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A national longitudinal dyadic analysis of spousal education and cognitive decline in the United States[☆]

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ABSTRACT

Education plays a significant role in shaping cognitive functioning throughout an individual's life. However, existing research has not adequately explored how the educational attainment of the spouse can impact cognitive functioning over time. This study presents one of the first longitudinal analyses of how spousal education is linked to cognitive trajectories of each member within couples during their later life in the United States. Guided by the linked lives perspective, we analyze data from 8370 couples in the Health and Retirement Study spanning from 2000 to 2018. Results from the Actor-Partner Interdependence Model (APIM) integrated with latent growth curve models reveal that cognitive trajectories exhibit a correlation between spouses over time. Moreover, our analysis uncovers gender-specific effects of spousal education on cognition, shedding light on the underlying mechanisms driving this connection. Notably, the lower educational attainment of husbands is associated with a faster cognitive decline in both themselves and their wives. This association is partially explained by economic resources, but not by health and social behaviors. The lower educational attainment of wives is linked to their own faster cognitive decline as well as lower initial cognitive levels of their husbands, in part via economic resources. However, wives' educational attainment is largely unrelated to their husbands' cognitive decline. Intriguingly, wives' education has a more pronounced impact on the health and social behaviors of their husbands than vice versa, although these health and social behaviors do not appear to influence husbands' cognitive decline. In conclusion, these results underscore the importance of considering spousal education in comprehending the complexities of cognitive decline within dyadic relationships.

Cognitive decline has emerged as a serious and growing public health concern in the context of rapid population aging (Centers for Disease Control and Prevention, 2019). Cognitive decline can range from mild cognitive impairment to dementia—a severe condition associated with disability, increased need for medical and personal care, and premature death (Centers for Disease Control and Prevention, 2019). Today, more than 16 million older Americans are living with either a slight or severe decline in cognitive abilities (Centers for Disease Control and Prevention, 2011). Numerous studies have been conducted to identify risk factors, causative agents, treatments, and preventive strategies for cognitive decline and dementia. Among the identified risk factors, education has consistently emerged as one of the most influential social determinants in shaping cognitive development trajectories throughout a person's entire lifespan, significantly impacting the risk of developing dementia (Alley et al., 2007; Lövdén et al., 2020; Meng and D'Arcy, 2012). However, previous studies have predominantly focused on an *individual's own education* when examining the impact of education on cognition (Alley et al., 2007; van Hooren et al., 2007). Surprisingly, little attention has been given to exploring how *spousal education* may influence an individual's cognitive function, despite leading scientists highlighting the interconnectedness and interdependence of spouses in various aspects of life.

Guided by the linked lives perspective, we analyze couple-level data from the Health and Retirement Study (HRS) 2000–2018 and provide one of the first nationally representative longitudinal dyadic analyses of how spousal education is linked to each couple member's cognitive

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trajectories in late life in the United States. Our research addresses four key research questions: 1) To what extent are spouses' cognitive trajectories correlated with each other in late life? 2) How does a husband's education influence both his own cognitive trajectory and that of his wife? 3) How does a wife's education influence both her own cognitive trajectory and that of her husband? and 4) Can economic resources and health and social behaviors help explain the effect of spousal education on cognitive trajectories? By illuminating these questions, our findings will offer valuable insights to health policymakers and practitioners in identifying vulnerable subpopulations. This will enable the design of effective intervention strategies, targeting both partners, to mitigate risks of cognitive decline and dementia.

1. The impacts of education on cognition in later life

Extensive literature has identified education as a key social factor influencing cognitive development over the entire life span (Clouston et al., 2015; Langa et al., 2017), suggesting that educational attainment can influence cognitive trajectories in later life through two distinct processes. Firstly, educational attainment is linked to the *levels* of cognitive function in later life through the development of cognitive abilities in early life that can persist into adulthood and later stages. During their schooling years, individuals are immersed in a cognitively challenging environment, where they acquire new knowledge and learn how to apply it to respond to evolving and novel tasks. These cognitive skills developed through education tend to endure and impact cognitive functioning in adulthood and older age (Hayward et al., 2021). This notion is supported by a handful of empirical studies, finding that individuals with higher levels of education generally maintain better cognitive functioning throughout their adulthood than their peers with lower levels of education (e.g., Lövdén et al., 2020).

Secondly, educational attainment may also be associated with *changes* in cognitive trajectories experienced during adulthood and older age, potentially resulting in individuals at different educational levels experiencing varying rates of cognitive decline in later life. Individuals with higher levels of education typically have a stronger sense of control over their lives, promoting and enabling a healthy lifestyle such as reduced drinking and smoking (Mirowsky and Ross, 2003), thereby reducing the risk of chronic conditions such as cardiovascular diseases associated with cognitive decline and dementia (Seefeldt et al., 2002). Moreover, higher levels of education not only equip individuals with the knowledge and skills needed to secure jobs that are autonomous, creative, and cognitively challenging, but also enhance their job stability by making them more competitive, adaptable, and well-connected in the job market (Mirowsky and Ross, 2003), thereby contributing to the promotion of good cognitive health. People with higher levels of education are also more likely to engage in cognitive activities such as reading, writing, and problem-solving, which can enhance cognitive reserve, which is the brain's ability to function despite age-related changes and brain damage (Lachman et al., 2010; Parisi et al., 2012; Foubert-Samier et al., 2012; Stern, 2012).

2. Previous empirical evidence on spousal education and cognition

Most studies on education and cognition are based on individual-level data with a focus on the impact of one's own education on cognitive function. We could only identify three published studies, each providing mixed evidence, that examined the association between spousal education and cognitive health. Xu (2020) analyzed 5846 married individuals from the Health and Retirement Study and found that more years of spousal education was associated with a slower decline in cognitive functioning over time, and this pattern was similar for men and women. Saenz et al. (2020) conducted a cross-sectional dyadic analysis of 4017 couples aged 50 and older from the 2012 Mexican Health and Aging Study. They found that higher spousal education was associated with better cognitive ability for both husbands and wives. In contrast, a regional study of 8835 members of the Kaiser Permanente Northern California healthcare system found no significant association between spousal education and diagnosed dementia after individuals' own education was controlled (Gilsanz et al., 2021). Although informative, none of these studies employed longitudinal dyadic analysis, which considers the complex interplay between two partners within a dyad over time, a process underscored by a life course perspective.

3. A life course perspective on "linked lives": spousal education and cognitive trajectories

The life course perspective asserts that lives are experienced interdependently in the context of social ties. These "linked lives" are highly contextualized and shaped by their interactions with ties over time (Elder, 1998). A spouse comprises the most important social tie during adulthood for most people due to their shared experiences and environments with individuals. The concept of "linked lives" between spouses indicates that the lives of married partners are intertwined, and their individual experiences, choices, and outcomes are interconnected. Highly educated spouses may positively influence their partner's cognitive abilities through shared experiences, intellectual stimulation, and exposure to new ideas and information. For example, highly educated spouses may be more likely to engage in stimulating intellectual conversations with their partners, which can help improve their cognitive abilities. This interconnectedness of spouses' lives can also manifest indirectly through various mechanisms, such as increased economic resources and engagement in healthier behaviors, which may shape individuals' own and their partners' cognitive health.

