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Rural/urban dwelling across the life-course and late-life cognitive ability in Mexico

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ABSTRACT

Background: Urban advantages in older adults' cognitive function have been observed. Less is known about early-life urban dwelling and late-life cognition. We evaluate how rural/urban dwelling throughout life and rural to urban shifts in life relate with cognition in Mexico, a country experiencing aging and urbanization.
Methods: Data came from the 2003 and 2012 Mexican Health and Aging Study (n = 12,238 adults age 50+). Early-life urban dwelling was self-reported. Late-life urban dwelling was based on population size of respondents' community of residence (community 2500+ people) at the time of survey. Cognitive function was measured across several cognitive tasks. We assess differences in baseline cognitive function and nine-year decline across groups using a latent change score model.
Results: Cross-sectionally, compared to always rural dwellers, rural-urban transitions were associated with cognitive benefits, though individuals residing in urban areas continuously through life exhibited the highest levels of cognitive function ($\beta = 0.89$, 95% CI: 0.83, 0.96) even after adjusting for SES, health, and health behaviors ($\beta = 0.28$, 95% CI: 0.22, 0.35). Longitudinally, always urban dwellers exhibited slower decline than always rural dwellers when adjusting for baseline cognition ($\beta = 0.11$, 95% CI: 0.03, 0.18), though faster decline when baseline cognition was not adjusted ($\beta = -0.11$, 95% CI: -0.18, −0.04). No differences were observed for cognitive change across comparison groups after adjusting for potential mechanisms.
Conclusions: Early- and late-life urban dwelling may result in cognitive advantages for older Mexican adults. Clinicians should consider where individuals resided throughout life to better understand a patient's likelihood of experiencing poor cognitive outcomes.

1. Introduction

Mexico experienced demographic shifts over the past century. The population age 65+ is projected to increase from 9.8 million in 2020 to 26.4 million in 2050 (United Nations, Department of Economic and Social Affairs, 2019). Population aging has been accompanied by a proliferation of research on factors influencing cognitive outcomes in late-life. Like other countries (Robbins et al., 2019), living in more urban areas in Mexico is positively related to late-life cognitive function. An "urban advantage" has been observed across several cognitive domains (Saenz et al., 2018a), in dementia incidence rates (Prince et al., 2012), prevalence of mild cognitive impairment (Arce Rentería et al., 2021), and years lived with cognitive impairment no dementia (CIND) and dementia (Garcia et al., 2020).

Urban advantages have been explained in part by urban areas facilitating access to health-promoting resources throughout life. Although there are health risks associated with urban-dwelling including ambient air pollution (Secretaría de Medio Ambiente y Recursos Naturales, 2014), sedentary lifestyles, and poor diet (Barquera et al., 2010; Ibarrola-Rivas and Galicia, 2017; Navarro-Meza et al., 2014; Uauy et al., 2001), urban dwelling provides key advantages. First, urban residents often have more educational opportunities than rural residents (Wong and Palloni, 2009). This is critical as education is closely related to cognitive functioning (Ritchie and Tucker-Drob, 2018) with benefits extending to lower dementia risk (Meng and D'Arcy, 2012; Stern, 2012). Educational differences may be key drivers of rural-urban cognitive

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disparities (Jia et al., 2014; Robbins et al., 2019; Saenz et al., 2018a).

Second, urban residence facilitates access to curative (Salinas et al., 2010) and preventive healthcare (Wong and Díaz, 2007). This potentially impacts how chronic conditions including diabetes and hypertension that influence cognitive outcomes (Deckers et al., 2015; Papademetriou, 2005) may be detected and controlled, which may put urban residents at an advantage.

Third, there are large differences in occupation profiles across rural and urban Mexico, with agricultural labor, which is often more precarious, playing a larger role in rural areas (ECLAC & ILO, 2016; Sanchez and Pacheco, 2012). Urban communities tend to have higher wages (Michaelsen and Haisken-DeNew, 2015) and better socioeconomic status (Sanchez and Pacheco, 2012), including higher levels of income and wealth, which have been associated with better cognitive function (Aguila and Casanova, 2020; Saenz et al., 2018a). Furthermore, urban areas have higher concentrations of skilled workers, more employer demand for skilled work, and a more diverse array of employment opportunities (Michaelsen and Haisken-DeNew, 2015) including specialized and cognitively stimulating jobs. Complex cognitively stimulating labor is related to better cognitive outcomes in mid and late-life (Andel et al., 2007) including in Mexico (Rodriguez and Saenz, 2021). Engagement in complex work may aid in building cognitive reserve to preserve cognitive function throughout life (Dekhtyar et al., 2015). Thus, differences in lifetime occupations across rural and urban areas may play a role in explaining urban advantages in cognitive function.

Last, although urban dwelling comes with higher exposure to outdoor air pollution, individuals in rural Mexico are more likely to rely on polluting cooking fuels (Hernández-Garduño et al., 2017). This may lead to exposure to household air pollution, which negatively impacts cognition in multiple countries (Krishnamoorthy et al., 2018; Qiu et al., 2019; Saenz et al., 2018b, 2021) and may contribute to rural/urban disparities in late-life cognitive function.

Current evidence for rural-urban differences in cognition among older adults generally focuses on late-life residence. Fewer have investigated residence in early-life or transitions between rural and urban areas (Cassarino et al., 2016; Wen and Gu, 2011; Xu et al., 2018; Zhang et al., 2008, 2018). Although urban residence facilitates access to health-promoting resources as mentioned above, these resources may be relevant at *different stages of life*. As education is an important mediator connecting urban dwelling to cognition, and schooling often takes place in early-life, rural/urban dwelling in *early-life* may more accurately reflect rural/urban disparities in educational achievement. Similarly, differences in employment opportunities and healthcare access indicate one must consider rural/urban-dwelling throughout the life-course including in mid to late-life.

