Regional Disparities in Cognitive Functioning of Rural and Urban Older Adults in Costa Rica

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Abstract

Prior research examining health disparities by region (urban vs. rural) on dementia and cognition have been studied using screening tools mostly, with conflicting results. Some studies support a rural health disadvantage, while other consider that urban dwellers are at greater risk of dementia and cognitive impairment. Latin American (LA) countries are underrepresented in these studies. Full neuropsychological assessment batteries have been administered in a limited number of studies, without addressing measurement equivalence of the tests across regions. The present study situates within a larger research project called EDAD (Epidemiology and Development of Alzheimer's Disease) with Costa Rican older adults. The EDAD included a group of 16 neuropsychological tests among other health-related measurement tools. The purpose of the present study was to (a) identify the cognitive dimensions of the EDAD neuropsychological battery, (b) examine the comparability of the measures and cognitive constructs across the urban and rural sample of EDAD participants from Costa Rica, (c) determine whether group differences exists in the cognitive constructs, and (d) evaluate the contribution of age and education in the group differences. An exploratory/confirmatory factor analytic approach was implemented to identify the baseline model for the EDAD neuropsychological measures. Then, based on multiple-group confirmatory factor analysis, measurement invariance was examined. Once measurement invariance was established, group comparisons of the latent cognitive factors were conducted to explore regional disparities. Three cognitive constructs were identified in the factor model: Verbal Memory, Spatial Reasoning and Cognitive Flexibility. The findings showed that most of the neuropsychological tests in EDAD can be directly compared across the groups, allowing for latent mean comparisons. The rural sample of Costa Rican older adults had a disadvantage in the Spatial Reasoning and Cognitive Flexibility abilities. When age and education were included in the models, no differences between the regions were found. The results of the present study suggested that norms for Costa Rican older adults should consider age and education adjustments. This study contributes to the growing are of measurement invariance in neuropsychological assessment as it highlights the importance of examining the comparability of assessment measures across different cultural groups.

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Introduction

The world population is aging rapidly. This demographic trend is occurring at a faster rate in some regions of the world than in others because of changes in fertility and mortality rates in the population (Bongaarts, 2009). According to the United Nations (2017), "two thirds of the world's older persons live in developing regions" (p. 1) like Latin America (LA). By 2050, it is expected that 25 percent of the population in LA will be aged 60 or over. This projection is higher than that expected in other developing regions of the world, like Asia and Africa (U.N., 2017). The projected growth of this population group in LA will demand more access to health care to increase health promotion and disease prevention, especially for age-related conditions like dementia (Cotlear, 2011). The present study will examine aging in LA, with a focus on cognitive functioning of older adults in urban and rural Costa Rica.

Studies on cognitive functioning of older adults in LA are warranted. The study of healthy cognition in older adulthood is important, among other reasons, because it predicts everyday functioning (Gross, Rebok, Unverzagt, Willis & Brandt, 2011) and indicates the absence of neurologically-related disorders, like dementia. In the LA region, the number of persons with dementia is growing fast. The LA countries and other low and middle-income countries (LMICs) account for about two thirds of the total cases of dementia worldwide (Alzheimer's Disease International [ADI], 2015). The geographical health disadvantage in this group of countries seems consistent with the World Bank (2009) statement of "place is the most important correlate of a person's welfare." (p.1). An environmental characteristic LMICs share is that they are more rural and less urbanized than high-income countries, which suggests that the region where older adults grow and live influences their cognitive health. The study of regional disparities in dementia has received some attention. However, there is a dearth of research about rural and urban differences in older adults' cognition. This study will focus on regional disparities of older adults' cognitive functioning.

Although dementia and cognition are well studied in wealthy industrialized countries, these constructs are poorly studied in LA countries. There are a limited number of studies on dementia and cognitive health in older age in LA causing this region to be underrepresented in the WHO dementia statistics and in clinical research (see Custodio, Wheelock, Thumala & Slachevsky, 2017; ADI, 2015; World Health Organization, 2017a). Studies conducted in the LA region show large variability of dementia prevalence. The sources of variability are not well understood; however, it has been suggested that at least some of the variability can be attributed to methodological differences between studies (see Parra, Baez, Allegri et al., 2018). Comparisons between rural and urban regions in LA are scarce, and moreover, there is no evidence to support that the measures used in these studies are equivalent or comparable across regions.

The regional disparities in dementia and cognition, the limited number of studies in the LA region and their methodological gaps argue for the importance of evaluating the relationship between regionality and cognitive functioning in older adults from the LA region. To address this fundamental gap in the literature, this study proposes to test the equivalence of neuropsychological components across rural and urban regions in a sample of older adults from Costa Rica, with the purpose of examining whether there are geographical regional disparities. In this work, regional disparity will be conceptualized as the difference between urban and rural regions resulting from the economic, physical and social environment. Although other regional categories (e.g., cities vs. towns) or socioeconomic variables (e.g., income) could be evaluated, these are beyond the scope of this study.

Health Disparities in Cognition of Older Adults

The study of regional disparities is included within the broader framework of health disparities body in LA. The term health disparity refers to "a particular type of health difference closely linked with social, economic, and/or environmental disadvantage" (Healthy People 2020, 2008, p.28). This definition highlights the nature of the health difference as a result of "outside-the-individual" factors, and not of inherent biological factors (e.g., APOE e4 genotype). Over the last two decades, there has been an increase in the research on health disparities in cognitive aging and neurological-related conditions. The bulk of research on health disparities in cognition and dementia has focused on disparities by gender, race/ethnicity, education, and income-level of countries. The findings have documented that there are higher rates of dementia for women, racial/ethnic minorities, individuals with less education and, as mentioned above, LMICs (see ADI, 2015). Most research on disparities in cognitive function in old ages focuses on gender (Singh, Jasilionis & Oksuzyan, 2018), socioeconomic status (Goveas et al., 2016; Lyu & Burr, 2016), early life health (Case & Paxson, 2009), and race and ethnicity (Masel & Peek, 2009; Sloan & Wang, 2005; Zahodne et al.,2016) . These findings not only have contributed to the understanding of unequal distribution of healthy cognition and dementia, but also provide guidelines for tailored interventions. Worldwide efforts aiming at reducing dementia rates for vulnerable groups in the population have already started with the WHO Global Action Plan on the Public Health Response to Dementia (WHO, 2017b). However, this plan has not focused on differences in healthy aging, nor is there explicit consideration of urban and rural disparities.

Public health policies on healthy aging would benefit from learning more about regional disparities, as interventions (primary or tertiary) should include context-specific actions.

Regional disparities in dementia and cognition. Studies conducted in countries across the world evidence differences between geographical regions. A significant limitation of this data is that more efforts have been placed in the understanding of dementia disparities, than in the study of healthy cognitive functioning in older adults.

One of the first studies that documented urban-rural disparities of dementia was conducted by Emard and colleagues (1992) in Quebec, Canada. Using data from the IMAGE (from the French: investigations de la maladie d'Alzheimer par la genetique et l'epidemiologie) registry, the researchers found that the prevalence of dementia was higher in one rural region than one urban region of Quebec. Other areas of Quebec did not show regional differences. The authors did not explain why the dementia disparities were observed in a single area of Quebec. However, they suggested that the study of environmental factors associated to AD was warranted.