Economic resources. Spousal education increases economic resources by enhancing earning potential, expanding career opportunities, and improving financial management abilities (Benham, 1974; Huang et al., 2009). For instance, when individuals have higher education, they may have access to higher-paying industries or professions and more stable employment opportunities (Bernasco et al., 1998; Greenstone and Looney, 2012). This, in turn, can lead to increased economic resources for both partners, including higher household income, greater wealth accumulation, and improved access to quality health insurance. Additionally, a higher-educated spouse can increase one's access to economic resources by contributing to the couple's financial literacy and management skills, enabling them to make informed decisions, optimize resources, and potentially invest in wealth-building opportunities (Bernasco et al., 1998).

Economic resources may enhance health and cognitive capacities by improving nutrition, providing for care of illnesses, and allowing the purchase of medical treatment and other health-enhancing resources (Liu et al., 2020). Greater economic resources may also increase opportunities to engage in activities that promote cognitive health, such as reading, attending cultural events, and pursuing continuing education. This can also positively impact their partner's cognitive function by providing them with access to these activities. Moreover, the extensive body of literature on the wealth-health gradient (e.g., Smith, 1999) suggests that financial strain resulting from a lack of economic resources can lead to cumulative and recurrent stress on the body over time. This stress can increase allostatic load and have adverse effects on endocrine and immunological processes, potentially harming cognitive health.

Health and social behaviors. A spouse typically has the greatest influence on an individual's health and social behaviors during adulthood. When a spouse has a higher level of education, they often possess greater knowledge about health promotion and more effective communication skills, positively impacting their partner's cognition in various ways. For example, highly educated spouses are more likely to encourage their partners to adopt healthy habits, such as quitting smoking, reducing alcohol consumption, maintaining regular physical activity, and engaging in social activities. Previous empirical studies support this perspective, demonstrating significant associations between lower spousal education and worse health behaviors, including higher smoking rates (Hernandez et al., 2018; Takagi et al., 2014), greater alcohol consumption (Banks et al., 2014), lower levels of physical activity (Murakami et al., 2017), and reduced participation in social activities (Hoppmann et al., 2008).

These compromising health and social behaviors have been linked to mechanisms that accelerate the risks of cognitive decline and dementia. Smoking directly stimulates white blood cells in the central nervous system to attack healthy cells, resulting in severe neurological damage and impaired cognitive function (Anstey et al., 2007; Peters et al., 2008; Zhou et al., 2014). Heavy drinking can also damage the brain's white matter and increase the risk of adverse brain outcomes and accelerated cognitive decline (Hayes et al., 2016; Ridley et al., 2013; Zhou et al., 2014). On the other hand, regular physical activity has been shown to prevent or delay cognitive decline associated with aging (Barnes, 2015; Mandolesi et al., 2018; Yaffe et al., 2001) and reduce the likelihood of Alzheimer's disease and related dementias, even at moderate intensity (Barnes and Yaffe, 2011; Buchman et al., 2012; Hamer and Chida, 2009; Smith et al., 2010). Additionally, growing evidence suggests that social engagement can lower the risk of dementia by enhancing cognitive reserves, which strengthen the ability to cope with neuropathological damage through compensatory cognitive strategies (Zunzunegui et al., 2003).

Sex differences. Empirical research on sex differences in the association between spousal education and dementia is limited and shows mixed results. For example, a study conducted in the United States found no sex differences in the relationship between spousal education and cognitive impairment (Xu, 2020). In contrast, other studies examining various health outcomes, such as chronic diseases and cardiovascular disease mortality, suggest that wives' education has a stronger impact on both partners' health than husbands' education (Guo et al., 2020; Jaffe et al., 2006). Still, other studies find that husbands' education is more important for wives' self-rated health than vice versa (Brown et al., 2014).

Indeed, a long-standing sociological tenet suggests that while women tend to receive more economic benefits from their spouses due to men's higher-earning jobs, men generally derive more health-promoting benefits from marriage, such as social engagement and the regulation of health behaviors (Liu and Waite, 2014; Simon, 2002; Kotwal et al., 2016). In a traditional marriage, women often take on the responsibility of maintaining connections with family and friends, regulate health behaviors of family members, as well as providing care and emotional support to their spouses (Liu and Waite, 2014; Simon, 2002; Kotwal et al., 2016). These factors can promote husbands' health and potentially slow down the progression of cognitive decline, reducing the risk of dementia.

Moreover, significant sex differences exist in potential mediating factors linking spousal education to cognition. For instance, women typically possess fewer economic resources than men (Toczek et al., 2021). Men are more likely than women to smoke and drink (Bauer et al., 2007; Holmila and Raitasalo, 2005), while women are less likely to engage in regular exercise (Nomaguchi and Bianchi, 2004) but more likely to participate in social activities (Naud et al., 2019). Given such gender differences and the potential influence of gendered spousal dynamics on these mediators, the education of both spouses may impact cognitive trajectories and dementia risk through distinct pathways for each partner.

4. Research hypotheses

We test the following research hypotheses.

Hypothesis 1. The cognitive trajectories of husbands and wives will be correlated with each other.

Hypothesis 2. The educational attainment of husbands will affect their own cognitive decline, as well as that of their wives (2a), partly through increased economic resources and engagement in healthier behaviors (2b).

Hypothesis 3. The educational attainment of wives will affect their own cognitive decline, as well as that of their husbands (3a), partly through increased economic resources and engagement in healthier behaviors (3b).

Hypothesis 4. The educational attainment of wives will have a stronger impact on both their own and their husbands' cognitive trajectories compared to the effects of the educational attainment of husbands on their own and their wives' cognitive trajectories.

5. Methods

5.1. Data and sample

Data are from the Health and Retirement Study (HRS), a national panel survey of adults over age 50 and their spouses in the United States. The HRS is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the Institute for Social Research at the University of Michigan (Health and Retirement Study, 2022). We used 10 waves of RAND HRS longitudinal data spanning from 2000 to 2018 (RAND HRS Longitudinal File, 2018, 2022). The 2000 wave of the HRS surveyed a nationally representative sample of 19,578 noninstitutionalized adults born before 1948 (aged 52 and older in 2000) and their spouses (HRS, 2017; Servais, 2010). The survey oversampled individuals from Black and Hispanic backgrounds and collected detailed information on cognitive, physical, economic, work, and family conditions, as well as health behaviors, approximately every two years. With response rates ranging from 81 % to 89 % in each wave, the HRS offers an excellent opportunity to address our research question due to its substantial sample size, long-term follow-up of both spouses and reliable measures of cognitive health and other crucial variables. For our analysis, we focused on heterosexual married/cohabiting couples who had at least three waves of follow-up data on cognition to enable robust longitudinal analyses, resulting in a final sample of 8370 couple dyads. Missing data were incorporated using Mplus' missing value handling feature based on the Full Information Maximum Likelihood (FIML) method (Muthén & Muthén, 1998–2017). The FIML approach maximizes a casewise likelihood function using only observed variables with the assumption that missing values are random (Muthén & Muthén, 1998–2017).