The need to consider rural/urban-dwelling throughout life is amplified in Mexico where large rural to urban population shifts occurred over the past century. The population in rural areas decreased from 70% in 1921 to 23% by 2010. This was accelerated by industrialization as rural residents were drawn to urban areas by employment and housing opportunities (Sanchez and Pacheco, 2012) with community-level growth simultaneously pushing the number of cities higher (Garza, 1999). Thus, many current older adults in Mexico lived in rural areas in childhood but urban areas in late-life. How rural to urban shifts relate to cognition is worthy of consideration because these individuals may not have benefited from resources that urban areas provide in early-life but may benefit from access to diverse employment opportunities, healthcare, and clean cooking fuels in late-life. Although not all who shift from rural to urban areas do so through migration, individuals who migrate may have done so to pursue new labor opportunities associated with modernization and industrialization (Sanchez and Pacheco, 2012) and may be positively selected for higher education (Arizpe, 1981; Davis et al., 2002). This may lead to a "healthy immigrant" selection of rural to urban migrants.

We assess whether urban residence throughout life conveys advantages in cognitive function and how rural to urban shifts relate with late-life cognitive function in Mexico. Following prior work on rural/urban and socioeconomic disparities (Jiang and Wang, 2018; Torres et al., 2018), we frame our hypotheses through cumulative advantage/disadvantage theory, which theorizes that socioeconomic differentials in health will expand throughout life, resulting in wide late-life health differences (Crystal and Shea, 1990; Dannefer, 2020). In the context of our aims, we theorize that the advantages associated with urban dwelling (access to education, higher SES, favorable occupations, and health facilitating resources) will accumulate over the life-course as individuals continue to benefit from the rewards of urban dwelling. Conversely, disadvantages involved with rural dwelling (fewer educational opportunities, lower SES, and less access to healthcare) will similarly accumulate throughout life. Thus, this accumulation of advantages/disadvantages throughout life may result in older adults entering late-life with different levels of cognitive function according to their level of exposure to rural/urban residency throughout life.

Specifically, we first hypothesize that those living in urban areas throughout life will have the highest levels of cognitive function. Second, we hypothesize that shifts from rural to urban dwelling will result in favorable cognitive function levels relative to residing in rural areas throughout life. Third, we hypothesize that living in urban areas throughout life will result in slower cognitive decline. Fourth, we anticipate that rural to urban shifts will result in slower cognitive decline relative to those in rural areas throughout life.

2. Materials and methods

2.1. Data

We use the 2003 and 2012 waves of the Mexican Health and Aging Study (MHAS Mexican Health and Aging Study, 2012; Wong et al., 2017), a longitudinal study of older adults (age 50+) in Mexico and their spouses. The MHAS is nationally representative of older adults in rural/urban areas. The MHAS began in 2001 with 15,186 respondents. Follow-up interviews have been conducted in 2003, 2012, 2015, and 2018. We evaluate cognitive change between 2003 and 2012 because early-life rural/urban dwelling was only assessed in the 2003 wave. This allows us to investigate cognitive decline over nine years and prevents studying cognitive decline over irregularly spaced intervals (9-year interval from 2003 to 2012 versus 3-year intervals after 2012).

Starting with 13,704 respondents in 2003, we eliminate 840 age ineligible respondents age$<$50. Although early-life rural/urban dwelling was assessed in the 2003 wave, rural/urban dwelling in *late*-life was based on one's community of residence in the 2001 wave of the MHAS. To ensure that rural/urban dwelling in 2001 was still valid in our baseline (2003), we exclude respondents who we could not confirm were living at the same address in the 2001 and 2003 waves. This involved excluding respondents who do not report living at the same address in 2001 and 2003 or report living at their current address for less than 11 years in the 2012 wave ($n = 626$). The final analytic sample included 12,238 respondents with 8509 (69.5%) reinterviewed in 2012; 2498 (20.4%) deceased by 2012, and 1231 (10.1%) lost to follow-up. Comparisons of those reinterviewed versus not reinterviewed in 2012 (deceased or lost to follow-up) demonstrated that, relative to those who were reinterviewed in 2012, those not reinterviewed had worse baseline cognition, higher age, higher early-life SES, less wealth, more chronic conditions, were more likely to be male, unmarried, have health insurance, cook with gas, have ever smoked, not exercise, and have lived in a rural area throughout life. Regression analyses used full information maximum likelihood estimation (FIML), allowing the inclusion of all 12,238 respondents including incomplete cases. We used FIML instead of employing listwise deletion and using only complete cases because FIML substantially reduces biases associated with missing data such as selective attrition and mortality (Enders, 2010).

2.2. Rural and urban dwelling

Measures. *Early-life* rural/urban was assessed by asking “when you were living with your parents, was your residence in a 1) more urban area, 2) more rural area.” *Late-life* rural/urban was assessed using the size of a respondent’s community of residence. We consider those in communities with <2500 persons as rural based on administrative definitions of rural areas in Mexico. We identified four groups based on patterns of rural/urban dwelling throughout life: 1) urban area in early- and late-life (hereafter “urban-urban," $n = 4268$); 2) urban in early-life and rural in late-life (hereafter “urban-rural," $n = 137$); 3) rural in early-life and urban in late-life (hereafter “rural-urban," $n = 4980$); and 4) rural in early and late-life (hereafter “rural-rural," $n = 1789$). We used the “rural-rural” group as the reference as all other groups report some degree of urban dwelling in life.