In the following two decades, studies conducted across the world have found that urban dwelling older adults have better cognitive performance and lower prevalence of dementia, compared to their rural counterparts (Cassarino et al., 2015; Guerchet et al., 2013; Hall et al., 2000; Jia et al., 2014; Sharma et al., 2013; Weden et al., 2017). These studies suggested that disparities in dementia between rural and urban older adults were attributable to two social determinants of health that often co-occur with regional differences: education and economic stability. In China, Jia et al. (2014) suggested that regional differences were an effect of education given that there was a higher percentage of illiterate individuals in the rural regions than the urban ones. Risk for AD was greater for women and illiterate individuals in the rural region, while manual labor was found to be a risk factor for AD in the urbanized areas. In the U.S., Weden et al. (2017) indicated that race/ethnicity and educational attainment could explain the dementia disparity found in the Health and Retirement Study data. Also in the U.S., Hall et al. (2000) reported that the intersectionality of low level of education (defined as 0 to 6 years of education) and childhood rural residence increased the risk of developing AD. Interestingly, data from the Health and Retirement Study showed that having just one risk factor (i.e., low education or rurality) did not increase the risk for AD in that sample. The findings from these studies are consistent, showing regional disparities in dementia and that socioeconomic and educational attainment and illiteracy are confounded with region.

The direction of the dementia disparity in the studies reviewed above is consistent with other studies examining cognitive functioning of cognitively-intact older adults. In Ireland, Cassarino, Sullivan, Kenny and Setti (2015) conducted a study with healthy older adults using different categories of regionality (i.e., urban, other settlements, and rural). They found that rural dwellers had poorer global cognition, verbal fluency, memory and executive function, but there were no differences in speed of processing or reaction time. Current and childhood rurality was associated with worse cognitive performance. Those living in rural areas but with an urban childhood had a cognitive advantage, similar to that of those living in urban areas. The geographical differences found were maintained even after controlling for typically included covariates of SES inequality: education, occupation, income, and father social class. The authors argued that relative to rural regions, living in urban areas stimulates high-level cognitive abilities because in urban areas there is more exposure to more sensorial stimulation and demand for shifting between multiple tasks.

There is another group of studies that have found consistent opposite results, suggesting that urbanity is associated with poorer cognition and higher prevalence of dementia. In India, Raina, Raina, Chander and colleagues (2014) compared urban, rural, migrant and tribal areas. They found that the urban population had a higher rate of dementia, while tribal rates were lower. In France, De Souto and colleagues (2014) reported that the prevalence of dementia and the behavioral and psychiatric symptoms (BPSD) of aggressiveness and screaming were higher in urban than in rural regions.

Epidemiological studies of dementia and cognition have also been conducted in other LMIC. The most relevant research effort is the 10/66 Dementia Research Group (10/66 DRG), which included DSM-IV diagnostic criteria and an ad-hoc diagnostic algorithm. Countries in Asia, Africa and LA participated in this research group. Using the 10/66 DRG data, Kalaria and colleagues (2008) found that LA countries had a higher prevalence of dementia, compared to other regions. As part of this study, India, China, Peru, Mexico and Portugal have conducted regional comparisons. In India, the prevalence of dementia in urban settings was lower than in the rural areas; while in China there was no difference between regions. In contrast, the urban regions in Mexico and Peru were found to have higher rates of dementia than their rural counterparts (Rodriguez, Ferri, Acosta et al., 2008). In an analysis comparing the diagnostic criteria, Gonçalves-Pereira and collaborators (2017) found that using DSM-IV criteria, dementia prevalence was higher in the urban region of Portugal than in the rural areas. However, no differences between regions were found when the 10/66 DRG algorithm was used. Unlike the DSM-IV criteria, the 10/66 algorithm did not require evidence of impairment in specific cognitive components and used the Community Screening Instrument for Dementia and CERAD verbal fluency and word recall (see Rodriguez, Ferri, Acosta et al., 2008). The differential findings from the 10/66 DRG studies highlight the role that outcome measures have on the study of health disparities.

A third group of studies have found null effects of region on dementia. In Canada, John and colleagues (2016) conducted a longitudinal study, in which they found no effect of rurality on the risk of having dementia, over a 5-year period. In the U.S., Wackerbarth and collaborators (2001) found that cognitive performance and activities of daily living were equivalent between the regions. In India, Sharma et al. (2013) found that the prevalence of cognitive impairment was higher in the rural than the urban region. However, the difference was not statistically significant. Similarly, Radford and colleagues (2015) found no significant differences in cognitive impairment between the Aboriginal urban and remote regions in Australia. In China, Ma (2016) and Tang and colleagues (2016) observed no disparities between regions and found differential specific risk factors for each region. For the urban sample, both Chinese studies reported that age, lack of physical activity, having three or more children, and diabetes were associated with cognitive impairment. While, being a woman, older in age, being exposed to pesticides, and having a history of head trauma or encephalitis increased the risk in the rural region. The studies reviewed suggest that there is diversity in the findings of regional disparities as there are other sociodemographic and environmental variables explaining the rural and urban differences in cognition.

The variability in findings reported across studies, motivated Russ, Batty, Hearnshaw, Fenton and Starr (2012) to conduct a meta-analysis of 13 studies comparing urban and rural differences in dementia prevalence. All the studies selected for the meta-analysis used DSM-IV diagnostic criteria. Russ and colleagues (2012) found a weak association between rurality and dementia, but stronger association for AD. They observed that early life rural living was an important factor associated with AD prevalence. The researchers noted that the methodological variability limited the comparability across studies. Moreover, they concluded that stricter diagnostic criteria tended to reduce the regional disparities.

In conclusion, from the existing literature, there is no clear evidence of the direction of the regional disadvantage and certain methodological and environmental questions remain. The studies that have found a rural and urban disparity in cognition and dementia relate their findings with differences in educational attainment and literacy. Some of these studies suggest that the disparities in cognition based on region are in essence confounded with education. Other studies do not support this association. The conflictive findings can also result from the methodological variability of the studies. As mentioned above, most of the studies based their results on screening instruments or single neuropsychological tests. Based on these gaps found in the literature, the present study will examine whether there are geographical disparities in cognition of older adults using a comprehensive neuropsychological battery and will test if the disparities result from a rural and urban distinction or an effect of education.

Assessment Instruments

Most of the studies comparing rural and urban regions have focused on dementia, not healthy aging, and have used cognitive screening questionnaires to identify dementia cases. A comprehensive and culturally appropriate neuropsychological battery could be used to identify differences in healthy aging and may attenuate the urban-rural disparity. Table 1 includes a description of the outcome measures used in the studies that were reviewed in the previous section. As can be seen in the table, most of these studies used screening tools, like the Mini-mental State Examination (MMSE), Modified MMSE, Telephone Interview for Cognitive Status, Community Screening Interview for Dementia (CSI-D), and the Hindi Cognitive Screening

Battery. A smaller number of studies used neuropsychological batteries. The clinical utility of a comprehensive neuropsychological evaluation is not only for the diagnosis and monitoring of dementia and other neurodegenerative disorders, but also for the assessment of healthy cognition (Fields, Ferman, Boeve & Smith, 2011). As can be seen in this table, more studies using a comprehensive neuropsychological assessment battery are needed to determine where there are true regional disparities in cognitive functioning in older adulthood.

Comparability of outcome measures across regions. The studies on regional disparities of dementia and cognitive functioning of older adults have not addressed the measurement equivalence of the instruments used across regions. There are no studies that have determined whether the assessment tools and cognitive factors are comparable and appropriate for comparisons between rural and urban dwellers. Researchers have assumed the tests and cognitive components are equivalent. However, the differential findings from the 10/66 DRG studies suggest that certain screening and neuropsychological tests are not comparable between the regions. In order to determine whether regional disparities in cognitive functioning exist, some additional questions need to be addressed. Research focusing on the measurement equivalence of neuropsychological batteries between rural and urban regions are warranted to learn if the neuropsychological tests and cognitive constructs are comparable across regions.

In the U.S. and Canada, studies have been conducted to test the measurement equivalence of older adults' cognitive functioning across different groups: levels of education (low vs. high education), neurological status (healthy vs. AD), language (English vs. Spanish), and ethnicity and gender (Blankson & McArdle, 2013; Brewster, Tuokko & MacDonald, 2014; Mungas, Widaman, Reed & Farias, 2011; Siedlecki, Honig & Stern, 2008). However, no study has been conducted to examine the measurement invariance of older adults' cognitive functioning across rural and urban regions.