5.2. Measures

Cognition. The HRS assessed cognitive function via the modified version of the Telephone Interview for Cognitive Status (TICS). A small percentage of respondents (0.8–3.1 %) refused to participate in tests of immediate and delayed recall and serial 7s; the HRS has developed an imputation strategy for cognitive variables for all waves (Servais, 2010). We followed previous studies in calculating a final summary score by summing the following cognitive items: immediate and delayed recall of a list of 10 words (1 point for each), five trials of serial 7s (i.e., subtract 7 from 100, and continue subtracting 7 from each subsequent number for a total of five trials; 1 point for each trial), and backward counting (2 points). The final summary score ranges from 0 (severely impaired) to 27 (high functioning) (Crimmins et al., 2016). This summary score has been implicated in providing data-based classifications of dementia (Choi et al., 2018), but we retained this continuous score to capture a broader array of variation in cognitive functioning over time.

Education. College education represents one of the most significant milestones in various aspects of life, such as the labor market and overall well-being, for individuals in the United States (Horowitz, 2018). Therefore, we assessed the education of respondents and their spouses based on college degree attainment. Individuals with less than 16 years of schooling (i.e., approximately a college degree equivalent) were classified as lower education (coded as 1), while those with 16 or more years of schooling were considered as higher education (coded as 0). We also conducted additional sensitivity analysis by adopting various coding methods for education (e.g., using 12 years as a cutoff for high school graduates, a 4-level classification of education); and the results are discussed and presented in the results section.

Household economic resources. We assessed household economic resources using two indicators at the baseline survey: total household income and net household wealth.

Total household income included the respondent's and their spouse's income from all sources such as earnings, pensions, and annuities, Supplemental Security Income and Social Security Disability, Social Security retirement, other government transfers, unemployment and workers' compensation, household capital income, and other income for the last calendar year.

Net household wealth was measured as the total value of household assets minus household debts.

We measured a couple's total household income by the average of the respondent- and spouse-reported household income; net household wealth was measured by the average of respondent- and spouse-reported wealth. If a respondent or spouse had missing reports on income or wealth, we used the other one's report to represent the household. We applied the RAND version of household income and wealth data, which included consistently imputed missing values across waves (RAND HRS Longitudinal File, 2018, 2022). Since household income and wealth occasionally had zero or negative values, we further adjusted the variables by adding a constant of $1 for income and adding a year-specific constant (depending on the minimum value of wealth in that specific year) for wealth to all respondents and spouses so that all wealth and income values were transformed to positive (and also preserving their rank order). We then divided the imputed income and wealth by the square root of household size and took the natural logs of the values (Zhang and Hayward, 2006). We constructed a factor score for total/composite household economic resources using income (factor loading: 0.47) and wealth (factor loading: 0.47) based on the iterated principal factor method and an oblique rotation.

Health and social behaviors. Health and social behaviors were measured using a summary index (0–4) of four behavior indicators at the baseline survey: smoking, heavy drinking, low physical exercise, and low social activity. *Smoking* was a dichotomous indicator with 1 indicating a current smoker and 0 indicating non-smoker. *Heavy drinking* was a dichotomous indicator for current heavy drinker (1 = yes; 0 = no). Based on the recommendation of the National Institute on Alcohol Abuse and Alcoholism (NIAAA) guidelines for older adults, men who consumed more than 14 drinks per week and women who consumed more than 7 drinks per week on average were coded as heavy drinkers (National Institute on Alcohol Abuse and Alcoholism, 2023). *Low physical exercise* indicates the frequency of participating in moderate physical activities (e.g., gardening, cleaning the car, walking at a moderate pace, dancing, floor or stretching exercises) (0 = at least once a month and 1 = less than once a month). *Low social activity* was measured based on the question asking how often the respondents socialized with neighbors or other people nearby (0 = at least once a month and 1 = less than once a month). The higher final summary score of health and social behaviors indicates a higher presence of unhealthy behaviors.

Covariates. We controlled for basic sociodemographic covariates of both partners measured at the baseline, including *age* (in years), *race-ethnicity* (0 = non-Hispanic white, 1 = others), *marital status* (0 = married, 1 = cohabiting), *order of marriage* (0 [reference], 1st, 2nd, 3rd and higher-order marriage), *marital duration* (0–9 years [reference], 10–19 years, 20–29 years, 30–39 years, 40–49 years, 50 years or more), *parental status* (0 = childless, 1 = at least one child), *having living siblings* (0 = no living sibling, 1 = at least one living sibling), and *self-rated health* (0 = fair/poor and 1 = good/very good/excellent). Table 1 shows weighted descriptive statistics of all analytic variables.

Table 1
Weighted descriptive statistics of all analytic variables[a].

	Percent/Mean (SD)			
	Husband (n = 8370)		Wife (n = 8370)	
Cognition	15.14	(4.21)	16.22*	(4.33)
Education (%) (ref: college and above)				
No college degree	72.58		78.35*	
Missing	0.43		0.32	
Household Economic Resources				
Household Income	$80,238	(118,722)	$80,238	(118,722)
Household Wealth	$428,639	(1,068,456)	$428,639	(1,068,456)
Health and Social Behaviors				
Current Smoker (%) (ref: no)				
Yes	17.50		15.27*	
Missing	0.84		0.62	
Current Heavy Drinker (%) (ref: no)				
Yes	6.93		5.95*	
Missing	0.01		0.00	
Low Physical Exercise (%) (ref: no)				
Yes	14.41		18.73*	
Missing	0.00		0.01	
Low Social Activity (%) (ref: no)				
Yes	29.89		32.81*	
Missing	0.84		0.74	
Sociodemographic Covariates				
Age	61.22	(9.15)	58.07*	(9.29)
Race/Ethnicity (%)				
Non-Hispanic White	70.48		70.54	
Missing	0.12		0.08	
Marital Status (%)				
Married	93.07		92.92	
Cohabiting	6.93		7.08	
Order of Marriage (%) (ref: none)				
1st	65.63		67.80*	
2nd	24.76		22.93*	
3rd and higher	8.15		7.78*	
Missing	0.33		0.26	
Marital Duration (%) (ref: 0–9 years)				
10–19 years	11.42		11.42*	
20–29 years	17.20		17.22*	
30–39 years	24.62		24.80*	
40–49 years	18.41		18.23*	
50 years or more	8.34		8.33*	
Missing	6.14		6.13	
Parental Status (%) (ref: childless)				
At least one child	90.67		91.19	
Missing	0.38		0.13	
Living Siblings (%) (ref: no living sibling)				
At least one living sibling	89.50		90.60*	
Missing	0.04		0.02	
Self-rated Health (%) (ref: fair/poor)				
Good/very good/excellent	77.80		78.59	

Note.
*Statistically significant difference comparing between husbands and wives at $p < .05$.
[a] Cognition is a time varying variable, and all others are time-invariant baseline measures.