Validation of early-life rural/urban dwelling. Self-reported early-life rural/urban dwelling is subjective and subject to recall bias. To evaluate convergent validity of self-report, we compare reports to other characteristics before age 10 consistent with living in a rural/urban community. Compared to early-life urban residents, respondents reporting early-life rural dwelling were more likely to report not having household electricity in childhood (86.9% vs. 42.2%); not having an in-home toilet in childhood (89.4% vs. 46.1%); and having a father who worked in agriculture (83.3% vs. 29.1%). These are consistent with observed historic disparities in household resources and differences in labor across rural and urban Mexico (Gutiérrez de MacGregor, 2003; Masera et al., 1993). There was also high concordance between early- and late-life rural/urban reports among respondents living in the same community they were born ($n = 4716$). Among always rural dwellers, only 23.8% currently resided in a community with 100,000+ inhabitants, whereas 75.2% currently resided in a community with <100,000 inhabitants. These expected differences provide evidence for convergent validity of the self-reported measure.

2.3. Cognitive function

We measure cognitive function through respondents’ performance on multiple cognitive tasks spanning several cognitive domains including memory, attention, visuospatial ability, and orientation. Cognitive tasks came from the Cross-Cultural Cognitive Examination (Glosser et al., 1993; Wolfe et al., 1992), which was chosen as the items do not rely on literacy or mathematical skills, which is necessary in populations with limited formal education. Memory tasks included Verbal Learning (average number of words recalled from an eight-word list across three trials, range: 0–8) and Verbal Recall (delayed recall of eight-word list, range: 0–8). Visual Scanning (identification of stimulus in visual array of stimuli, range: 0–60) was included as an attention task. Visuospatial (copying a figure, range: 0–2) and Visual Memory (delayed recall of figure, range: 0–2) tasks captured respondents’ visuospatial ability. Orientation was assessed through identification of the day, month, and year, range: 0–3). Respondents completed tasks in 2003 and 2012, but Visuospatial and Visual Memory tasks were each scored 0–6 in 2012.

2.4. Control variables

Confounders. We included items pertaining to life before age 10 that were intended to capture early-life SES. Respondents reported if, before age 10, they 1) had an in-home toilet (reverse coded); 2) went to bed hungry; 3) wore shoes regularly (reverse coded); 4) had siblings who dropped out of school to help parents; 5) had family members sleep in the same room used for cooking; and 6) received help due to economic problems. These items were summed to create a measure of early-life SES (range 0–6) in which higher numbers indicated lower early-life SES. These items have been used to assess early-life SES in prior studies (Grimard et al., 2010). Basic demographic confounders included married/partnered, age, and gender.

Potential Mechanisms. Several variables capture urban advantage mechanisms. For early-life, we included years of education. For midlife, occupation was the main job worked in life reported in 2001 (white-collar, blue-collar, agricultural/fishery/forestry work, and not reporting an occupation or never working) (Wong and DeGraff, 2009). Although we would ideally know more about cognitive demands surrounding work activities, white/blue collar classifications have been used to proxy occupational differences in cognitive demand in prior studies (Ihle et al., 2020; Opdebeeck et al., 2015). Late-life SES was measured as income (monthly income from various sources), household wealth (money in accounts and stocks, real estate, vehicles, and businesses), and health-care access (having right to medical attention) in 2003. Income/wealth values were imputed by the MHAS (Wong et al., 2016) and categorized into deciles.

We captured health/health behavior in 2003 using chronic condition count (diabetes, hypertension, stroke, heart attack, respiratory illness, and cancer), ever/never smoking, and exercise (whether respondent exercised or did hard physical work three or more times a week on average in past two years). We included primary cooking fuel in 2003 to proxy household air pollution from polluting cooking fuels, categorized as wood/coal versus gas.

2.5. Analysis

We used latent change score (LCS) models to test how rural/urban dwelling throughout life related to cognitive function. The LCS model (Ferrer and McArdle, 2003; McArdle, 2009) is a structural equation model tool to assess change in a latent variable. Measurement invariance was tested to ensure latent cognitive function had the same meaning across waves. Model fit was compared in three models (configural, metric, and scalar invariance) and decreases in the comparative fit index (CFI) of >0.01 indicated non-invariance (Cheung and Rensvold, 2002) following prior studies (Li et al., 2014; Oschwald et al., 2019; Shigemoto, 2020). Factor loadings/intercepts for Visuospatial and Visual Memory were freely estimated across waves *a priori* given scoring changes. We established partial scalar invariance by further freely estimating Verbal Learning intercepts across time.

The LCS is diagramed in Fig. 1. Dependent variables of interest include “Cognition T1” (*baseline* [2003] cognitive function) and “Δ Cognition” (*change* in cognitive function 2003–2012). Differences in cognitive function by rural/urban dwelling groups were tested using paths from “urban-urban," “urban-rural," and “rural-urban” to dependent variables. Coefficients represent differences relative to the “rural-rural." First, models included paths from confounding variables to dependent variables. Second, we added paths from potential mechanisms (education, income, wealth, health insurance, occupation, fuel use, smoking, and exercise) to dependent variables. We mean-center independent variables, and center observed cognitive variables at 2003 means. LCS models often include regressions of change on initial levels of dependent variables (“β” in Fig. 1), capturing dependence of change on initial level. Controversy exists regarding adjustment for baseline cognition in analyses of change (Glymour et al., 2005) with potential effects on conclusions (Grønkjær et al., 2019). We estimate models “adjusted” (specifying regressions of Δ Cognition on Time 1 Cognition) and “unadjusted” for baseline function (specifying co-variances between Δ Cognition and Time 1 Cognition) (Kievit et al., 2018).

