.9, 18)	8.5 (8.0, 9.1)	2.6 (2.3, 2.9)
	4. High	31.7 (30.8, 32.7)	19.1 (18.4, 19.9)	9.7 (8.9, 10.6)	2.9 (2.3, 3.5)
	High – Low	8.3 (7.3, 9.2)	4.6 (3.8, 5.4)	3.0 (2.1, 4)	.6 (.1, 1.2)
US born black	1. Low	22.6 (21.8, 23.5)	9.2 (8.6, 9.8)	8.4 (7.8, 9.1)	5.0 (4.4, 5.6)
	2.	25.1 (24.1, 26.1)	10.2 (9.7, 10.8)	9.4 (8.7, 10.2)	5.4 (4.7, 6.2)
	3.	27.1 (25.9, 28.5)	11.3 (10.6, 12.0)	10.2 (9.3, 11.3)	5.6 (4.7, 6.7)
	4. High	30.0 (28.0, 32.1)	12.4 (11.4, 13.5)	11.4 (9.9, 13.1)	6.1 (4.7, 7.9)
	High – Low	7.4 (5.4, 9.4)	3.2 (2.2, 4.3)	3.0 (1.5, 4.6)	1.2 (-.3, 2.9)
b. Females					
US born Hispanic	1. Low	29.2 (27.8, 30.7)	12.3 (11.3, 13.4)	9.1 (8.1, 10.3)	7.7 (6.5, 9.1)
	2.	32.1 (30.3, 34.1)	13.6 (12.6, 14.7)	10.3 (9.1, 11.6)	8.3 (6.8, 10.1)
	3.	34.2 (31.7, 36.8)	14.7 (13.4, 16.1)	11.0 (9.4, 13.0)	8.4 (6.5, 11.0)
	4. High	37.2 (33.4, 41.3)	16.0 (14.0, 18.1)	12.2 (9.6, 15.4)	9.0 (5.9, 13.3)
	High – Low	8.0 (4.3, 11.9)	3.7 (1.4, 6.0)	3.1 (.4, 6.2)	1.2 (-2.0, 5.3)
Migrant Hispanic	1. Low	31.1 (29.8, 32.6)	13.4 (12.5, 14.3)	10.2 (9.2, 11.3)	7.5 (6.4, 8.8)
	2.	34.2 (32.6, 35.9)	14.3 (13.5, 15.2)	12.2 (11.0, 13.5)	7.7 (6.4, 9.2)
	3.	36.4 (34.4, 38.6)	15.1 (14.0, 16.3)	13.7 (12.1, 15.5)	7.6 (5.9, 9.6)
	4. High	39.8 (36.6, 43.1)	16.0 (14.4, 17.8)	16.2 (13.6, 19.2)	7.5 (5.1, 10.6)
	High – Low	8.6 (5.4, 12.0)	2.6 (.8, 4.6)	6.0 (3.1, 9.0)	.0 (-2.6, 3.1)
US born white	1. Low	26.8 (26.3, 27.3)	17.0 (16.5, 17.4)	6.6 (6.2, 6.9)	3.2 (2.9, 3.5)
	2.	29.9 (29.4, 30.4)	19.3 (18.9, 19.8)	7.2 (6.9, 7.6)	3.3 (3.1, 3.7)
	3.	32.3 (31.8, 32.9)	21.4 (20.9, 21.9)	7.6 (7.1, 8.1)	3.4 (3.0, 3.8)
	4. High	35.7 (34.9, 36.6)	24.0 (23.3, 24.8)	8.3 (7.6, 9.0)	3.4 (2.9, 4.0)
	High – Low	9.0 (8.1, 9.9)	7.0 (6.3, 7.8)	1.7 (1.0, 2.5)	.2 (-.3, .8)
US born black	1. Low	25.0 (24.2, 25.8)	9.4 (8.9, 9.9)	9.2 (8.6, 9.8)	6.4 (5.7, 7.1)
	2.	27.9 (26.8, 28.9)	10.6 (10.2, 11.1)	10.4 (9.8, 11.1)	6.8 (6.0, 7.7)
	3.	30.2 (28.9, 31.5)	11.9 (11.3, 12.5)	11.4 (10.5, 12.3)	7.0 (5.9, 8.1)
	4. High	33.3 (31.4, 35.4)	13.3 (12.4, 14.2)	12.8 (11.4, 14.3)	7.3 (5.7, 9.2)
	High – Low	8.4 (6.4, 10.3)	3.8 (2.9, 4.8)	3.6 (2.3, 5.1)	.9 (-.8, 2.7)