5.3. Statistical analyses

We used the Actor-Partner Interdependence Model (APIM), a widely employed approach for analyzing dyadic data, to account for the interdependence of partners in couples (Kashy and Kenny, 2000). The APIM enables us to examine how one partner's behaviors or characteristics influence the outcomes of the other partner (partner effects) beyond the effects of each partner's behaviors and characteristics on their own outcomes (actor effects). To leverage the longitudinal nature of the data, we combined the APIM with latent growth curve modeling to simultaneously model the intervening process of the respondent's and partner's cognitive trajectories. Within both the respondent's and partner's cognitive trajectories, the APIM latent growth curve model estimates the effects of one's own education and their partner's education on the initial level (latent intercept) and rate of change (latent slope) in cognition over the study period.

The APIM latent growth curve model is estimated using the structural equation modeling (SEM) approach, which has several advantages over standard regression methods (Cook and Kenny, 2005). A major advantage of using SEM in this study is its ability to integrate the complex relationships linking spousal education, economic resources, health and social behaviors, and cognitive trajectories into a single model and simultaneously estimate all these relationships. We conducted two APIM latent growth curve models. Model 1 estimated the overall associations of husbands' and wives' education with each other's cognitive trajectories. Model 2 included additional variables as potential mediators, namely household economic resources and husbands' and wives' health and social behaviors. To evaluate model fit, we used three goodness-of-fit indices: Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA). Results suggested that for all final reported models, the CFI and TLI were greater than or close to 0.95 and RMSEA was less than 0.05, suggesting good model fits (Lance et al., 2006). All models were estimated using Mplus software (Muthén & Muthén, 1998–2017).

6. Results

Table 1 presents the weighted descriptive statistics for the analytic variables, categorized by husbands and wives. The findings indicate that, on average, wives exhibited higher cognitive function scores compared to husbands (with mean scores of 16.22 for wives and 15.14 for husbands, $p < .05$). Regarding education, a greater proportion of wives than husbands did not possess a college degree (78.35 % for wives and 72.58 % for husbands, $p < .05$). In terms of health and social behaviors, a larger percentage of husbands than wives were identified as current smokers (17.50 % for husbands and 15.27 % for wives, $p < .05$), as well as heavy drinkers (6.93 % for husbands and 5.95 % for wives, $p < .05$). Furthermore, in comparison to husbands, wives displayed higher proportions of engaging in low levels of physical exercise (18.73 % for wives and 14.41 % for husbands, $p < .05$), as well as low levels of social activity (32.81 % for wives and 29.89 % for husbands, $p < .05$). Concerning sociodemographic characteristics, husbands tended to be older, in higher order marriages, in longer marital duration, and had a lower proportion of having at least one living sibling compared to wives.

6.1. *Estimated associations between spousal education and cognitive trajectories*

Fig. 1 shows the structural path diagram of the APIM latent growth curve model to assess how the wife's and husband's education are related to each other's cognitive trajectories. As spousal education is dichotomous and its standardized value is not meaningful, we have depicted the unstandardized coefficients in the diagrams. Results suggest that the wife's and husband's cognitive trajectories were correlated with each other at both initial levels (*covariance* = 1.509, $p < .001$) and subsequent changing rates (*covariance* = 0.006, $p < .001$). For both husbands and wives, higher initial levels of cognition were associated with a more rapid cognitive decline over time (*covariance* = −0.096, $p < .001$ for wives and *covariance* = −0.044, $p < .001$ for husbands).

Results in Fig. 1 further suggest that both wife's and husband's lower education (i.e., without a college degree) was negatively related to their own initial levels (i.e., latent intercept) and changing rate (i.e., latent slope) of cognitive trajectories. Specifically, wives' no college degree was associated with their own lower initial cognition levels ($b = -1.531$, $p < .001$) and a faster cognitive decline ($b = -0.018$, $p < .05$). Likewise, husbands' no college degree was associated with their own lower initial cognition levels ($b = -1.862$, $p < .001$) and a more accelerated rate of cognitive decline ($b = -0.021$, $p < .01$).

Moreover, husbands' no college degree was also negatively associated with their wives' initial levels ($b = -0.578$, $p < .001$) and changing rate ($b = -0.016$, $p < .05$) of cognitive trajectories. In contrast, wives' no college degree was only associated with their husbands' initial levels of