Models were estimated with robust standard errors in the R lavaan package (Rosseel, 2012). Model fit was evaluated using the Root Mean Square Error of Approximation (RMSEA) and CFI. Values below 0.08 and above 0.90, respectively, indicate acceptable model fit.

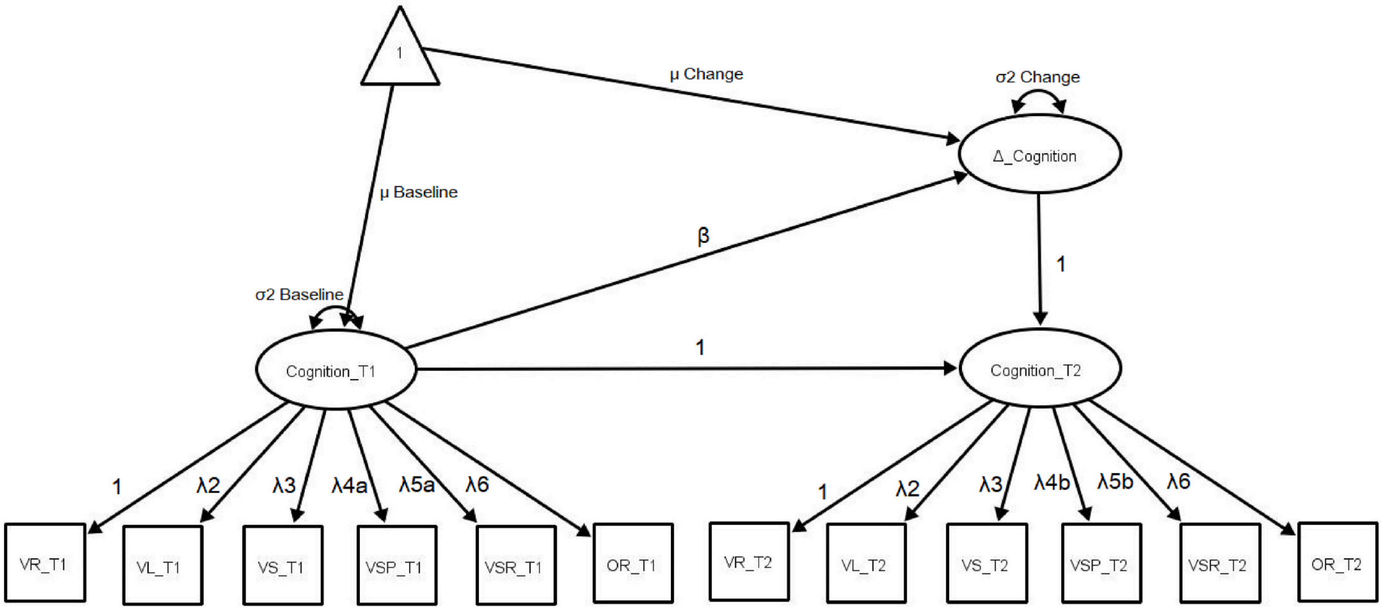

Fig. 1. Diagram of the latent change score (LCS) model
Note: VR – Verbal Recall; VL – Verbal Learning; VS – Visual Scanning; VSP – Visuospatial; VSR – Visual Memory; OR – Orientation. T1 represents 2003. T2 represents 2012. Factor loadings are indicated by λ, variances are indicated by σ2, and means are indicated by μ. Factor loadings for Verbal Recall were fixed to 1 and Verbal Learning, Visual Scanning, and Orientation loadings were constrained to equality for Times 1 & 2 whereas Visuospatial and Visual Memory loadings were freely estimated. Intercepts were fixed to zero for Verbal Recall and constrained to equality in Times 1 & 2 for Visual Scanning and Orientation whereas Visuospatial, Visual Memory, and Verbal Learning intercepts were freely estimated for Times 1 & 2. β indicates a directional effect from Time 1 Cognition to Cognitive Change. Models "adjusted" for baseline cognition include this as a regression whereas those "unadjusted" for baseline cognition specify this association as a covariance.

3. Results

3.1. Descriptive results

Table 1 shows characteristics of the life-course rural/urban groups. The most prevalent group was the rural-urban (weighted: 41.4%), followed by urban-urban (32.0%), rural-rural (25.1%), with few (1.5%) in the urban-rural group. The urban-urban group performed best across cognitive tasks whereas the rural-rural group had the lowest mean scores. Relative to the rural-rural, the rural-urban group performed better across tasks. Similar patterns of rural/urban differentials in cognitive function were observed in summary cognitive function factor scores at both baseline and follow-up. The urban-urban group reported the fewest low early-life SES markers (1.2) and the highest education (7.1 years) whereas the rural-rural group reported the most low early-life SES markers (3.0) and lowest education (1.7 years). The rural-rural group was over-represented in agricultural occupations, had lower income/wealth, and was least likely to have healthcare access. The urban-urban group, generally, enjoyed the most favorable levels of each of these variables.