Note: [a]Social integration quartile

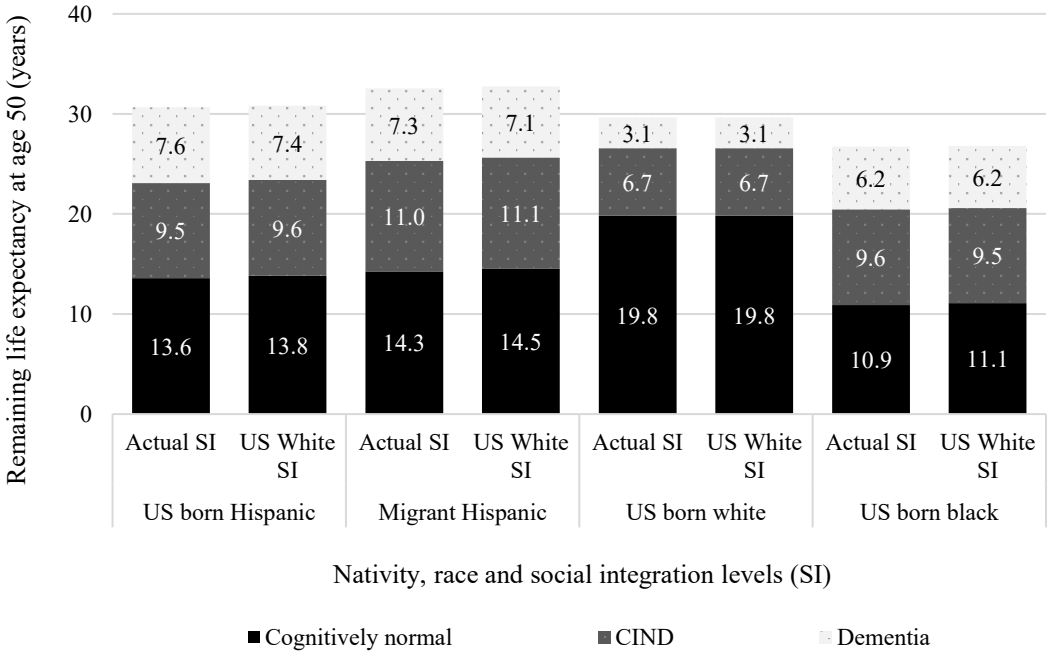
Source: authors' calculations from Health and Retirement Study (HRS 2004-2020)

Figure 2 Estimated contribution of social integration to differences in cognitive life expectancy across gender, nativity and race

a. Males



b. Females



Social integration is associated with longer life expectancies in each cognitive state for most groups. Figure 3 shows that within migrant-racial groups, the proportion of remaining life spent in cognitively health and impaired states remains remarkably

consistent across different levels of social integration. For example, a US-born Hispanic male who remains in the lowest quartile of social integration throughout their life is expected to spend 52 percent of their life in the cognitively normal state, compared with 51 percent among those in the highest quartile of social integration. The results are similar for foreign-born Hispanics and non-Hispanic US-born blacks. The implication of this finding is that social integration is associated with a slowing in cognitive deterioration and risk of death at different stages of impairment. Thus, if experienced across the cognitive life course of later life, social integration does not appear to contribute to either an expansion or compression of cognitive morbidity. However, this is likely due to offsetting effects. On the one hand, social integration is associated with a reduced risk of cognitive impairment and a compression of time spent with impairment and dementia. On the other hand, integration is associated with a lower risk of death among people with impairment and dementia and an expansion of time spent in the CIND and dementia states.