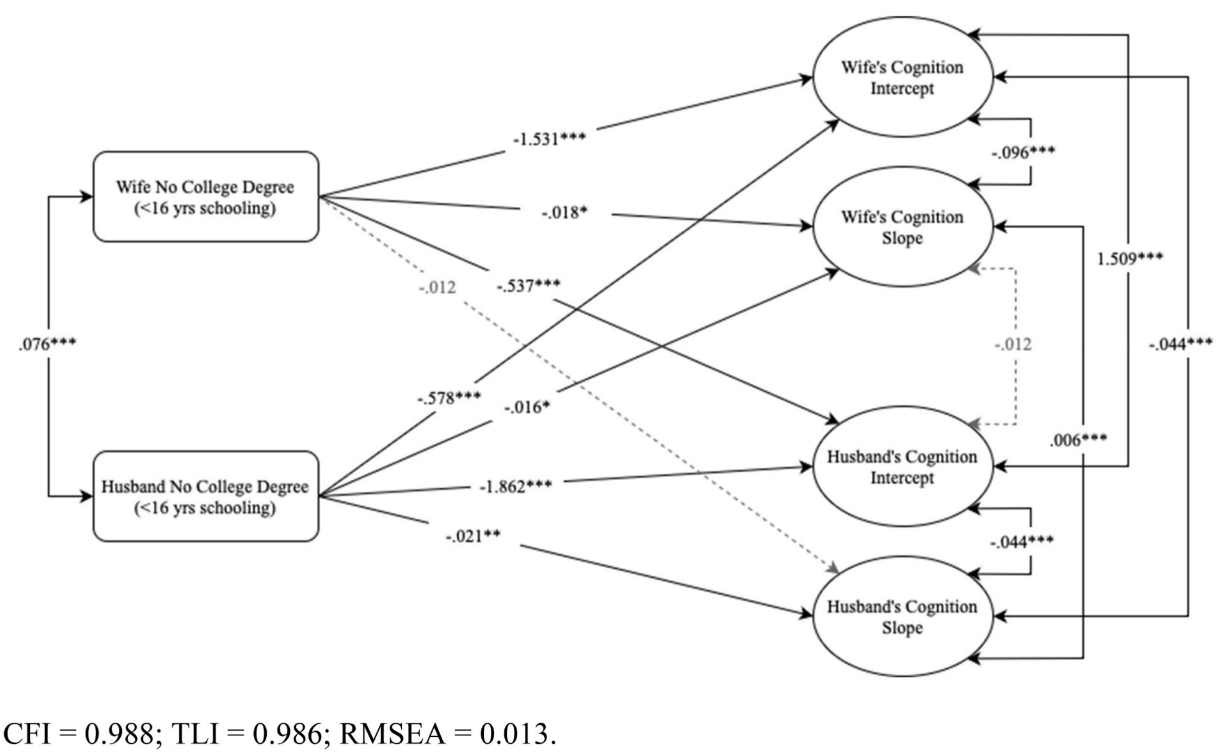

Fig. 1. Structural path diagram of APIM latent growth curve model to assess how wife's and husband's education is related to each other's cognitive trajectories. Note: ***$p < .001$, **$p < .01$, *$p < .05$. Unstandardized coefficients were presented due to binary exogenous variables. Model controlled for both partners' age, race-ethnicity, marital status, order of marriage, marital duration, parental status, having living siblings and self-rated health.

cognition ($b = -0.537$, $p < .001$), but wives' no college degree was not significantly associated with their husbands' changing rate of cognitive trajectories.

6.2. Mediating roles of economic resources and health and social behaviors

Fig. 2 added the potential mediators of economic resources and health and social behaviors through which spousal education may affect cognitive trajectories. Table 2 provides a summary of these estimated indirect effects. These results suggest that household economic resources were a significant mediator linking spouse education to each other's cognitive trajectories, but health and social behaviors were not. Specifically, both wives' ($b = -0.229$, $p < .001$) and husbands' ($b = -0.234$, $p < .001$) no college degree was associated with lower household economic resources, and greater household economic resources were associated with both husbands' and wives' higher initial cognition levels ($b = 0.894$, $p < .001$ for wives and $b = 1.208$, $p < .001$ for husbands) and slower rates of cognitive decline ($b = 0.029$, $p < .001$ for wives and $b = 0.015$, $p < .05$ for husbands).

In terms of health and social behaviors, wives' no college degree was associated with both their own ($b = 0.161$, $p < .001$) and their husbands' ($b = 0.142$, $p < .001$) unhealthier behaviors (consistent with previous research), but husbands' no college degree was associated with only their own unhealthier behaviors ($b = 0.122$, $p < .001$) but not their wives' health behaviors. Wives' unhealthier behaviors was negatively associated with their own initial levels of cognition ($b = -0.336$, $p < .001$), but not so with their own or their husbands' subsequent changing rate of cognition over time. In contrast, husbands' unhealthier behaviors were associated with both their own ($b = -0.254$, $p < .001$) and their wives' ($b = -0.166$, $p < .01$) lower initial levels of cognition, but husbands' unhealthier behaviors were not associated with either their own or their wives' subsequent changing rate of cognition over time. To test Hypothesis 4 (that wives' education would have a stronger impact on their husbands' cognition than vice versa), we conducted t-tests to compare corresponding path coefficients (Figs. 1 and 2) between husbands and wives within each APIM model, which showed that all differences between husbands and wives are statistically significant at least at the level of $p < .05$; readers should interpret the subsequent reporting of sex differences as being significantly different between husbands and wives.

6.3. Sensitivity analysis results

We conducted additional sensitivity analyses to test our key findings using different coding methods for education. The results are presented in the appendix, which includes two figures: Figure A1, using 12 years as a cutoff for high school graduates, and Figure A2, using a 4-level education (1 = less than high school, 2 = high school graduate, 3 = some college, and 4 = college graduate). These results indicate that our key findings remain robust when employing these different methods of coding for education.

Specifically, all effects on the initial levels of cognition (i.e., cognition intercept) remain robust, suggesting that both spouses' lower education is associated with lower initial levels of cognition for both partners (both partner and actor effects). Moreover, the partner effects on cognitive decline (i.e., cognition slope) – our most important findings – also remain robust, revealing a significant association between a husband's lower education and a wife's more rapid cognitive decline, as well as an insignificant association between a wife's education and a husband's cognitive decline. However, the effect of one's own education on their cognitive decline (i.e., actor effect on the cognition slope) loses statistical significance in some cases when using these different coding methods for education. This is consistent with recent studies that have reported mixed evidence regarding the effect of an individual's education on their cognitive decline through individual-level analysis (e.g., Zahodne et al., 2015; Berggren et al., 2018).

7. Discussion

The current study examined the effect of spousal education on cognitive decline and the potential mediating roles of economic resources and health and social behaviors. Our results suggest that considering spousal education is crucial in explaining cognitive decline