3.2. LCS results

Table 2 presents results of LCS models, which simultaneously estimate the effects of variables on both baseline cognitive function and cognitive change. Panel 1 shows the effects of each variable on baseline cognition. Panel 2 describes cognitive change and the effects of variables on change. Negative parameters indicate lower baseline cognitive function or more rapid cognitive decline. Models 1-2 adjusted for baseline cognitive function. In Model 1, relative to the rural-rural group, the urban-urban had the highest baseline cognitive function ($\beta = 0.89$, 95% Confidence Interval (CI): 0.83, 0.96), followed by the rural-urban ($\beta = 0.38$, 95% CI: 0.32, 0.44), with urban-rural exhibiting advantages relative to the rural-rural group ($\beta = 0.22$, 95% CI: 0.03, 0.41). Regarding cognitive change, the urban-urban group exhibited a slower cognitive decline in Model 1 ($\beta = 0.11$, 95% CI: 0.03, 0.18) but no other group differed from the rural-rural group. Those starting with better cognitive function tended to experience faster cognitive decline ($\beta = -0.25$, 95% CI: 0.29, −0.21).

In Model 2, baseline cognition differences were smaller across groups, suggesting potential mechanisms may explain a portion of urban advantages. The urban-urban ($\beta = 0.28$, 95% CI: 0.22, 0.35) and rural-urban ($\beta = 0.09$, 95% CI: 0.03–0.15) groups still had better baseline cognition than the rural-rural. Differences in cognitive decline were not observed after adjusting for potential mechanisms.

Models 3–4 were unadjusted for baseline cognitive function. Whereas associations between variables and baseline function do not differ, associations between variables and change differ across adjusted/unadjusted models. Comparing models including only confounding variables (Models 1 & 3), contrary to the model adjusting for baseline function (Model 1) which indicated that the urban-urban group had slower cognitive decline relative to the rural-rural group, the model unadjusted for baseline function (Model 3) indicated the urban-urban group experienced a *faster* cognitive decline ($\beta = -0.11$, 95% CI: -0.18, −0.04). When potential mechanisms were included (Models 2 & 4), both models found no difference in cognitive decline across groups.

4. Discussion

Rural/urban areas exhibit disparities in access to health-promoting resources across the life course (Salinas et al., 2010; Sanchez and Pacheco, 2012; Wong and Palloni, 2009), which may extend to cognitive aging (Arce Rentería et al., 2021; Garcia et al., 2020; Prince et al., 2012; Saenz et al., 2018a). Whereas most evidence comes from differences by *late-life* residence, we find that this may not fully characterize rural/-urban disparities. Rather, urban dwelling in *early-life* adds to our understanding of urban advantages in cognitive function.

Table 1
Cognitive, sociodemographic, and health characteristics of older Mexican adults (Age 50+) from the 2003 and 2012 Mexican Health and Aging Study by rural/urban dwelling throughout life (n = 11,174).

	Urban, Urban (n = 4268)		Urban, Rural (n = 137)		Rural, Urban (n = 4980)		Rural, Rural (n = 1789)		
Cognitive Function	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Sig.*
Verbal Learning	4.8	1.4	4.0	1.4	4.0	1.4	3.5	1.3	***
Verbal Recall	4.7	1.8	3.9	1.8	4.0	1.8	3.4	1.8	***
Visual Scanning	30.6	15.4	18.5	12.2	21.4	14.0	16.3	12.5	***
Orientation	2.6	0.7	2.2	0.9	2.4	0.9	2.1	1.0	***
Visuospatial	1.8	0.5	1.6	0.6	1.5	0.7	1.4	0.8	***
Visual Recall	0.9	0.8	0.5	0.6	0.6	0.8	0.5	0.7	***
Time 1 Summary Cognitive Score	0.4	0.9	−0.3	1.0	−0.3	1.0	−0.6	0.9	***
Time 2 Summary Cognitive Score	0.0	0.9	−0.6	0.9	−0.5	0.9	−0.8	0.8	***
Demographics									
Age	63.4	8.9	64.6	9.9	64.7	9.1	65.1	9.5	
Female (n, %)	2461	55.6	75	57.9	2844	56.6	906	50.9	***
Married/Partnered (n, %)	2937	65.4	100	74.4	3351	65.4	1338	71.8	***
Low Early-Life SES Markers	1.2	1.4	2.1	1.4	2.4	1.4	3.0	1.4	***
Years of Education	7.1	4.8	2.6	3.2	3.0	3.3	1.7	2.1	***
Primary Occupation									
White Collar (n, %)	1155	27.8	11	3.6	402	7.7	22	1.1	***
Blue Collar (n, %)	2315	55.9	50	31.6	2855	56.6	420	22.2	
Agricultural (n, %)	130	3.3	41	33.6	700	15.4	928	55.1	
Missing/Never Worked (n, %)	668	13.0	35	31.2	1023	20.2	419	21.6	
Primary Cooking Fuel									
Gas (n, %)	4123	97.0	95	71.6	4576	92.1	986	46.8	**
Wood/Coal (n, %)	123	3.0	42	28.4	378	8.0	793	53.2	
Late-Life SES									
Income Decile	4.8	3.0	4.3	3.1	4.1	2.8	3.6	2.4	***
Wealth Decile	4.9	3.0	4.0	3.0	4.2	2.7	3.5	2.6	***
Health									
Chronic Condition Count	0.8	0.9	1.1	0.9	0.9	0.9	0.7	0.9	***
Ever Smoked (n, %)	1884	43.7	62	40.9	2022	38.3	762	34.4	**
Healthcare Access (n, %)	3303	74.1	68	43.0	3243	60.6	640	29.3	***
Exercise (n, %)	1409	30.3	59	42.7	1761	33.2	798	47.4	***