Geographical Disparities or Educational Disparities?

When comparing urban and rural regions, it is potentially important to distinguish between the effects of region and the effects of social determinants that are correlated with regionality, but are potentially modifiable. For instance, regionality is often confounded with educational opportunities and the association between education/literacy and dementia is a common -but not a universal- finding across studies. Some of the studies previously reviewed explained the regional disparity by addressing the education disadvantage in the rural area (Hall et al., 2000; Jia et al., 2014); while only one study found that regional disparities were not driven by education (Raina et al., 2014). The question of a rural or an education effect on dementia and cognition disparity remains. Independent of region, education appears to have a consistent association with dementia and cognition in high-income countries (Meng & D'Arcy, 2012); however, this association seems to be weaker in countries with lower access to education (see Paddick, Longdon, Gray et al., 2014). In LMICs, like India, studies do not support the association between education and dementia (Chandra et al., 1998). In a systematic review, Sharp and Gatz (2011) found that years of education did not consistently reduce the risk for dementia. These authors concluded the effect of education is not present in some studies. They suggest that the association is less consistent in developing nations. Given that research on education and regional disparities in cognition and dementia is unclear, it would be valuable to examine urban and rural disparities, in a case where differences in education and literacy have been minimized.

Is Rurality the Same Everywhere?

There are conflicting findings in the studies on regional variations in cognitive functioning and dementia. Even though there are more studies indicating a rural health disadvantage than an urban disadvantage, reaching a solid conclusion about the relationship between region and cognition is difficult, in part because there is a lot of variability in how rurality is defined. Some studies have defined urban and rural regions by using population density from census data (see De Souto et al., 2014). Other studies have defined the regions based on their geographic location (see Goncalves-Pereira et al., 2017); while other studies did not state how rurality and urbanity was defined (see Raina, Raina, Chander et al., 2014). Russ and colleagues commented on how regional differences in some studies could be confounded by ethnic differences and population mobility due to migration forces. The variability in operational definitions of rurality may be problematic for consolidating the literature on urban and rural disparities in health. This gap can be addressed by studying rural and urban disparities in cognitive health within the specific context of a nation.

The need for studies in middle-income LA countries is supported by the limited number of studies of cognitive functioning in this region, and the lack of studies examining measurement invariance of older adults' cognition. Continued research may lead to clarification of the regional disparities on cognition in LA, and contribute to context-specific prevention plans for the cognitive health of older adults.

The Present Study

Most of prior research evaluating regional disparities in dementia and cognition of older adults has been conducted in high-income countries from Europe and North America and LMICs from Asia. In the LA region, only Peru and Mexico from the 10/66 DRG have looked at regional disparities in cognition. All prior studies have focused mainly on dementia identification and have often lacked a comprehensive assessment of neuropsychological components. Those studies that have examined disparities using neuropsychological assessment tools (or cognitive screening tools) have undertaken that these measures are comparable across regions and, consequently, proceeded with hypothesis testing about group differences (e.g., *t* tests, analysis of variance or logistic regressions; see Cassarino et al., 2016 for an example of group comparisons). Implicitly assuming comparability in neuropsychological measures, which are mainly designed and normed in higher-income countries, can result in underestimation or overestimation of the cognitive functioning of older adults. If measurement comparability is not examined for these tests, there is no certainty of whether the disparities found are due to a true difference between groups, or if it is the result of a biased measure.

Studies focusing on health disparities of pathological and healthy cognition in aging that test the measurement equivalence of the neuropsychological tests and the conceptual equivalence of cognitive constructs tools across groups are warranted. As previously discussed, studies examining cross-country comparisons (i.e., 10/66 DRG studies) have indicated that some of the tools that assess cognitive status do not necessarily measure the same construct across nations. This finding suggests that examination of measurement equivalence in cross-cultural studies should be conducted before assessing health disparities between groups. Measurement invariance provides a methodology that aims at examining if constructs and indicators (i.e., neuropsychological measures) are similar in different socio-cultural settings, which allows to test meaningfully group mean differences (Little, 1997). Measurement invariance testing of neuropsychological assessments is a limited but growing area of research within cultural neuropsychology and quantitative psychology. Limited attention has been given to examining the regional disparities of older adults' cognitive functioning. To fill this identified gap, this present study evaluated the measurement invariance of a neuropsychological battery across a rural and urban sample of older adults from Costa Rica, and then, examined the group mean differences in cognitive factors to test regional disparities. Importantly, this study examined the contribution of education in the regional disparities in cognition between the regions.

Why Study Regional Disparities in Cognition in Costa Rica?

Costa Rica offers a unique test case for examining urban-rural cognitive disparities in older adults. Costa Rica is a Central American country, with an advanced healthcare system and socioeconomic context that differentiates it from its near and distant neighbors. According to the Pan-American Health Organization ([PAHO], 2017), Costa Rica is more urbanized and educated than other countries in Central America. Costa Ricans spend a higher percentage of their gross domestic product in public health and have more healthcare professionals than the average of Central American and LA countries. Their social security system provides universal coverage of medical insurance, in both urban and rural regions with social programs like 'Salud Rural y Comunitaria' (Salas Chavez, 2010). The overall health and socioeconomic advantages are more uniform across the country, reflected in their lower inequality index (GINI) compared to other LA countries. Costa Rica has a growing older adult population, with a median age larger than the one for the average LA region. In fact, this country has the highest percentage of adults 65 and older of the Central American and LA region (PAHO, 2017), probably because of their healthcare system. Costa Rica's social, health and population characteristics provide the appropriate context to isolate urban-rural cognitive disparities that are independent of differences in literacy and minimize SES disparity.

The Costa Rican territory is divided in 'provincias' or states, then in 'cantones' or counties and, finally, in 'distritos' or districts (see Figure 1). Of interest in this study were two Costa Rican counties: San Jose and Liberia, which are the capital counties of the states of San Jose and Guanacaste, respectively. San Jose and Liberia counties were the target for data collection of the Epidemiology and Development of Alzheimer's Disease (EDAD) research project. The present study is framed within this larger project (further information is presented in the Methods section of this document, see also Valdivieso-Mora, Ivanisevic, Shaw et al., 2018).

For the purposes of the urban-rural comparison, residents of San Jose the capital city of Costa Rica (urban) were compared to residents of Liberia (rural). San Jose is characterized by a highly urbanized area. Liberia is a rural region in the state of Guanacaste that is slowly becoming suburbanized. The main economic activity in all the Guanacaste region is tourism and agriculture. Liberia is near the Nicoya region of Guanacaste, which is known as a region of high healthy life expectancy for 90-year-old adults (i.e., blue zone) (Biesanz, Biesanz & Biesanz, 1999). The EDAD project focused on the Guanacaste region because of its low population density, and preserved rurality. According to the 2011 Costa Rican Census, Guanacaste is the state with lower changes in their rural population; that is, this region is not becoming urbanized as fast as other states in Costa Rica. Importantly, Guanacaste has the lowest internal and external migration rates of the country (Instituto Nacional de Estadistica y Censos [INEC], 2011). The previously described characteristics suggest that Guanacaste is a rural region with a steady economy and population, with potentially more homogeneity than in other regions of Costa Rica. The stability of this region is ideal for the purposes of this study given the homogeneity of its population and context.

Study Aims and Hypothesis.

There are two fundamental assumptions underlying this study. First, there are no previous studies examining the appropriateness of a neuropsychological assessment battery in urban and rural older adults in Costa Rica. And second, this study is framed within a larger study (EDAD), which aims to establish relationships between health and psychosocial behaviors with the cognitive functioning of Costa Rican older adults. With these assumptions in mind, the purpose of the present study was: (a) identify the cognitive dimensions that explain the correlations of the EDAD neuropsychological battery in a parsimonious and conceptually meaningful way, (b) examine the comparability of the measures and cognitive constructs across the urban and rural sample, (c) determine whether urban and rural disparities exists in the cognitive constructs, and (d) evaluate the contribution of education on the regional disparities in the constructs.