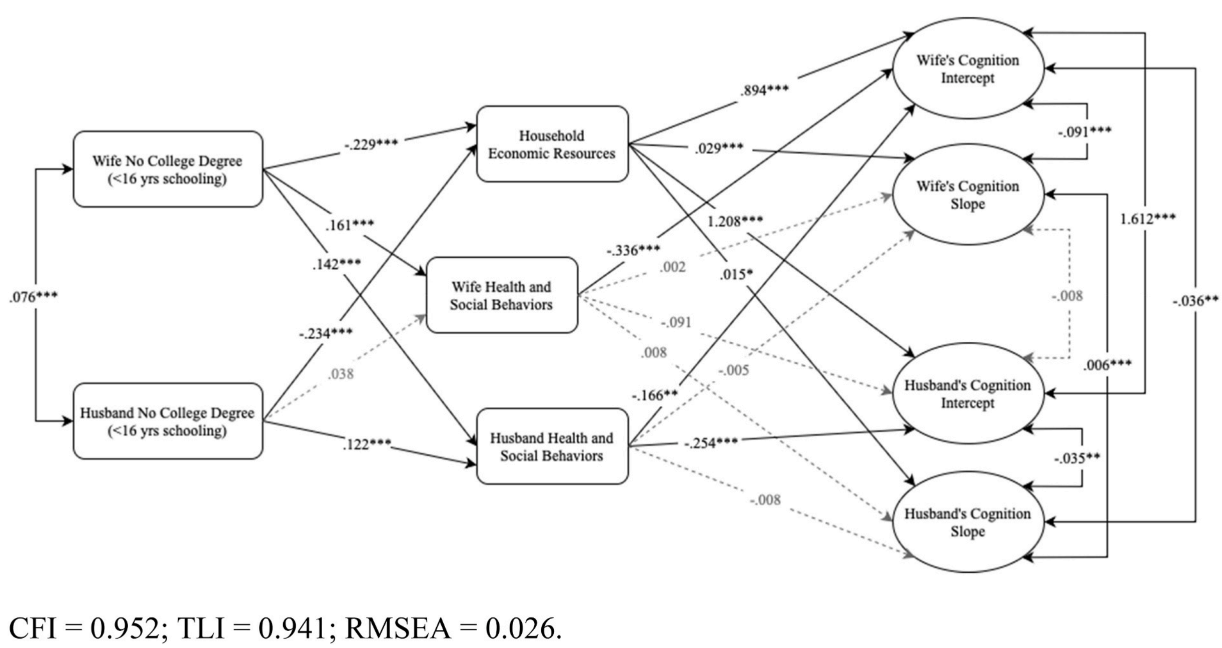

Fig. 2. Structural path diagram of APIM latent growth curve model to assess potential mediators of economic resources (at the household, or dyad, level) and health and social behaviors (at the individual level) through which spousal education may affect cognitive trajectories.
Note: ***p < .001, **p < .01, *p < .05. Unstandardized coefficients were presented due to binary exogenous variables. Model controlled for both partners' age, race-ethnicity, marital status, order of marriage, marital duration, parental status, having living siblings and self-rated health.

Table 2
Estimated indirect effects from spouses' No college degree to cognitive trajectories.

From Husband No College Degree to	Husband's Cognition Intercept			Wife's Cognition Intercept		
	Estimate	S.E.	P-Value	Estimate	S.E.	P-Value
Total	−0.317	0.029	0	−0.242	0.025	0
Household Economic Resources	−0.283	0.027	0	−0.209	0.023	0
Husband Health and Social Behaviors	−0.031	0.010	0.002	−0.020	0.008	0.017
Wife Health and Social Behaviors	−0.003	0.003	0.278	−0.013	0.008	0.089
From Wife No College Degree to	**Husband's Cognition Intercept**			**Wife's Cognition Intercept**		
	Estimate	S.E.	P-Value	Estimate	S.E.	P-Value
Total	−0.327	0.029	0	−0.283	0.028	0
Household Economic Resources	−0.277	0.027	0	−0.205	0.024	0
Husband Health and Social Behaviors	−0.036	0.011	0.001	−0.024	0.010	0.019
Wife Health and Social Behaviors	−0.015	0.010	0.141	−0.054	0.013	0
From Husband No College Degree to	**Husband's Cognition Slope**			**Wife's Cognition Slope**		
	Estimate	S.E.	P-Value	Estimate	S.E.	P-Value
Total	−0.004	0.002	0.007	−0.007	0.002	0
Household Economic Resources	−0.003	0.001	0.017	−0.007	0.002	0
Husband Health and Social Behaviors	−0.001	0.001	0.116	−0.001	0.001	0.357
Wife Health and Social Behaviors	0	0	0.218	0	0	0.689
From Wife No College Degree to	**Husband's Cognition Slope**			**Wife's Cognition Slope**		
	Estimate	S.E.	P-Value	Estimate	S.E.	P-Value
Total	−0.003	0.002	0.038	−0.007	0.002	0
Household Economic Resources	−0.003	0.001	0.017	−0.007	0.002	0
Husband Health and Social Behaviors	−0.001	0.001	0.116	−0.001	0.001	0.356
Wife Health and Social Behaviors	0.001	0.001	0.113	0	0.001	0.683

S.E.: Standard Errors.

among older couples. Below, we highlight some of the more prominent findings, their implications, and how they are aligned with previous research.

First, our results suggest that spousal education was related to cognition over time, extending previous research showing that an individual's education level shapes cognitive development across the life span (Alley et al., 2007; Lövdén et al., 2020; Meng and D'Arcy, 2012) to a dyadic context. In addition to replicating the individual-level finding that education levels were associated with an individual's own cognition, our findings that a spouse's education levels were also associated with both initial levels and changes in cognitive trajectories (Hypotheses 2a and 3a) provide a fascinating opportunity to examine why characteristics of close others might be associated with individual cognition. On the original 27-point TICS scale, the effects of education, both individual's own and spousal, were as large as a gain of 1.531 and 0.578 points, respectively, with a college degree. Given that most participants fell around the middle range of the scale, such gains carried forward over time may translate to many participants not meeting the threshold for cognitive impairment. Though these are the average effects—and some people benefitted more—the findings provide a major consideration to keep in mind when evaluating the effect sizes and the impact education has on individuals and their spouses.

In addition to the many explanations provided for why an individual's education might be beneficial for their own cognitive outcomes (e.g., health, cognitive stimulation), our results suggest a broader ecosystem in which individuals operate: education levels of other people, and most notably spouses, might enhance many opportunities to preserve cognitive health, including buttressing physical health and providing additional cognitive stimulation. Our findings of the interdependence of spouses' trajectories in cognition (Hypothesis 1) suggests that we cannot fully understand cognitive development in late life in a vacuum; we must consider a person's social environment. These findings provide a more precise description of how and why education within the couple system might enhance cognitive functioning across the lifespan. Moving forward, in characterizing the risk and resilience factors for late life cognitive ability, researchers and practitioners need to consider this underappreciated source of variation—a person's spouse.

Related, in the current study, we found that one of the main cognitive enhancements an educated spouse provides is better economic prospects (Hypotheses 2b and 3b). Economic prospects provide several benefits to spouses, particularly as they get older. Wealth accumulation serves as both a safety net (to protect individuals as they get older by providing easier access to preventative health resources) and also as an opportunity to stave off cognitive decline (by providing a larger number and wider variety of cognitively stimulating activities). The results with respect to health and social behaviors were a bit more mixed. Although there are many reasons to privilege greater social and physical health in late life (Banks et al., 2014; Hernandez et al., 2018; Murakami et al., 2017), the findings suggest that if the goal is enhanced cognition, it might be more beneficial for practitioners to target the salubrious benefits that come along with greater economic resources than to focus on health and social behaviors more explicitly. This could be particularly relevant to older adults who live in poverty and face economic challenges. Public policies and programs designed to bolster economic resources for older adults, especially those in poverty, may promote cognitive health within this vulnerable group.

Finally, there were some unexpected results in the current study, particularly around the influence of wives' education on husbands' outcomes. Wives' education was related to their husbands' *initial* levels of cognition but not to husbands' *rate of change* in cognitive trajectories. Although wives experienced particularly dramatic declines in cognition over time if their husbands had less than a college degree. Husbands, however, did not experience such a cognitive decline from their wives' lower education. This is contrary to our hypothesis as wives' education was largely unrelated to their husbands' cognitive decline.