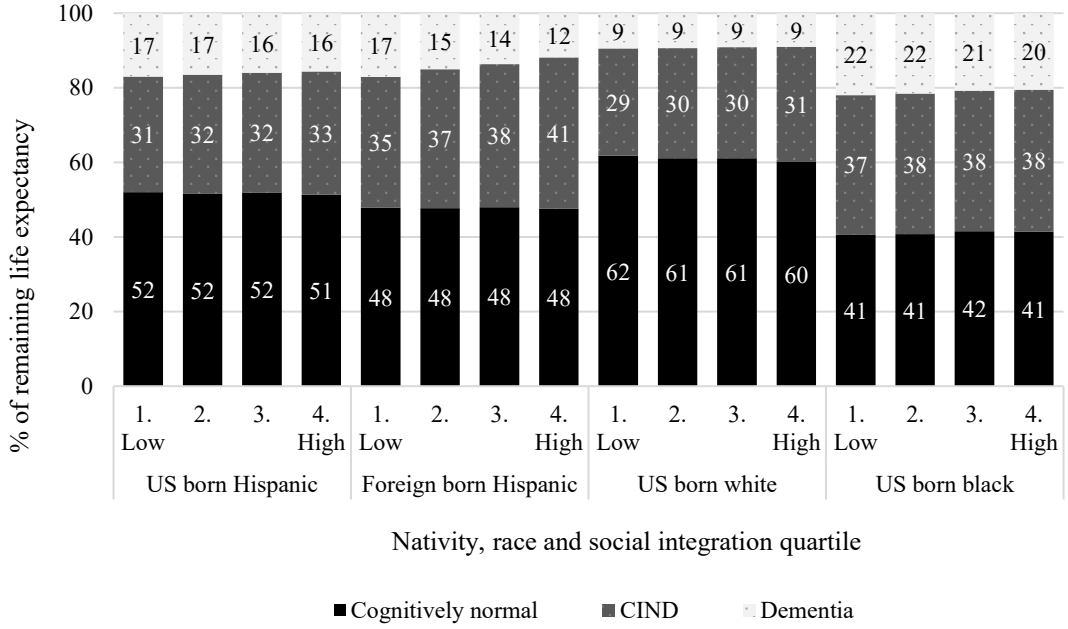
Social integration may have a particularly protective effect for migrant Hispanic Americans in slowing the progression from early impairment to dementia. As shown in Figure 3, social integration is associated with a compression of years lived with dementia among migrant Hispanic males and females and an expansion of years lived in the CIND state. The share of remaining years lived with dementia declines from 17 percent to 12 percent for migrant Hispanic males and from 24 percent to 19 percent for females across the lowest and highest integration quartiles, while the proportion of years spent in the CIND state increases from 35 to 41 percent for males and from 33

to 41 percent for females. Table 4 indicates that the gap in years spent with CIND between the highest and lowest integration quartiles – 4.1 years for males and 6.0 years for females – accounts for most of the difference in total life expectancy (6.3 years for males and 8.6 years for females). The prolonged CIND period among migrant Hispanics is driven by their lower transition probabilities from CIND to dementia (Odds Ratio 0.80 for males and 0.78 for females), suggesting that social integration may have a particularly strong protective effect in preventing further cognitive decline among migrant Hispanic Americans.

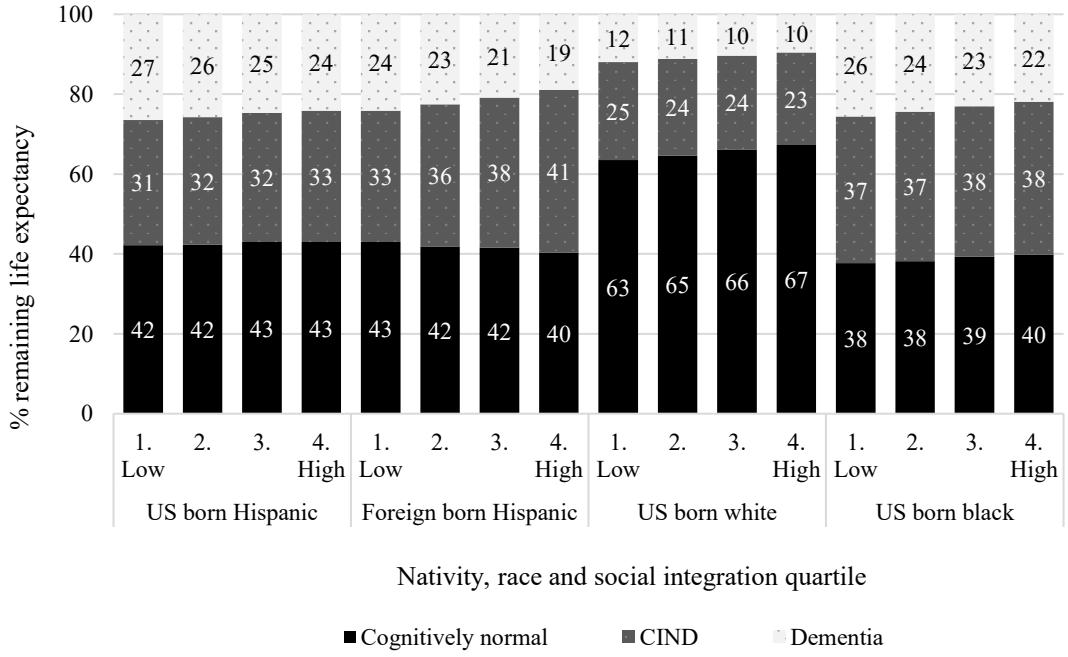
Figures 2 and 3 reveal potential intersectional gender differences in cognitively healthy life expectancy. Across all social integration quartiles (Figure 3) and in aggregate (Figure 2), US-born non-Hispanic white females are expected to spend a similar or larger proportion of their remaining life in the cognitively normal state than males. White females in the highest social integration quartile, for example, are expected to spend 67 percent of their remaining life expectancy in the normal state, compared with 60 percent for males. Among US and foreign-born Hispanics, on the other hand, males in each integration quartile spend at least as long, if not a greater proportion, of their lives in the cognitively normal state.