For the first objective of this study, an exploratory factorial approach will be used (justification for the data analytic approaches used in this study are presented in the Methods section). Based on the exploratory nature of the analysis, no factor structure was specified in the hypothesis. Nevertheless, it was expected for the factor analytic model to converge and indicate the underlying structure of the cognitive functions in Costa Rican older adults. The overall hypotheses this study tested were that: (a) regional disparities would exist in the cognitive constructs identified, with the rural sample of Costa Rican older adults showing lower latent scores compared to their urban counterparts; and (b) the regional disparities in cognition would be explained by an effect of education.

Methods

This study used data from the Epidemiology and Development of Alzheimer's Disease in Costa Rica (EDAD). EDAD is an exploratory/developmental research project with the primary aim of assessing healthy aging in rural and urban regions of Costa Rica. The study was conducted by the Universidad de Costa Rica (UCR) and the University of Kansas (KU) from June 2014 to May 2016. The principal investigators of this study were Monica Salazar-Villanea, Ph.D. (UCR) and David K. Johnson, Ph.D. (KU). Their study was financed by the National Institute of Health – Fogarty International Center. The EDAD study included measures to characterize Costa Rican older adults' cognitive functioning, personality and psychosocial domains, physical health, diet, functional ability and physical fitness. The present study is part of this larger project. The Institutional Review Board of both UCR and KU approved the EDAD study.

Participants

Recruitment. The EDAD used a convenience sample of Costa Rican older adults who were living in the rural (Guanacaste) and urban (San Jose) regions of the country. Participants were recruited through the Programa Institucional para la Persona Adulta Mayor (Institutional Program for the Older Adults of the University of Costa Rica), the Asociacion Gerontologica Costarricense (Costa Rican Gerontology Association), the Programa de Ciudadano de Oro de la Caja Costarricense del Seguro Social (Golden Citizen Program of the Costa Rican Social Security Bureau), and other groups such as retired teachers and community groups. Flyers were posted on different state and community centers of San Jose and Guanacaste, where older adults are users. Flyers included information about the study and its eligibility criteria.

Participants in this study were psychologically and cognitively healthy older adults. Eligibility requirements for EDAD included: adults be between 65 to 85 years of age, community dwellers, be free of cognitive impairment (MMSE > 23, Blesa et al., 2001; Folstein, Folstein, & McHugh, 1975), able to read and write, have adequate visual and auditory abilities to complete study procedures, have a stable dose of medication for a minimum of 30 days prior to screening, sign an informed consent, and verbally assent to participate in all scheduled evaluations. Participants were excluded based on the following criteria: moderate cognitive impairment (determined by a MMSE score less than 24), current clinically significant major psychiatric disorder or significant psychiatric symptoms, history of clinically-evident stroke, brain trauma and neurocognitive disorder, clinically-significant infection within the last 30-days, history of drug or alcohol abuse or dependence within the past 2 years, and significant pain or musculoskeletal disorder. For all participants, Spanish was their primary or only language.

Sample. Participants of EDAD were 295 Costa Rican older adults between the ages of 60 and 85, who lived in the Greater Metropolitan Area of San Jose (n = 181) and the rural region of the Guanacaste province (n = 114). Relevant demographic information about the sample is presented in the Results section.

The results from the EDAD study are generalizable only to those healthy older adults living in the urban region of San Jose and the rural region of Guanacaste, in Costa Rica.

Instruments

Demographic questionnaire. The EDAD assessment protocol included a section for collecting information about socio-demographic variables: date of birth, age, sex, handedness, region of residency, ethnic group, highest level of education, years of education, marital status, household size, and work status (retired or still working). Based on the self-report of the participants, older adults in EDAD were categorized as urban or rural dwellers. The region of residency variable was treated as an objective, categorical and dichotomous variable.

Neuropsychological assessment. A comprehensive neuropsychological battery was compiled to assess different cognitive domains in EDAD. The cognitive measures included were: *Logical Memory I* and *II* from the WMS-III (Wechsler, 1997a), *Verbal Fluency Animals* and *Vegetables* (Goodglass & Kaplan, 1983), *Trail Making Test A* and *B* (Armitage, 1946), *Digit Symbols* and *Block Design* from the WAIS-R (Wechsler, 1997b), *Stroop Color Naming* (Golden, 1978), *Boston Naming Test* (see Goodglass & Kaplan, 1983; Fernandez & Fulbright, 2015; Jahn et al., 2013), *Selective Reminding Test* (Grober et al., 1988), *Crossing off* (Botwinick & Storandt, 1973), *Spatial Relations* from the DAT (Bennett, Seashore, Wesman, 1947), *Paper Folding* test (Workman & Lee, 2004), *Hidden Patterns* (Vanderberg & Kuse, 1978), and *Identical Pictures* (Ekstrom, French, Harman & Dermen, 1976). A list of all the measures can be found in Table 2. Spanish versions of the Wechsler's tests were used. For the remaining measures, a committee of bilingual U.S. and Costa Rican researchers on aging reviewed all the measures administered.

Procedures

All participants were recruited from the state and community centers mentioned in the Participants section. Once participants expressed interest in the study, graduate students from the Clinical Psychology master's program at UCR conducted a screening interview to exclude those older adults who did not meet criteria for the study as described in the Participants section above. Eligible participants were read and had the informed consent form verbally explained the informed consent form to them. A copy of this document was provided to each participant. All participants signed the informed consent form and verbally agreed to participate in each assessment session.

Graduate students from the UCR completed a two-day training on the EDAD protocol. Researchers obtained informed consent from each participant. In this stage of the study, research assistants (RAs) recruited participants from two community centers. RAs contacted all older adult users of the community centers, described the study (and exclusion criteria) and asked them if interested in participating. Once they verbally agreed, RAs scheduled individual appointments with each participant in which they read the consent form. Once participants agreed to the informed consent by signing the document, RAs proceeded with collection of demographics and medical history. A separate appointment was scheduled for completion of extensive neuropsychological testing.

One-on-one interviews and testing were conducted in private offices of the UCR campus and the community centers. All interview and testing protocols required identifiable information (name, date of birth and age). Once the interviews and testing were completed, RAs protected all protocols in a secured office. All completed documentation was transported to the main campus at UCR, where each participant was coded with a randomly assigned ID. PIs and RAs had access to all documentation. No identifiable information was entered in the main database.

In San Jose, each participant attended two sessions of data collection. During the first session, participants completed socio-demographic, psychosocial and health questionnaires. A physical evaluation was conducted as well. During the second assessment session, participants were administered the neuropsychological test battery described previously. In Guanacaste, most of the participants attended an average of three sessions of data collection: the first two sessions were primarily used for filling out the questionnaires; and the third session included both the physical evaluation as well as the neuropsychological evaluation. The experimenters reported that the additional sessions were requested by participants as assistance was needed to complete some of the questionnaires.

Data Revision and Cleaning

Once all the data was collected, the testing protocols were revised by a clinical neuropsychologist in Costa Rica and scores were transferred to a summary score sheet was completed. All administered materials and score sheets were digitalized to populate a predesigned database. I checked the data for each of the participants by comparing the protocols administered with the summary score sheets and the electronic database. All missing values were substituted with a standard code (999). Variables that were out of scope of this study were eliminated from the data. The finalized and cleaned database was used for the analyses.

Design and Data Analyses

The present study used a quantitative, cross-sectional between-group design, with a factor analytic approach. The analyses included five steps.