Because of the null association of wives' education on husbands' cognitive changes, we also did not find support for Hypothesis 4, which expected that wives' education would predict their husbands' cognitive outcomes more strongly than husbands' education would predict that of their wives. However, we found evidence that wives' lower education was associated with their own and their husbands' poorer health and social behaviors, whereas husbands' education only predicted health and social behaviors for themselves but not for their wives. These findings suggest that, compared to husbands, wives may have stronger impacts on their spouses' cognition indirectly through health and social behaviors. Wives may have had stronger health and social behavior effects because, compared to men, women are more likely to regulate family health behavior, lend emotional support, and provide care within the family system (Liu and Waite, 2014; Simon, 2002; Kotwal et al., 2016). The current study illustrates the importance of modeling the effects of education on cognitive outcomes in a dyadic context, with a particular emphasis on the gendered effects and mechanisms linking individual and spousal education to cognition over time.

The primary extension of the present research is situating the education—cognition associations within a dyadic context by considering cross-partner associations. Our questions were motivated by some ambiguity from previous research about the direction, size, and significance of spousal education effects on cognition (Gilsanz et al., 2021; Saenz et al., 2020; Xu, 2020). The most relevant previous study is Xu (2020), which explored a question similar to ours using HRS data but employed a multi-level modeling approach with a few consequential assumptions about the education—cognition link, such as constraining some of the husbands' and wives' effects to be equal. We go beyond Xu's study (which only tested gender differences by using simple interaction terms) by specifically focusing on the *gendered* influence of education on cognition in a dyadic context. This included an examination of how the mechanistic processes varied between husbands and wives. We tested all these processes within one parsimonious model and found important insights about the gendered link between spousal education and cognitive outcomes, as we discussed above, which Xu (2020) failed to identify. Moreover, our mechanistic approach revealed that the education—cognition link operated more through economic resources and that there was some stronger evidence for wives affecting their husbands' social and health behaviors than vice versa. Further, our additional years of data (2000–2018), in comparison to Xu's study (1996–2012), provided a stronger and longer test of the impact of individual and spousal education on cognition. After the age of 65, the risk of Alzheimer's disease doubles every five years for individuals (Roy et al., 2023). Having additional information later in life was a major boon for modeling the impact of individual and spousal education on cognitive outcomes. Although Xu (2020) along with a few studies outside of the United States have provided an important first step in illustrating the importance of spousal education on cognition, our approach provides a more complete description of how and why spousal education is associated with cognition over time in a dyadic context and how different these patterns are for husbands and wives.

7.1. Limitations and future directions

The current study had many strengths. We had a large number of couples and were able to model both couple members' education, economic, and health and social behavior factors as predictors of cognitive trajectories across late life. Thus, we are among the few studies to examine the mechanisms linking spousal education to cognition over time. Likewise, using nationally representative longitudinal data allowed us to demonstrate a spouse's educational benefits to cognition over 18 years in a diverse sample of adult couples. Importantly, we demonstrated these effects over and above important sociodemographic, marital, and social covariates. Nevertheless, some limitations need to be acknowledged.

First, we did not exhaustively test all the possible mechanisms linking spousal education to cognition over time. For example, we hypothesized that spousal education would lead to many benefits—both financially and for health and social behaviors. Some mechanisms, like health and social behaviors, may have more immediate and clear implications for cognitive health. We assumed that enhanced financial resources would lead to other benefits, for example, access to quality health care and exposure to more stimulating cognitive activities (e.g., reading, community cultural events, and pursuing more educational opportunities). However, partly due to the limitations of using an existing data source, we did not formally model many of these processes, although there is support for these possibilities based on other research (Solomi and Casiday, 2017; van Nes et al., 2013). Further, there are likely additional mechanisms not modeled here, such as social support processes (e.g., different forms of emotional and instrumental support), biomedical risk processes (e.g., heightened risk for compromised health or chronic illness), or epigenetic mechanisms (e.g., epigenetic clocks). Future research should examine more proximate mechanisms linking spousal education to cognitive outcomes over time.

Second, although we controlled for several socio-demographic characteristics in our models (e.g., race/ethnicity, parental status, health), we did not thoroughly examine boundary conditions (i.e., moderators) of our proposed mechanistic processes. We chose to focus on sex differences in the effects of spousal education, given the extensive literature demonstrating the gendered effects of marriage on health across the lifespan (Liu and Waite, 2014). However, future research should pay particular attention to additional contextual variables that might alter the associations we studied here. For example, there is some evidence to suggest that African Americans do not benefit from educational attainment as greatly as White Americans with respect to health across life (Fuller-Rowell et al., 2015) and might even experience social *costs* in the process of matriculating (Fuller-Rowell and Doan, 2010). Likewise, other forms of minority stress might also attenuate the benefits of individual and spousal education on cognitive outcomes. In the current study, we focused primarily on different-sex couples. Future research should adopt a broader approach to see how the benefits of spousal education might differ among sexual and gender minority populations (Liu et al., 2021; Liu and Wilkinson, 2017).

Third, our measurement of cognition is constrained by the modified version of the TICS battery employed in the HRS, which can be administered either via telephone or face-to-face. The modified TICS is limited in terms of the number of cognitive domains it assesses and faces constraints, particularly when assessing older adults with hearing difficulties (de Jager et al., 2003). Nevertheless, the TICS exhibits a strong correlation with the Mini-Mental State Examination (MMSE), which is the most widely utilized instrument for evaluating global cognitive impairment (Fong et al., 2009). The cognitive measures in the HRS have demonstrated excellent sensitivity and specificity in distinguishing participants with Alzheimer's disease (AD) from those who are cognitively normal (Crimmins et al., 2011). Relatedly, our measures of social and health behaviors are also constrained by using dichotomous indicators. Additionally, the social activity measure solely includes socialization with neighbors or other people nearby, overlooking other social activities such as gathering with family who live far away and participating in volunteer activities.

Finally, individuals with higher cognitive function are more inclined to pursue college education, suggesting a possible reverse causality. Given the tendency for individuals to select partners with similar educational backgrounds, it is plausible that one's cognitive abilities may predict their spouse's level of education. This reverse causality has garnered increasing attention, particularly among health economists (e.g., Smith, 1999), and warrants consideration in future research studies.

8. Conclusion

Education is a frequently documented social determinant of cognitive functioning across the life course. Previous research has not dedicated adequate attention to how one spouse's educational attainment might affect cognitive functioning over time, despite evidence illustrating spouses' interconnected lives and health effects. We found that both wives' and husbands' education predicted better cognition among themselves and their spouses. Spousal education affected cognition primarily through enhanced economic resources, although there was some evidence that wives' education enhanced the health and social behaviors of both themselves and their husbands. The sex differences were a bit mixed, with husbands' education being more likely to affect their wives' cognitive decline over time rather than vice versa. Still, wives' education was more likely to affect their husbands' health and social behaviors. Examining associations between spousal education and cognitive outcomes in couples is an important illustration of how spouses have "linked lives"—such that the educational attainment of one spouse not only has implications for their own cognitive health but has the potential to shape the late-life quality of life and conditions of their spouse. Having insight into the mechanisms linking education to cognitive functioning in late life provides opportunities for couples-focused interventions and guiding policies to alleviate the adverse effects of educational disparities in the population.