Figure 3 Estimated share of remaining life expectancy in cognitive states by gender, nativity, race and social integration quartile

a. Males



b. Females



Sensitivity analyses

The results are robust to most model specifications. The results of the sensitivity analyses are shown in the Appendix. Nine tests are performed where we examine the

effects of the imputation strategy, model transition risks across age with different parametric forms, examine different measures of social integration, swap the education control variable with a control variable based on pre-retirement income and test interactions between age, gender, nativity, race and social integration. The only test that produces substantially different estimates of cognitive life expectancy are those where no imputation is performed. Specifically, if no imputation of missing data is performed, the results give substantially higher estimates of life expectancy, especially in the cognitively impaired states, with discrepancies across social integration levels varying across gender, racial and nativity groups. The reason for the discrepancies is that there are a large number of respondents (approximately 9,500) who did not complete a Leave Behind questionnaire in the wave before their death, leaving missing data on the social integration levels just prior to death. Thus, without imputation of missing data, probabilities of transitioning to death are substantially under-estimated.

Discussion

Our research provides further evidence of the significant role of social integration in enhancing cognitive health life expectancy, with variations observed across gender, racial, and nativity groups. After adjusting for education, our analysis reveals that higher levels of social integration are associated with both an increased lifespan and an extended duration of life without cognitive impairment. Aligning with the findings of Garcia et al., US-born non-Hispanic white men and women appear to benefit most from social integration in terms of both their total and cognitively healthy life expectancy

(38), though all racial-nativity groups studied also benefit. Our findings indicate that women are likely to enjoy longer periods of life without cognitive impairment, possibly due to a later onset of cognitive impairment (69). However, women across racial and nativity groups are also expected to have a longer period living with dementia than men, aligning with prior research that underscores the complex relationship between gender, cognitive decline, and social integration (40,81).

The findings contribute to the understanding of the 'Healthy Immigrant Effect'. Our study finds that migrant Hispanic men and women have a pronounced life expectancy advantage over US-born non-Hispanic and Hispanic groups. However, a decent share of the advantage is spent with cognitive impairment. Nearly three-quarters (74 percent) of the additional average life expectancy of migrant Hispanic males over their US-born counterparts, for instance, is spent living with cognitive impairment. The Healthy Immigrant Effect, in terms of cognitive life expectancy, does not appear to extend to US-born Americans, especially men. US-born Hispanic men have a similar overall life expectancy to non-Hispanic white men after controlling for education and spend a shorter proportion of their lives in the 'Cognitively Normal' state and a longer proportion with dementia.

Despite strong associations with cognitive life expectancy, social integration explains little of the Healthy Immigrant Effect. Social integration is associated with longer life expectancies and perhaps also a compression of years lived with dementia among migrant Hispanic Americans. However, we find different observed levels of integration

produce few differences in cognitive life expectancy, suggesting that the quantity of ties – as distinct from their quality – does not explain the healthy immigrant effect. Potential intersectional gender differences emerge from the finding that the advantage white non-Hispanic women experience in terms of cognitive life expectancy over men is not shared by Hispanic and black women. Again, social integration cannot explain these gender differences, though integration may contribute to a compression of years lived with cognitive impairment for non-Hispanic white women more so than other groups.

The findings suggest that social integration has the potential to expand or compress morbidity. Social integration is associated with a slowing in cognitive deterioration and risk of death at different stages of impairment. If the association between social integration and longer life expectancy in the cognitively normal state reflects a causal relationship, this suggests that integration at this stage contributes to a compression of time spent with cognitive impairment. In post-impairment stages, social integration is associated with a reduced risk of further cognitive decline and death. While the reduced risk of further decline also suggests a compression of time spent with severe cognitive impairment including dementia, the reduced risk of death suggests that integration may help to extend the lives of dementia sufferers, though with a corollary effect of expanding cognitive morbidity. Importantly then, the apparent disadvantage that migrant Hispanic Americans face in spending a greater proportion of their lives with dementia relative to non-Hispanic white Americans is perhaps at least partly a positive consequence of the social support Hispanic migrants receive while living

with cognitive impairment and its protective effect in delaying further cognitive decline and death.