Note: Authors' own calculations using data from the 2003 and 2012 Mexican Health and Aging Study. Sample size for variables differ due to missing data. "Sig" column indicates whether differences in variables were significant across the four groups. Summary cognitive scores are factor scores, estimated using the cognitive tasks from both times, which often have variances which differ from estimated factor models. Differences were tested using ANOVA for continuous variables and chi-square tests for categorical variables. Percentages, standard deviations, and means apply sampling weights. * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

4.1. Life course rural/urban dwelling and level of cognitive function

Consistent with our first hypothesis, we observed the highest levels of cognitive function among those spending their entire lives in urban areas and the lowest levels among those spending their entire lives in rural areas. This agrees with work in India finding the most favorable cognitive outcomes among those living in urban areas across life (Xu et al., 2018). This may be due to health-promoting resources in urban areas resulting in a cumulative advantage. Individuals in urban areas in early-life likely had greater educational access and quality of education. Individuals remaining in urban areas may have been better positioned to turn education into favorable employment. Greater availability of healthcare in urban settings (Salinas et al., 2010; Wong and Díaz, 2007) may have helped to prevent, treat, and manage chronic illnesses whereas greater access to clean cooking fuels in urban areas (Hernández-Garduño et al., 2017) may have reduced one's likelihood of exposure to household air pollution. These may be important factors explaining advantages given associations between occupation (Andel et al., 2007; Rodriguez and Saenz, 2021), chronic illness (Deckers et al., 2015; Papademetriou, 2005), and household air pollution (Krishnamoorthy et al., 2018; Qiu et al., 2019; Saenz et al., 2018b), and cognition. Urban advantages, especially for early-life urban dwelling, may also stem from benefits respondents gained from parental resources in early-life such as better education, high-paying jobs, and healthy lifestyles.

Consistent with our second hypothesis, rural to urban shifts were associated with better late-life cognitive function levels compared to those remaining in rural areas. Past studies frame this as a "healthy migrant" effect of rural to urban migration (Cassarino et al., 2016; Xie et al., 2020; Xu et al., 2017) whereby individuals may be positively selected for education and drive to migrate. Although selection is certainly relevant, individuals who changed from rural to urban residence may also benefit from gaining access to resources available in urban areas. Changing from rural to urban residence may also reflect community-level development even if individuals do not move. In this case, the cognitive advantages of the rural-urban group may be explained by expansions in health-promoting resources available in growing communities.

4.2. Life-course rural/urban dwelling and cognitive decline

We find mixed evidence for our third hypothesis, that living in urban areas throughout life would result in slower cognitive decline. Results depended on adjustment for baseline cognition. Models adjusting for baseline function found advantages for the urban-urban (relative to the rural-rural) whereas models unadjusted for baseline function indicated disadvantages for the urban-urban. Similar results have been reported for the effects of education on cognitive decline (Grønkjær et al., 2019). One explanation for faster decline among urban-urban dwellers is that these older adults may have greater cognitive reserve than rural residents due to their cumulative advantages (Stern, 2002; Tucker and Stern, 2011). Cognitive reserve is important to maintaining cognitive function in old age (Roe et al., 2007; Zahodne et al., 2011), but older adults with a high reserve can experience accelerated decline once reserves are depleted (Mungas et al., 2018).

Careful consideration should be given to adjustment for baseline

Table 2
Effects of variables on baseline cognitive function and 9-year cognitive change estimated from latent change score models among older Mexican adults (n = 12,238).