CRediT authorship contribution statement

Hui Liu: Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **William J. Chopik:** Writing – review & editing, Writing – original draft. **M. Rosie Shrout:** Writing – review & editing. **Juwen Wang:** Formal analysis, Data curation.

Data availability

HRS is publicly available.

Appendix

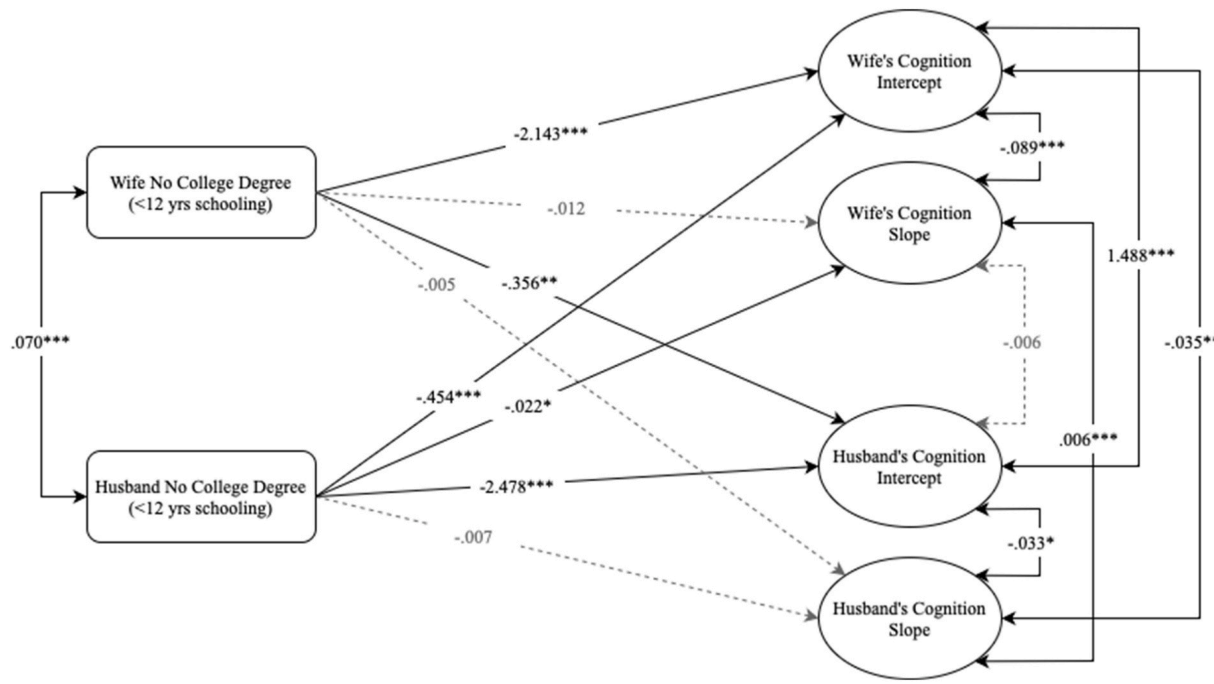

Fig. A1. Structural path diagram of APIM latent growth curve model to assess how wife's and husband's education (<12 years of schooling) is related to each other's cognitive trajectories.

Note: ***p < .001, **p < .01, *p < .05. Unstandardized coefficients were presented due to binary exogenous variables. Model controlled for both partners' age, race-ethnicity, marital status, order of marriage, marital duration, parental status, having living siblings and self-rated health.

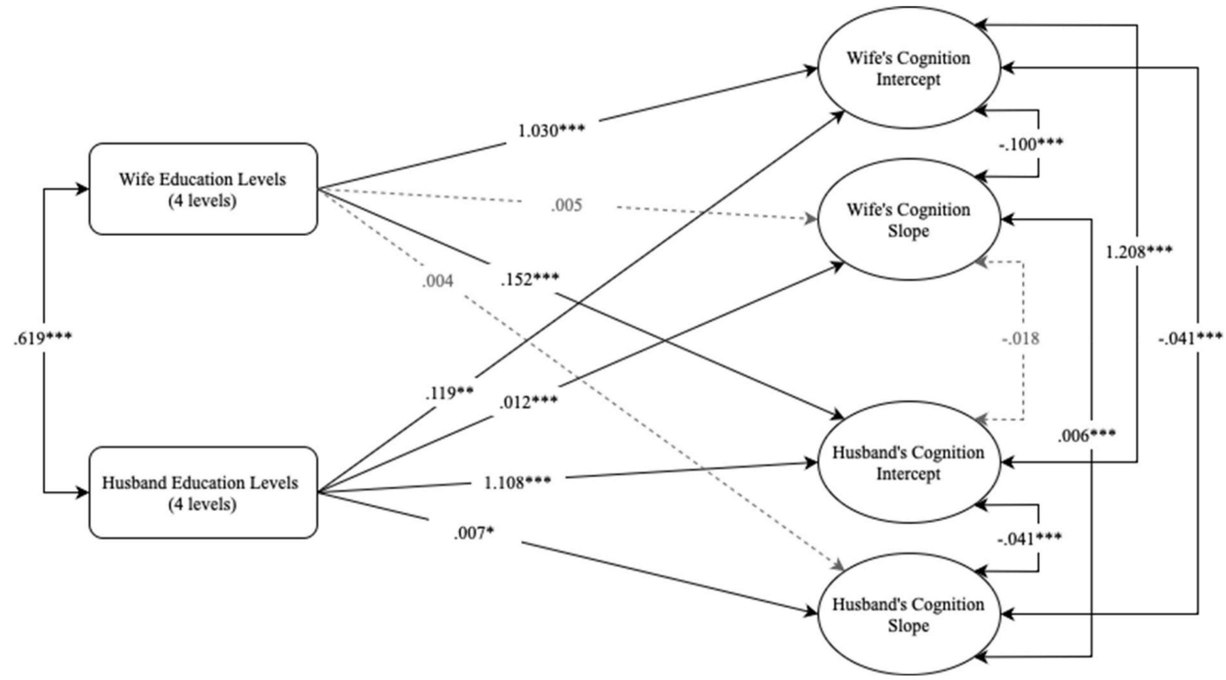

Fig. A2. Structural path diagram of APIM latent growth curve model to assess how wife's and husband's education (4 levels: 1=<less than high school, 2 = high school graduate, 3 = some college, 4 = college graduate) is related to each other's cognitive trajectories.
Note: ***p < .001, **p < .01, *p < .05. Unstandardized coefficients were presented due to binary exogenous variables.

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