Limitations and strengths

There are some limitations in this study. The measurement of social integration was confined to the quantity of social ties surpassing a commonly accepted threshold, neglecting the qualitative aspects of these connections. Given the Health and Retirement Study (HRS) dataset's current limitations on assessing relationship quality, it remains challenging to ascertain how the quality of social ties influences the observed variations in life expectancy associated with cognitive impairment (66). Further, while the quartile-based analysis underscores the importance of social integration for cognitive health, it raises questions about its real-world applicability as it represents hypothetical individuals who remain in the same integration quartile throughout their later life. The multistate life tables used in this study assume cognitive decline is a unidirectional Markov process. Specifically, we assume that people only face a risk of transitioning to an advanced state of cognitive decline and that this risk is a function of current characteristics, including age and current cognitive state, and not the longer history of a person's cognitive functioning. Further, while we incorporate the intermediate state of CIND to capture different stages of cognitive decline, the actual process of decline is still more complex.

The main strength of our study is the longitudinal analyses of the potentially heterogeneous associations between social integration and cognitive health. This

longitudinal approach, encompassing a longer timeframe and more frequent follow-up periods compared to prior research (7,82,83) enhances the reliability and robustness of our findings. Despite the Markov assumption, the use of multistate life tables is a significant strength. The method allows for a detailed prospective analysis of the associations between social integration and subsequent cognitive health transitions. Compared with approaches based on the Sullivan method (40,81,84), the multistate approach calculates cognitive life expectancy in a way that better controls for confounding factors and the bidirectional relationship between social integration and cognitive health.

Our findings underscore the critical role of late-life social integration in enhancing cognitive health among the elderly, advocating for policies that extend years of cognitive wellness and ameliorate the conditions of those experiencing cognitive decline. Such insights warrant public health and policy strategies that bolster social participation among older adults, particularly through volunteer and continuing education opportunities. These interventions may be especially beneficial for minority groups, like Latino elders, who face heightened risks of dementia exacerbated by socioeconomic and educational disadvantages (29). These measures not only aim to expand the cognitively healthy lifespan of the elderly but also seek to alleviate familial caregiving burdens (14), highlighting the intersection of social integration, public health, and policy.

Conclusion

Our research provides support for the hypothesized protective effects of social integration on cognitive life expectancy. The associations we find are particularly pronounced among non-Hispanic white populations, though were found across all migrant and nativity groups that we study. Despite the strength of the associations and the variability across groups, we do not find evidence that social integration explains the longer life expectancies experienced by migrant Hispanic Americans, but it may help to explain their relative disadvantage in terms of cognitive life expectancy. The full appreciation of these dynamics is achieved through the multistate life table approach, operationalizing progressive cognitive decline and the potential protective effect of social integration at different stages. Estimates of cognitive life expectancy across several key groups in society provide intuitive and policy-relevant summary measures of the potential effects of one of the known key influences on cognitive health (social integration). This provides nuanced information to help study and respond to one of the most important public health challenges of the 21st century.

List of abbreviations

Abbreviation	**Definition**
CN	Cognitive Normal
CIND	Cognitively Impaired not Dementia
SI	Social Integration
GED	General Educational Development
HRS	Health and Retirement Study

Declaration

Ethics approval and consent to participate

This study uses a public dataset and therefore does not require additional Institutional

Review Board approval. Primary data collection for the Health and Retirement Study was approved through the University of Michigan Institutional Review Board.

Consent for publication

Not applicable.

Availability of data and materials

The Health and Retirement Study is a publicly available dataset available through the University of Michigan at https://hrs.isr.umich.edu/.

Competing interests

The authors declare that they have no competing interests.

Funding

James O'Donnell (or JO) is the recipient of an Australian Research Council Discovery Early Career Researcher Award (project number DE240100232) funded by the Australian Government.

Authors' contributions

YC conducted the analyses, drafted the manuscript, and contributed to conceptualize the study. JO performed the imputation, assisted with manuscript writing, and contributed to the study's conceptualization and analysis. Both authors have read and approved the final manuscript.

Acknowledgements

Not applicable.