Overview of the measures. Descriptive analyses were conducted using IBM SPSS version 24. Univariate normality assumptions were assessed for the sixteen neuropsychological tests included in the EDAD battery. Analyses included examination of means, kurtosis, skewness, and the Shapiro-Wilk test. Kurtosis estimates greater than 7.0 and skewness estimates greater than 2 were not considered normally distributed (West, Finch & Curran, 1995). The Shapiro-Wilk test with p-values less than 0.05 were not considered normally distributed, as this test examines the null hypothesis of data coming from a normally distributed population. Kurtosis, skewness and Shapiro-Wilk's p-value estimates for *Crossing Off* and *Identical Pictures* were outside the acceptable limits (see Table 3). These tests were not included in the exploratory stage for the model identification.

Identification of the basic dimensional model. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted to evaluate the dimensional structure of the EDAD neuropsychological measures, using Mplus version 8.2 (Muthén & Muthén, 1998-2017). This EFA and CFA approach followed the work previously conducted by Siedlecki, Honing and Stern (2008) for measurement invariance testing of a neuropsychological battery in older adults with different cognitive-status groups. In the present study, EFA was used to determine a parsimonious conceptual factor model. EFA was considered appropriate for two reasons: (a) the inexistence of previous studies examining the factor structure and measurement invariance of a neuropsychological battery in a sample of Costa Rican older adults; and (b) the multiple correlations among measures in the EDAD neuropsychological battery (see Table 4) would have resulted in a large number of possible hypothesized models that would be impractical to test (Fabrigar, Wegener, MacCallum & Strahan, 1999; Preacher & MacCallum, 2003; see also Mungas et al., 2011, for an example of testing multiple hypothesized models to identify a baseline model). EFA was conducted with the overall sample, using the maximum likelihood (ML) estimator and quartimin (oblique) rotation. ML allowed for estimation of factor loadings, unique variances, statistical inference (likelihood ratio statistic, with a χ^2 distribution), model fit indices and confidence intervals (Preacher & MacCallum, 2003). The quartimin (oblique) rotation was selected to allow correlations among the factors, which provided a more realistic representation of the dependence that exists among cognitive functions (Mungas et al., 2011; see also Preacher & MacCallum, 2003). Using the ML parameter estimation, the number of factors retained was determined based on significance testing of the χ^2 test and model fit indices. (Brown, 2015). A non-significant χ^2 test was interpreted as good fit of the model to the data. Because of the χ^2 test sensitivity to sample size, greater emphasis was placed on examination of three model fit indices: comparative fix index (CFI), the Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA). The CFI and TLI are indices that measure improvement in fit by comparing target models with a more restricted baseline model (Hu & Bentler, 1999). CFI and TLI values range from zero to one, with higher estimates indicating better fit of a model. The RMSEA is an estimate of discrepancy between the model and the data. Smaller RMSEA values are better indicators of good fit. A model was considered to have a good fit if the CFI and TLI values were equal or greater than 0.95 and RMSEA values were equal or smaller than 0.06 (Hu & Bentler, 1999). In addition to the quantitative measures of model fit, the judgement about which model best fit the data was based on model parsimony and conceptual interpretability of the extracted factors (see Preacher & MacCallum, 2003).

Next, CFA was performed to confirm the emergent factor structure identified in EFA, allowing each variable to load only on to one factor or latent construct (Brown, 2015). Model fit was evaluated using the same combination of criteria used in the EFA step (i.e, χ^2, CFI, TLI and RMSEA). If the specified CFA model fit poorly, then the model was revised by examination of modification indices and residuals (Harrington, 2009). Modification indices guided by conceptual considerations were used to identify observed indicators that were contributing to model misfit. Modification indices above the minimum value of 10.00 were considered for improvement in model fit (Muthén & Muthén, 1998-2017). Once the best-fitting model was identified, invariance testing was conducted across the two regional groups.

Under the assumption that difference in the metric among the neuropsychological measures could cause difficulties in the EFA and CFA models, all observed variables were changed using a monotonic transformation. A percentage of maximum scoring using the observed maximum score was used [(score/highest score) * 100] to put the variables on a common metric without changing the individual differences (Little, 2013). A comparison of the CFA outputs indicated that there were no differences between the raw and transformed data when examining the model fit test, goodness-of-fit indices and the parameter estimates. The measurement invariance testing was conducted with the raw data.

Measurement invariance testing. Multigroup CFA (MGCFA) was used to examine three levels of measurement invariance: *configural*, *metric* and *scalar*[1]. All levels of measurement invariance testing were conducted in Mplus version 8.2 (Muthén & Muthén, 1998-2017). MGCFA allowed simultaneous analysis of CFA in the urban and rural sample (see Brown, 2015) to evaluate the equivalence of the factor model at different levels (i.e., factor loadings, intercepts, latent means). Urban was set as the reference group, with differences estimated for rural participants. Covariate for age and education were included in the analyses.

Measurement invariance testing followed Vandenberg and Lance (2000) and Little (2013) suggestions of progressively restricting parameters in the model by testing nested models. The *configural invariance* model (Model 1) examined if the conceptual framework in the factor model was the same across the urban and rural group, that is, if there was an identical factor structure in each group. The configural model required only that the same relations between factors and observed variables were present in the urban and rural groups. This model allowed

[1] Following Little (2013), the strict measurement invariance model was not tested because it assumes that "the amount of random error present in each indicator [across groups] would be the same" (p. 143), which leaves no room for individual differences across groups.

factor loadings, intercepts and residuals to be estimated freely. For model identification purposes in Mplus, the factor means were fixed at 0.0 and the factor variances were fixed at 1.0. Also, the loading and intercept of the first indicator of each latent factor were constrained to equality across groups. Model fit was tested using the same combination of criteria described for the EFA and CFA steps. Modifications indices were examined as well. Once configural invariance was established, the next nested models in measurement invariance assured that latent factors had the same meaning in different groups. Configural invariance allowed the next nested model to be evaluated.

The *metric invariance* model (Model 2), also referred as the weak invariance model (see Brown, 2015), tested if the urban and rural groups responded to the indicators in the same way. This model was tested by constraining all factor loadings to equality and allowing intercepts and residual variances to differ across groups. Model fit was compared with the configural invariance model (Model 2 vs. Model 1). Once metric or weak invariance was established, then the next nested model could be tested.

The *scalar invariance* model (Model 3), also called strong invariance (Brown, 2015), tested if latent factor means and variances can be compared across groups, and the relationship of latent factors with external variables (e.g., covariates). In other words, scalar invariance provides evidence of construct comparability (see Little, 2013). In the scalar model, the factor loadings and indicator intercepts were constrained to be the same across the urban and rural groups, and residual variances were freely estimated. The scalar invariance model was compared to the metric invariance model (Model 3 vs. Model 2).

The metric and scalar invariance models were tested by examining three combined criteria. First, model fit test and indices were reviewed using the same criteria used in the EFA and CFA steps. Second, metric and scalar measurement invariances were also assessed by evaluating the change of χ^2 and *df* ($\Delta\chi^2$, Δdf), RMSEA value (ΔRMSEA), TLI value (ΔTLI) and CFI value (ΔCFI) from the previous model (e.g., Model 2 vs. Model 1, Model 3 vs. Model 2). Evidence for metric and scalar invariance was determined if $\Delta\chi^2$ was not significant (indicating that the nested model holds the invariance of the previous model), ΔRMSEA was equal or smaller than 0.015 (Chen, 2007, as cited in Putnick & Bornstein, 2016), ΔTLI was less than or equal to 0.05 (Little,1997, as cited in Cheung & Rensvold, 2002) , and ΔCFI was equal or smaller than 0.01 (Cheung & Rensvold, 2002). According to Little (2013), the ΔCFI criteria of 0.01 is a sufficiently good rule of thumb for determining invariance. Other studies examining measurement invariance of neuropsychological tests, have applied this guideline and concluded that lack of evidence for full metric and scalar invariance was determined by a ΔCFI larger than 0.01 (see Blankson & McArdle, 2013; Siedlecki, Honing & Stern, 2008; Tuokko et al., 2009). In the present study, the four criteria ($\Delta\chi^2$, ΔRMSEA, ΔTLI and ΔCFI) were also considered when judging if measurement invariance can be established for each model. Greater emphasis was placed in the criteria proposed by Cheung and Rensvold (2002), though. Meeting all the previously listed criteria indicated that the more restricted model (e.g., Model 3) fit the data better than the less restricted ones (e.g., Models 2 and 1).