	Adjusted for Baseline Cognition		Unadjusted for Baseline Cognition	
	Model 1	Model 2	Model 3	Model 4
PANEL 1. Baseline Cognition	*β (95% CI)*	*β (95% CI)*	*β (95% CI)*	*β (95% CI)*
Mean Baseline Cognition (Intercept)	−0.08 (−0.11, −0.05)***	−0.09 (−0.11, −0.06)***	−0.08 (−0.11, −0.05)***	−0.09 (−0.11, −0.06)***
Variance of Baseline Cognition (Intercept)	0.70 (0.66, 0.75)***	0.45 (0.42, 0.49)***	0.70 (0.66, 0.75)***	0.45 (0.42, 0.49)***
Effects of Variables on Baseline Cognition				
Urban-Urban (Ref: Rural-Rural)	0.89 (0.83, 0.96)***	0.28 (0.22, 0.35)***	0.89 (0.83, 0.96)***	0.28 (0.22, 0.35)***
Urban-Rural (Ref: Rural-Rural)	0.22 (0.03, 0.41)*	0.05 (−0.11, 0.22)	0.22 (0.03, 0.41)*	0.05 (−0.11, 0.22)
Rural-Urban (Ref: Rural-Rural)	0.38 (0.32, 0.44)***	0.09 (0.03, 0.15)**	0.38 (0.32, 0.44)***	0.09 (0.03, 0.15)**
Age	−0.06 (−0.06, −0.06)***	−0.05 (−0.05, −0.04)***	−0.06 (−0.06, −0.06)***	−0.05 (−0.05, −0.04)***
Female	−0.17 (−0.21, −0.13)***	0.05 (0.00, 0.10)*	−0.17 (−0.21, −0.13)***	0.05 (0.00, 0.10)*
Married/Partnered	0.07 (0.03, 0.12)**	0.08 (0.03, 0.12)***	0.07 (0.03, 0.12)**	0.08 (0.03, 0.12)***
Low Early-Life SES Markers	−0.16 (−0.18, −0.15)***	−0.05 (−0.06, −0.03)***	−0.16 (−0.18, −0.15)***	−0.05 (−0.06, −0.03)***
Years of Education		0.11 (0.10, 0.11)***		0.11 (0.10, 0.11)***
Blue Collar Occupation (Ref: White Collar)		−0.03 (−0.09, 0.03)		−0.03 (−0.09, 0.03)
Agricultural Occupation (Ref: White Collar)		−0.12 (−0.21, −0.04)**		−0.12 (−0.21, −0.04)**
Missing Occupation/ Never Work (Ref: White Collar)		−0.13 (−0.21, −0.06)***		−0.13 (−0.21, −0.06)***
Household Air Pollution (Ref: No)		−0.29 (−0.35, −0.23)***		−0.29 (−0.35, −0.23)***
Income Decile		0.02 (0.01, 0.02)***		0.02 (0.01, 0.02)***
Wealth Decile		0.02 (0.01, 0.02)***		0.02 (0.01, 0.02)***
Chronic Condition Count		−0.03 (−0.05, −0.01)**		−0.03 (−0.05, −0.01)**
Ever Smoked		0.08 (0.04, 0.12)***		0.08 (0.04, 0.12)***
Healthcare Access		0.13 (0.09, 0.17)***		0.13 (0.09, 0.17)***
Exercise		0.08 (0.05, 0.12)***		0.08 (0.05, 0.12)***
PANEL 2. Cognitive Change				
Mean Cognitive Change (Slope)	−0.39 (−0.42, −0.36)***	−0.37 (−0.40, −0.34)***	−0.37 (−0.40, −0.34)***	−0.34 (−0.37, −0.31)***
Variance of Cognitive Change (Slope)	0.26 (0.23, 0.30)***	0.23 (0.20, 0.26)***	0.31 (0.26, 0.35)***	0.29 (0.25, 0.33)***
Effects of Variables on Cognitive Change				
Urban-Urban (Ref: Rural-Rural)	0.11 (0.03, 0.18)**	0.02 (−0.05, 0.10)	−0.11 (−0.18, −0.04)**	−0.08 (−0.16, 0.01)
Urban-Rural (Ref: Rural-Rural)	−0.04 (−0.22, 0.14)	−0.06 (−0.23, 0.11)	−0.10 (−0.29, 0.10)	−0.08 (−0.27, 0.10)
Rural-Urban (Ref: Rural-Rural)	0.04 (−0.02, 0.10)	0.01 (−0.06, 0.08)	−0.05 (−0.12, 0.01)	−0.02 (−0.09, 0.05)
Age	−0.03 (−0.03, −0.03)***	−0.03 (−0.03, −0.02)***	−0.01 (−0.02, −0.01)***	−0.01 (−0.01, −0.01)***
Female	0.04 (−0.01, 0.08)	0.08 (0.02, 0.13)**	0.08 (0.03, 0.13)***	0.06 (0.00, 0.12)
Married/Partnered	0.06 (0.01, 0.11)*	0.08 (0.04, 0.13)***	0.04 (−0.01, 0.10)	0.06 (0.00, 0.11)*
Low Early-Life SES Markers	−0.01 (−0.03, 0.01)	0.01 (−0.01, 0.02)	0.03 (0.01, 0.05)***	0.03 (0.01, 0.04)**
Time 1 Cognition (Regression in Model 1–2, Covariance in Models 3–4)	−0.25 (−0.29, −0.21)***	−0.36 (−0.40, −0.31)***	−0.17 (−0.21, −0.14)***	−0.16 (−0.19, −0.13)***
Years of Education		0.04 (0.03, 0.04)***		0.00 (−0.01, 0.01)
Blue Collar Occupation (Ref: White Collar)		−0.02 (−0.09, 0.04)		−0.01 (−0.09, 0.06)
Agricultural Occupation (Ref: White Collar)		−0.11 (−0.21, −0.02)*		−0.07 (−0.17, 0.03)
Missing Occupation/ Never Work (Ref: White Collar)		−0.08 (−0.16, −0.01)*		−0.03 (−0.12, 0.05)
Household Air Pollution (Ref: No)		−0.03 (−0.10, 0.04)		0.07 (0.00, 0.15)
Income Decile		0.00 (0.00, 0.01)		0.00 (−0.01, 0.01)
Wealth Decile		0.00 (0.00, 0.01)		0.00 (−0.01, 0.01)
Chronic Condition Count		−0.05 (−0.07, −0.02)***		−0.04 (−0.06, −0.01)**
Ever Smoked		−0.01 (−0.06, 0.03)		−0.04 (−0.09, 0.01)
Healthcare Access		0.00 (−0.04, 0.04)		−0.04 (−0.09, 0.00)
Exercise		0.00 (−0.04, 0.04)		−0.03 (−0.08, 0.01)