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Appendix

Figure S1 Predicted survivorship in the cognitively healthy state

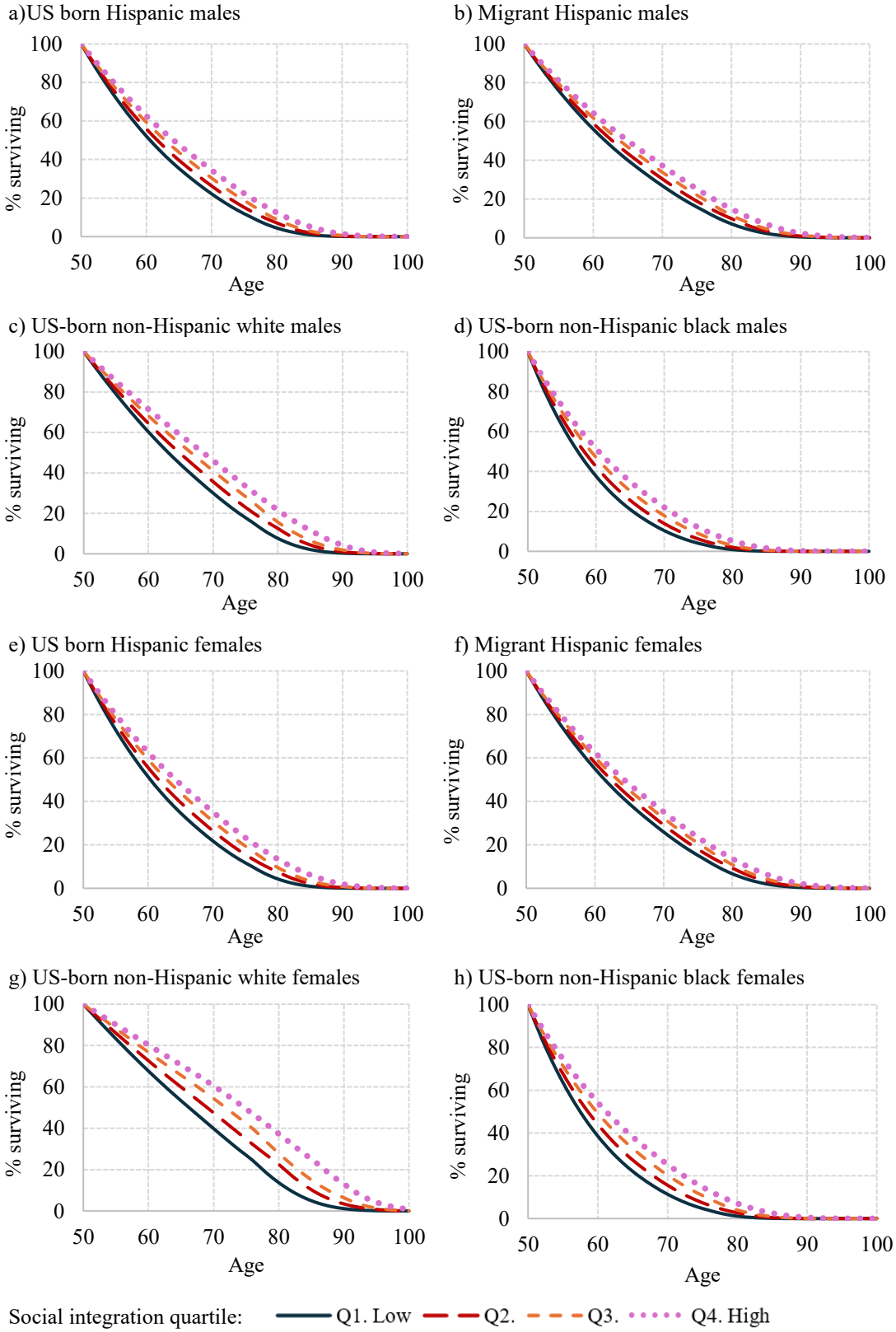
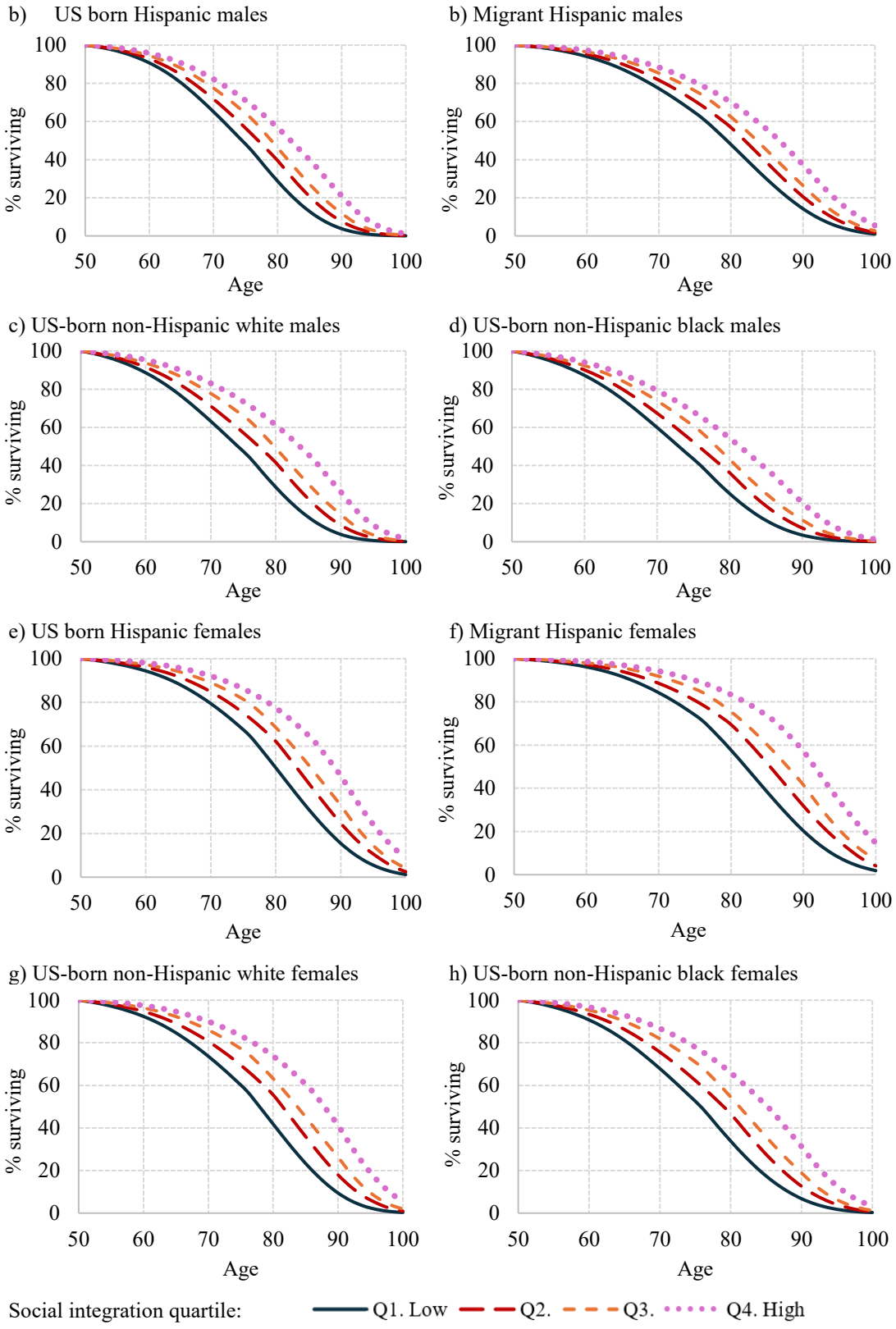