When the full metric and/or scalar invariance tests violated the model-fit criteria, modification indices were used to identify and freely estimate non-invariant parameters. The resulting model with some freed parameters and many invariant parameters was called *partial invariance model* (Byrne, Shavelson & Muthén, 1989). Testing partial invariance models is important because full or partial metric invariance must be established to evaluate scalar invariance; similarly, full or partial scalar invariance is required to compare the factor variances and means across groups (Vandenberg & Lance, 2000). The identification of the partial invariance model was based on a backward method for testing partial factorial invariance (Jung & Yoon, 2016), which consisted on the full (metric or scalar) invariance model and a sequential process of releasing constraints one parameter (factor loading or intercept) at a time in the partial model. Modification indices were used to identify which parameters should be released, with a conservative cutoff value of 10.00. Next, the model was re-estimated and the model fit test and indices of the newly partial invariance model (e.g., Model 2.1) were compared to the full model (Model 2) and the less restricted model (Model 1). The partial model was expected to have no modification indices exceeded a value of 10.

Group-mean differences with structural invariance testing. Once the final partial scalar invariance model was established, structural invariance was tested. *Structural invariance* consists of two models: (a) *factor variance invariance* model, and (b) *factor mean invariance* model. The factor variance invariance model compared the variances of the latent constructs across the groups. Model fit test and indices were compared to those of the final measurement invariance model (i.e., partial scalar model). Once factor variance invariance was established, then the factor means were compared across the groups. Again, model fit test and indices were compared to those of the factor variance invariance model. If $\Delta\chi^2$ was not significant, the model indicated that the latent means of the cognitive constructs were equivalent across regions. However, if $\Delta\chi^2$ is significant, new models that sequentially released constrained factor means should be tested, until the non-invariant and invariant cognitive constructs are identified. This stage of model testing was conducted to determine if regional disparities existed between rural and urban Costa Rican older adults at a factor level.

Effect of age and education in the measurement and structural invariance models. New models with age and education as covariates were tested following the steps previously described for measurement and structural invariance testing. Model fit test and indices were examined using the same criteria mentioned above. In addition, regression coefficients of each cognitive construct on the covariates were examined.

Results

Descriptive Statistics

Sample demographic and test characteristics are presented by region in Table 3. The percentage of female participants was similar between the urban and rural regions, $p > .05$. The mean age and education markedly differed across regions, $p < .001$. Urban CR older adults had a lower mean age and more years of education, compared to their counterparts in the rural region. The significant differences in age and education found between the groups were considered in the testing of the measurement invariance models. Pearson correlations between neuropsychological measures are shown in Table 4.

Objective 1. Identify the Cognitive Factors of the Neuropsychological Assessment Battery of the EDAD Study

Model identification. Exploratory factor analysis was used to identify the underlying factors or latent variables in the EDAD battery. It was not possible to perform separate EFAs stratified by region because the sample size of the rural group did not allow the model to converge properly. With the overall sample, the EFA model with 14 indicators did not converge due to negative residual variance for variables *Logical Memory II* and *Verbal Fluency-Vegetables*. The two indicators were removed and the EFA was conducted with the remainder variables.

The EFA analysis with 12 indicators yielded a three-factor and a four-factor solution. Upon inspection of the test of model fit and goodness-of-fit indicators, the three-factor model was preferred, χ^2 (33, N = 295) = 34.81, p = .38 (RMSEA = 0.014 [90% CI = 0.00-0.046]; CFI = 0.999, TLI = 0.997). The three-factor model was more parsimonious and consistent with theoretical models based on neuropsychological tests (see Table 5 for the factor structure matrix). The latent factors were conceptually identified as Verbal Memory, Spatial Reasoning and Cognitive Flexibility.

Baseline model for the urban and rural samples. The three-factor model specified in the EFA stage was examined in a context of a CFA with each regional group. The model fit for the urban group was adequate, $\chi^2(51, N = 181) = 64.188$, $p = .10$ (RMSEA = 0.038 [90% *CI* = 0.000-0.064]; CFI = 0.979, TLI = 0.973). However, the modification indices suggested that freeing the loadings of *Boston Naming Test*, *Paper Folding* and *Trails Making Test A* would help with model fit. The model fit the rural group well and there were no modification indices reported, $\chi^2(51, N = 114) = 67.57$, $p = .06$ (RMSEA = 0.053 [90% *CI* = 0.000-0.085]; CFI = 0.970, TLI = 0.961). The model was revised and *Boston Naming Test, Paper Folding* and *Trails Making Test A* were excluded to achieve homogeneity in the baseline model between the groups. The modified model was tested again with each group. The final version of the three-factor model fit the data adequately for each of the groups (see Table 6). No modification indices were reported in the single-group analyses. These estimates indicated that the model was able to provide a reasonable representation of the data in the urban and rural samples. The identified baseline model preserved the same conceptual constructs found in the EFA step, i.e., Verbal Memory, Spatial Reasoning and Cognitive Flexibility. All factor loadings in the model were strong (> .40), except for those of *Logical Memory I* (in the urban sample), *Selective Reminding Test* and *Spatial Relations* (in the rural sample). In both groups, strong positive correlations between the latent constructs were observed (see Figure 2).

Objective 2. Examine the Invariance of the Neuropsychological Battery and Identified Cognitive Factors across Rural and Urban Regions

Measurement invariance across regions. After identifying the baseline models, measurement invariance models were tested using MGCFA analyses. Different nested models progressively evaluated the *configural, metric* and *scalar* invariance of the three-factor model with nine indicators across the urban and rural groups.

Configural invariance. Model 1 (see Figure 3a) tested whether the relationship among the Verbal Memory, Spatial Reasoning and Cognitive Flexibility latent constructs and the neuropsychological tests was invariant across the regional groups (Is the structure of the factorial model the same for urban and rural older adults?). The MGCFA indicated that the baseline model had an excellent fit across groups (see Table 7). No modification indices were reported. Configural invariance of the model was established, allowing for the assessment of the metric invariance model (Model 2).

Metric invariance. Model 2 (see Figure 3b) tested whether the magnitude of the factor loadings was equivalent across groups (Is the factorial model comparable at the level of the factor loadings?). The resulting fit test and indices of Model 2 were compared to those of Model 1 (see Table 7). The $\Delta\chi^2$ suggested that the metric invariance model resulted in a significant decrease in fit relative to Model 1. The ΔCFI, ΔTLI and ΔRMSEA were above the cutoff scores set a priori (see Data Analysis in Method), indicating that full metric invariance could not be established. To identify the factor loading(s) that could not be constrained to equality across the groups, follow-up analyses were conducted using the backward method. When the factor loading for *Spatial Relations* was freed in the metric invariant model, the test of model fit and the fit indices were acceptable and partial metric invariance was established (Model 2.1). A comparison of this model with the previous invariance models indicated that the partial metric invariance model (Model 2.1) had better model fit and was significantly different from the full metric model (Model 2). A comparison with the configural model (Model 1) showed that the partial metric model did not suffer a significant loss of fit, with a ∆CFI smaller than 0.01. Therefore, partial metric invariance was established (Model 2.1), with *Spatial Relations* freely estimated. The established partial metric model indicates that cross-region comparisons are acceptable if the cognitive constructs tested (i.e., Verbal memory, Spatial reasoning and Cognitive flexibility) were measured with the neuropsychological tests that have invariant factor loadings. That is, all observed variables included in the model (with the exception of *Spatial Relations*, which is noninvariant) relate to the latent factors in the same way across regions. The test of model fit and fit indices for Model 2.1 are presented in Table 7.