Note: Authors' own calculation using the 2003 and 2012 Mexican Health and Aging Study. Model 1 (RMSEA: 0.043; CFI: 0.950), Model 2 (RMSEA: 0.033; CFI: 0.968), Model 3 (RMSEA: 0.043; CFI: 0.950), Model 4 (RMSEA: 0.033; CFI: 0.968). "Time 1 Cognition" represents a regression in Models 1–2 (change in cognition regressed on Time 1 cognition) whereas "Time 1 Cognition" indicates a covariance (between change in cognition and Time 1 cognition) in Models 3–4. Household air pollution proxied by primarily using wood or coal for cooking versus gas. * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

cognition when examining cognitive decline (Glymour et al., 2005). Grønkjær and colleagues (2019) point to theoretical directions of association between baseline cognitive function and exposures. If baseline function is *caused* by exposures, unadjusted analyses are preferred. Urban dwelling throughout life may influence baseline function in several ways (access to cognition promoting resources throughout life). However, if exposures are caused by baseline function, adjusted results are preferred. Individuals with high cognitive function may be better positioned to seek urban areas for employment, healthcare, and other amenities. Given underlying theories of beneficial urban dwelling effects (Garcia et al., 2020; Jia et al., 2014; Prince et al., 2012; Robbins et al., 2019; Saenz et al., 2018a), faster decline among individuals with high cognitive reserve (Mungas et al., 2018), and potential biases from baseline adjustment (Glymour et al., 2005) we cautiously favor results unadjusted for baseline cognitive function. However, more research is needed.

We found no support for our fourth hypothesis, that rural to urban shifts would be related with slower cognitive decline relative to those always in rural areas. This may be because the resources that individuals gain from shifting from a rural to an urban area, although associated with levels of cognitive function, were not consistently associated with *change* in cognitive function in our analysis. For instance, individuals who shifted from rural to urban areas may have enjoyed better SES (Sanchez and Pacheco, 2012) yet our findings showed that important SES markers (income, wealth, and healthcare access) were not related with cognitive decline in our sample. This is consistent with prior studies reporting larger socioeconomic advantages in cognitive function cross-sectionally than longitudinally (Aartsen et al., 2019; Wilson et al., 2004; Yang et al., 2016; Zahodne et al., 2011).

4.3. Limitations

This analysis comes with limitations. First, although we tested the convergent validity of self-reported early-life rural/urban dwelling, the measure is subjective and subject to recall error. Individuals differ in their conceptualizations of what constitutes an "urban" area, which may differ across relevant dimensions (birth cohort and degree of urbanization in one's community and surrounding communities). Future studies should use administrative data to gain a comprehensive picture of urbanization in childhood communities. Second, although we hypothesize that urban communities may provide access to health-promoting resources, actual community-level resources are unobserved. Future work should assess relevant characteristics (number of schools, healthcare facilities, and employment types) to better capture the role of community-level resources. Third, although we included measures of cognition spanning memory, attention, visuospatial ability, and orientation, cognitive domains such as executive function and language ability were not assessed in the 2003 MHAS. We were limited to this time period because early-life urban dwelling was only assessed in 2003. Nevertheless, future work should evaluate rural/urban disparities in cognitive function using more comprehensive cognitive batteries with measures of language and executive function. Fourth, even though we measured cognitive function using tasks that do not require literacy or mathematical skills, which should limit bias associated with education, it is possible that individuals with more schooling may be more familiar and comfortable with cognitive testing. This could lead to potential educational biases in our cognitive measures. Fifth, our occupation measure was based on categories of workers that are unlikely to align perfectly with cognitive demand or complexity of work. Future studies should incorporate nuanced analyses incorporating mental demand and complexity of work to answer whether these factors explain urban advantages in cognitive function. Nevertheless, we note that even our occupation classification of blue collar, white collar, and agricultural workers exceeds what many studies have included, making this an important contribution of our study. Last, around 30% of baseline respondents were not reinterviewed in 2012 due to mortality or lost to follow up. We used FIML estimation, using all available data to reduce bias from missing data (Enders, 2010). However, selective attrition and mortality may still bias our parameter estimates. Future studies should aim to reduce lost to follow up and test how much attrition may affect observed differences across rural/urban groups.

4.4. Conclusions

We observed disparities in cognitive function across rural and urban areas but our findings suggest disparities may be explained, in part, by socioeconomic benefits associated with urban dwelling. Differences in baseline cognitive function across rural/urban groups declined when we adjusted for potential mechanisms, and no differences in cognitive decline were observed after these adjustments were made. Many potential mechanisms added throughout models (education, occupation, healthcare, and cooking fuels) represent *modifiable* factors. Policy efforts aimed at improving access to education, cognitively stimulating activity, healthcare, and clean cooking fuels in rural areas may improve cognitive health in rural areas and result in a more equitable society.

Ethics approval

The Mexican Health and Aging Study was approved by the Institutional Review Boards or Ethics Committees of the University of Texas Medical Branch in the United States, the Instituto Nacional de Estadistica y Geografia (INEGI) and the Instituto Nacional de Salud Publica (INSP) in Mexico.

Data availability

Data files and documentation are public use and available at *www.MHASweb.org*.

Sponsor's role

The sponsors (National Institutes of Health/National Institute on Aging and the Institute Nacional de Estadística y Geografía) were not involved in the research design, methodology, data analysis, article preparation, or decision to submit this article for publication. This content is the responsibility of the authors and does not necessarily represent the views of the aforementioned sponsors.

Author statement

J.L.S. conducted the data management, contributed to the research design and theory, conducted statistical analysis, and drafted the first draft of the manuscript and serves as the guarantor. B.D. contributed to the theory, research design in coding and selection of variables, guided the statistical analysis, wrote sections of the discussion, and edited the manuscript. M.A.G contributed to the theory, research design in coding and selection of independent variables, guided the statistical analysis, and edited the manuscript. R.W. contributed to the theory, research design in coding and selection of independent variables, provided suggestions on using the data to validate measures, and edited the manuscript.

Declaration of competing interest

The authors have no conflicts.

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