Figure S2 Predicted survivorship in all cognitive states



Sensitivity analyses

We test the robustness of the results to the following nine model specifications.

Test 1: In this test, we do not impute any missing values.

Test 2: In this test, we impute missing values but not where respondents have not at least partially completed the Leave Behind questionnaire.

Test 3: In this test, we model associations between age and cognitive transitions with a piecewise constant function of time. In these models, transition probabilities are assumed to be constant within each five-year interval between ages 50 and 95 and are allowed to vary between intervals. For example, transitions are constant between ages 50 and 54, 55 and 59, 60 and 64 etc. Transitions from age 95 onwards are assumed to be constant.

Test 4: In this test, we model associations between age and cognitive transitions with a polynomial function of time. In these models, transition probabilities are assumed to be a linear function of age and age squared.

Test 5: In this test, we replace the time-varying measure of social integration with a time-invariant pre-dementia measure. We do this by calculating respondents' average social integration while they were aged 50-69 years and in the cognitively normal state.

Test 6: In this test, we replace the seven item measure of social integration with a four item measure based on items collected in every survey wave: employment, marriage, volunteering and weekly engagement in religious activities.

Test 7: In this test, we include in the regression models an interaction term between age, gender, nativity, race and social integration.

Test 8: In this test, we shift all respondents who migrated to the United States as children (before their 18^{th} birthday) to the US born group.

Test 9: In this test, we replace highest education as the key control variable with the natural logarithm of respondents' pre-retirement income – measured as the average annual income earned between ages 50 and 64 for years in which respondents' were

employed.

The following figures show estimates of remaining life expectancy in the cognitively normal state (Figure S3), overall remaining life expectancy (Figure S4) and the share of remaining life expectancy spent in the cognitively normal state (Figure S5).