***Scalar invariance*.** Based on Model 2.1, the full scalar measurement invariance model (Model 3; see Figure 3c) was tested by constraining the model intercepts to equality across groups (Can the absolute scores of the observed variables be directly compared across regions?). Model 3 resulted in a significant decrease in model fit (see Table 7) when compared to Model 2.1, suggesting that scalar invariance could not be established. An examination of the modification indices informed that the intercepts of *Logical Memory I* and *Spatial Relations* contributed to the loss of model fit. A partial scalar model (Model 3.1) was tested with the intercepts of these variables freed. The results indicated that model fit was improved when the *Logical Memory I* and *Spatial Relations* intercepts were released and, therefore, partial scalar invariance was established. This finding suggested that it could be appropriate to compare group-mean differences in the cognitive constructs (Verbal memory, Spatial reasoning and Cognitive flexibility) as they capture the mean differences in the scores of the neuropsychological measures across regions, except for *Logical Memory I* and *Spatial Relations* which cannot be directly compared across groups (noninvariant intercepts).

With partial scalar invariance established, the model can be compared at the group-mean level of the cognitive constructs.

Objective 3. Determine Whether There are Differences in the Cognitive Factors across Rural and Urban Regions

Structural invariance. After achieving partial scalar measurement invariance, structural invariance was tested with two additional models. The first model tested the *factor variance invariance* (see Figure 3d), which constrained all factor variances to 1 (i.e., to be equal across regions). The resulting $\Delta\chi^2$ indicated that there was a nonsignificant decrease in model fit when compared to the partial scalar model (Model 3.1). Thus, Costa Rican older adults in the urban and rural region had equivalent amounts of individual differences in each cognitive factor (i.e., range of scores on each latent factor does not vary across groups).

The second model tested to *factor mean invariance* (see Figure 3e), which constrained to 0 (zero) the factor means to be equal across regions. As shown in Table 7, the resulting $\Delta\chi^2$ indicated that there was a significant decrease in model fit when compared to the factor variance invariance model, which suggested that one or more constraints were significantly different across the regions. To examine the source of noninvariance, modification indices were reviewed, and new factor mean invariance models were tested. The resulting model had Verbal Memory as the only invariant (i.e., equivalent or comparable) factor, while the other two latent factors had factor means significantly different from zero (i.e., not comparable across groups). The model suggested that the sample of rural and urban Costa Rican older adults had a comparable functioning of their Verbal Memory on average (p = 0.25); with standardized factor means for Spatial Reasoning and Cognitive Flexibility lower in the rural group (μ = -0.764, SE =

0.140, $p < 0.001$ and $\mu = -1.081$, SE = 0.145, $p < 0.001$, respectively) than in the urban group (see Table 8).

Objective 4. Investigate the Effect of Education and Age in the Cross-Regional Differences in the Cognitive Factors

Measurement invariance across regions, with age and education as covariates. Given the results from the independent t test (see Table 3), age and education were included as covariates in the models. All levels of measurement invariance (i.e., configural, metric and scalar) and structural invariance (variance and mean invariance) testing were conducted with age and education. All model fit test and indices are presented in Table 9.

The *configural invariance* model test indicated that the baseline model had an excellent fit across groups. Configural invariance of the model was established, allowing for the assessment of the metric invariance. The *metric invariance* model test suggested that the model was not invariant at the metric level. Like the previous full metric invariance model tested (i.e., without age and education as covariates), ΔCFI, ΔTLI and ΔRMSEA were above the cutoff scores. Follow-up analyses were conducted using the backward method. Test of model fit and fit indices indicated that when the factor loading of *Spatial Relations* was released, the model was acceptable and partial metric invariance was established. Using the partial metric model, the *scalar invariance* model testing followed the same previously described pattern. Full scalar invariance could not be established, and modification indices pointed to *Logical Memory I and Spatial Relations* as main contributors to the loss of model fit. A partial scalar model was tested with the intercepts of these variables freed. Partial scalar invariance was established, and structural invariance models were tested.

The first structural invariance model tested the variance invariance across regions. The changes in model fit and indices indicated that there was an equal amount of interindividual variation in the three cognitive constructs across groups. The mean invariance model was not significant either (see Table 10). Unlike the previous set of models tested (regional comparison without age and education as covariates), the latent mean invariance model with the covariates suggested that factor means for all three cognitive constructs were invariant (i.e., comparable) across the rural and urban groups of older adults. No follow-up comparisons were warranted.

Regression coefficients for the latent cognitive constructs regressed on age and education are presented in Table 11. In both urban and rural groups, Verbal Memory, Spatial Reasoning and Cognitive Flexibility had a negative relationship to age and had a positive relationship with education. These results indicated that with older age, latent scores were lower, while with more years of education the latent scores were higher. An examination of the effect sizes (R^2) for age and education suggested that these covariates had a larger effect in the rural group than the one found in the urban group.

The correlations between latent factor were positive and ranged from moderate to strong. Stronger inter-factor correlations were found when the models excluded age and education as covariates, compared to those models that accounted for these variables (see Table 12).

Summary of results. The identified factor structure for the EDAD neuropsychological battery resulted in a three-factor model with nine observed measures. Measurement equivalence was established across regions for the factor loadings and intercepts of the neuropsychological tests in the model, except for *Logical Memory I* and *Spatial Relations*. Group-mean differences for the latent factors of Spatial Reasoning and Cognitive Flexibility were found. Such differences were not present when age and education were included as covariates in the factor models. Age had a negative small effect on the mean latent scores of the cognitive constructs of both regional groups, while education had a positive and larger effect on the constructs for the rural group in comparison to the urban sample.

Discussion

The study of disparities in pathological and healthy cognition in aging uses neuropsychological measures or screening tests for comparing the cognitive functioning between two or more groups (e.g., Singh et al., 2018; Masel & Peek, 2009; see also Fields, Ferman, Boeve & Smith, 2011). For health disparities to be identified, researchers and clinicians depend on neuropsychological measures that assure fair and unbiased comparisons across groups. Ideally, the test of measurement invariance should precede the group comparisons in cognition needed to study health disparities. However, most studies on health disparities in cognition often just assume that the tests administered are comparable across the groups of interest, without examining their measurement invariance or equivalence. As noted by Little (1997), using measurement invariance provides a mathematical and theoretical basis to test if constructs are similar in different sociocultural settings, which allows to test meaningfully the relationship of latent factors with any other constructs. There has been a limited, but growing, amount of research examining the equivalence or comparability of neuropsychological measures in aging across groups, though. These studies have focused on invariance across languages (Tuokko et al., 2009), racial and ethnic groups (Mungas et al., 2011), gender (Blankson & McArdle, 2013), educational levels (Brewster et al., 2014) and cognitive or neurological conditions (Bowden et al., 2004; Siedlecki et al., 2008). Previous to the present study, no studies had addressed the question of measurement invariance of neuropsychological tests across urban and rural older adults before examining disparities in cognition between regions.

The present study examined and established measurement invariance across a sample of urban and rural older adults in Costa Rica who were part of the EDAD study. Several steps were taken to test the equivalence of measures across regions. First, an EFA/CFA approach was used to identify the factor model that best described the EDAD neuropsychological battery. The baseline model consisted of three cognitive factors: Verbal Memory, Spatial Reasoning and Cognitive Flexibility and nine neuropsychological indicators (see Figure 2). Then, using MGCFA, measurement invariance examined the comparability of the neuropsychological measures and cognitive constructs across the urban and rural groups. The results showed that direct comparisons across regions can be made for most of the neuropsychological tests. Once comparability of the cognitive factors and neuropsychological measures was established, regional differences in the cognitive factors were tested. A rural disadvantage was found for the Spatial Reasoning and Cognitive Flexibility abilities. Further measurement invariance model testing suggested that the rural disadvantage can be explained by the influence age and education had in the cognitive functioning of Costa Rican older adults.