Figure S3 Estimated remaining life expectancy at age 50 in the cognitively normal state under different model specifications

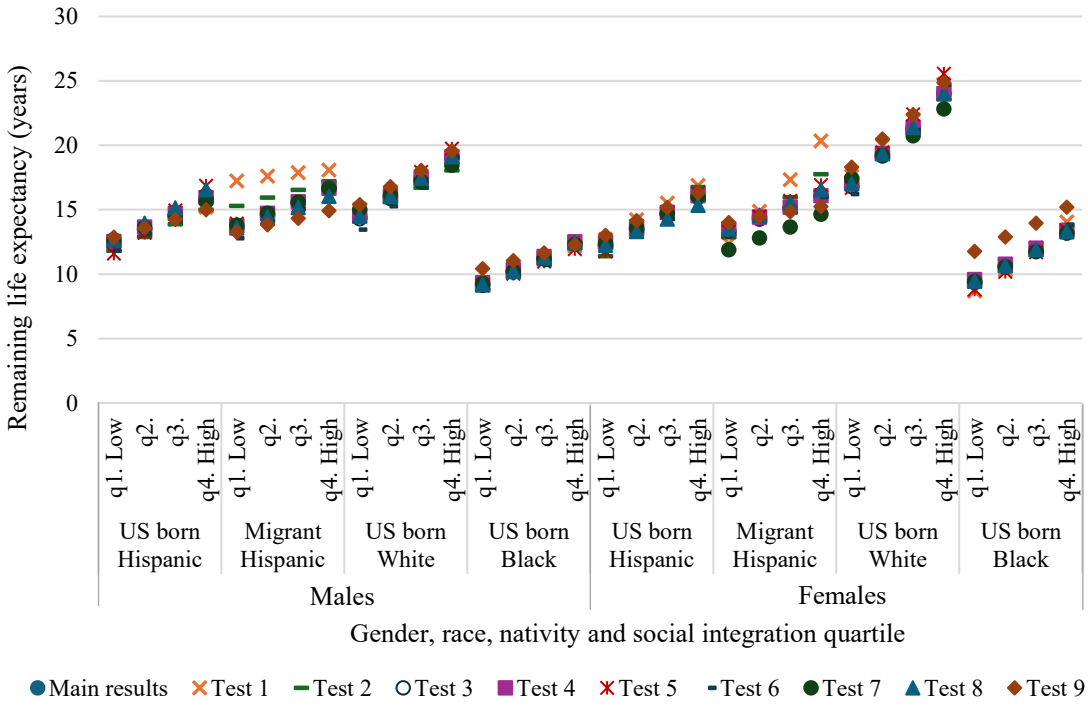


Figure S4 Estimated total remaining life expectancy at age 50 under different model specifications

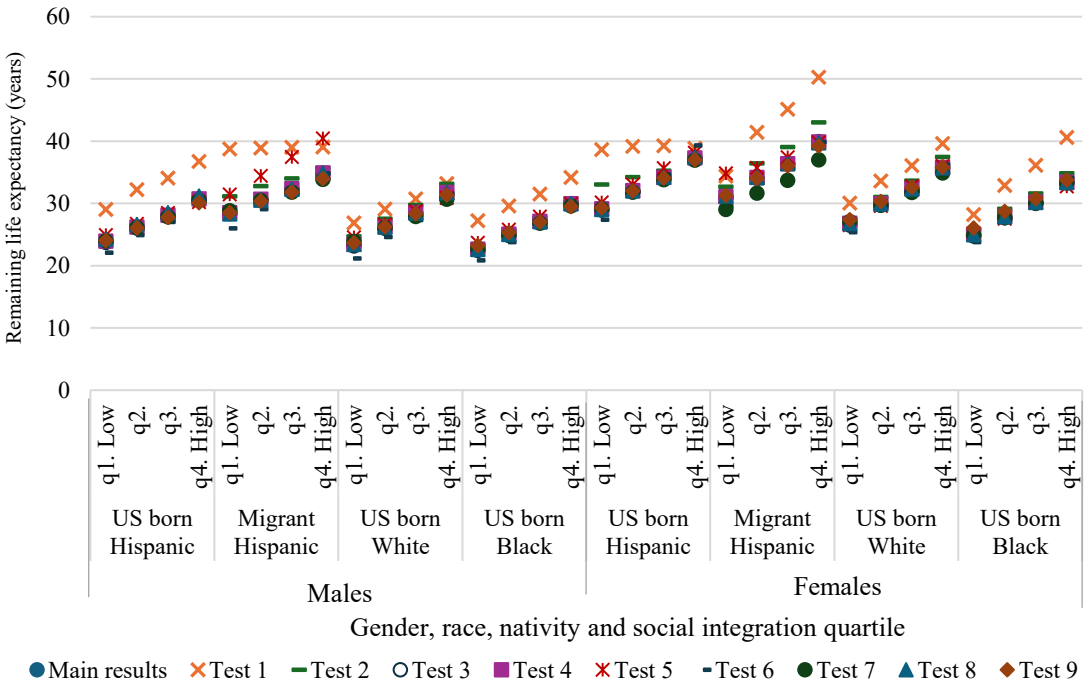


Figure S5 Estimated share of total remaining life expectancy at age 50 spent in the cognitively normal state under different model specifications