The EDAD neuropsychological battery included a comprehensive set of 16 measures, designed to measure verbal memory, verbal ability, visuospatial processing and executive function. However, the identified baseline model resulted in a three-factor model with nine neuropsychological measures, that loaded on Verbal Memory, Spatial Reasoning and Cognitive Flexibility factors. A total of seven of EDAD's measures behaved differently across urban and rural settings. Two measures, *Crossing Off* and *Identical Pictures* were excluded in the initial stages of the study because of clear departures from normality. The remaining five, *Logical Memory II*, *Verbal Fluency Vegetables*, *Boston Naming Test, Trails Making Test – A* and *Paper Folding* were sources of model misfit in the EFA and CFA stages. Model misfit was caused by negative residual variance (i.e., residuals were not normally distributed), which is an indicator that the model was not appropriate for the data and that model modification was warranted (Muthén & Muthén, 1998-2017). The present study added to the broader goals of the project by identifying the remaining nine neuropsychological tests as the most parsimonious set of measures to characterize the cognitive functioning of CR older adults' participants in the EDAD study, in a conceptually valid way.

The second aim of this study was to assess whether the neuropsychological measures that comprehensively assess cognition are equivalent or comparable across urban and rural settings. This was an important goal because studies examining regional disparities tend to rely on screening interviews or neuropsychological measures that are assumed to be comparable across groups, but no studies have been conducted to test their invariance. Therefore, it remains unclear if the disparities reported reflect true differences in cognition between groups or bias in the tests used for examining older adults' cognitive functioning. In this study, the process of testing for invariance followed the logical model specified by Little (2013) (see also Vandenberg & Lance, 2000), the first test was designed to test configural invariance, followed by metric (weak) and scalar (strong) invariance. The results of this study established that the reduced set of nine measures from the EDAD neuropsychological battery demonstrated configural and partial metric and scalar invariance.

The first step in this process was to establish configural invariance, using the three-factor model shown in Figure 2. Configural invariance indicated that the relationship between each neuropsychological measure and cognitive construct had the same pattern across the groups, producing the same factor structure (latent cognitive dimensions and neuropsychological measures) in the rural and urban sample.

The second step was to test for metric invariance. The partial metric invariance model indicated that all factor loadings associated to their specific latent constructs were comparable across regions (with Spatial Relations being the exception). The size of the factor loadings and explained variance (R^2, shown in Table 8 and 10) can be considered estimates of the reliability (i.e., consistent results across the two samples) of the neuropsychological measures (see Brown, 2015). This suggests that in the EDAD sample, these measures were consistently and meaningfully related to their cognitive constructs across groups. Further, establishing partial metric invariance evidences discriminant (how distinguishable the tests are by the cognitive ability they measure) and convergent validity (how related the tests that measure one specific cognitive ability are) measures that of the neuropsychological measures. Discriminant and convergent validity are types of construct validity, which informs that when the neuropsychological tests were administered to the urban and rural sample of older adults, the tests measured the same cognitive abilities (see Little, 2013).

The next step was to test for scalar invariance. The finding of partial scalar invariance established that raw scores of the neuropsychological measures were comparable when the same cognitive ability or construct was present across the regions (except for Logical Memory I and Spatial Relations). This is an important component of invariance as it is necessary to establish construct validity. In other words, if an urban and a rural Costa Rican older adult with the same cognitive ability (e.g., Cognitive Flexibility) were measured with the neuropsychological tools used in this study, they would produce comparable scores on the measures related to that cognitive ability (e.g., Digit Symbol). Therefore, we would conclude that the measures are unbiased across urban and rural populations. The invariance found in the loadings and intercepts indicates that any differences across groups on the cognitive constructs can be attributed to a true latent variable group difference. Establishing partial scalar invariance is critical because only in the context of scalar invariance can group comparisons of the latent means be considered valid (see Little, 2013).

The findings of invariance across groups excluded two measures. *Logical Memory I* and *Spatial Relations* were noninvariant measures that significantly contributed to model misfit in the metric and scalar invariance testing. There are two major implications of this finding. Firstly, the observed scores of these measures were not directly comparable across regions. Specifically, *Spatial Relations* did not have a comparable relationship with Spatial Reasoning (latent construct) in the urban and rural samples. In the rural sample, this neuropsychological measure did not load in Spatial Reasoning, suggesting that *Spatial Relations* was a biased measure of Spatial Reasoning in the rural older adult group. Secondly, the noninvariance found in *Logical Memory I* and *Spatial Relations* suggested that the differences by region in their mean scores were not due to factor differences. In other words, the lower mean scores observed in these tests among rural Costa Rican older adults were likely not due to poorer abilities in their Verbal Memory and Spatial Reasoning, as these observed measures appeared to have a different meaning across groups.

With *Logical Memory I* and *Spatial Relations* freely estimated in the model comparison (i.e., they were not constrained to be equal in the rural and urban groups), partial invariance was established. Some other studies examining the measurement invariance of neuropsychological batteries have been very restrictive in their model testing approach, as they stopped examining model fit if full metric invariance testing could not be established (see Siedlecki, Honig & Stern, 2008). In the present study, the sources of model misfit in each nested model of measurement invariance were examined and partial invariance was established. This approach proposed by Byrne and colleagues (1989) has been applied in other studies examining neuropsychological tests across different groups of older adults (see Mungas et al., 2011; Tuokko et al., 2009). Allowing the model to be partially invariant is considered a strength of the present study.

The third and fourth aims of this study were to test for group differences between urban and rural Costa Ricans and to determine whether those differences were related to age and education. With measurement invariance established, group comparisons of the latent means of the cognitive constructs were interpretable. Structural invariance models were examined to test whether the latent factors' means and variance were invariant across groups. The first test showed that although there was an equivalent amount of individual differences (variances) there were group differences between urban and rural Costa Ricans on the latent factors: Spatial Reasoning and Cognitive Flexibility. However, after including age and education in the model, there were no group differences. In other words, the disadvantage for rural Costa Ricans in latent means disappeared when age and education were included in the analysis. Thus, the discrepant findings in mean invariance between the models suggested that comparability of all three cognitive constructs could be attained if scores and norms were adjusted by age and years of education. These findings suggest that age and education need to be considered when interpreting scores of the observed measures and cognitive factors in both urban and rural samples of Costa Rica.

The direction of the regional disparity found in the present study and its association with education is consistent with other studies examining regional disparities in normal and pathological cognition of older adults. Studies conducted in the U.S., China, India, Ireland and C.A.R. have found that rural dwelling older adults have lower cognitive performance and prevalence of dementia, compared to their urban counterparts (Cassarino et al., 2015; Guerchet et al., Hall et al., Jia et al., Sharma et al., Weden et al.). Most of these studies documented a rural disadvantage in cognition that resulted from illiteracy or low levels of education. The study conducted by Cassarino and colleagues (2015) concluded that the regional differences found were maintained even after controlling for education and other SES-related variables (e.g., income, occupation). The authors argued that there is more to the rural and urban disparities than educational and SES disadvantages. In contrast, the present study found that the regional disparities in cognition were explained by the older age and lower number of years in education in the rural sample. The present study is a step toward the understanding of health disparities by region in the cognitive functioning of Costa Rican older adults, and the contribution of age and education in the study of regional disparities in cognition among older adults. This study can serve as a push to advance the research of cognition in older adulthood in the Central American region.

Although age and education had a significant influence on the cognitive constructs in the urban and rural sample, these two demographic variables behaved differently across groups. The negative regression coefficients associated with age were very similar in their sizes across the regions. Latent scores decreased in a linear fashion with age. This finding is not surprising as the negative association between age and cognitive functioning is very well documented (WHO, 2017b). In contrast, the positive regression coefficients associated to education differed (see Table 11) across regions. Larger coefficients were found in the rural group than in the urban group, which indicated that the influence of education on the latent constructs was stronger in the rural sample compared to the urban region.

Why would education have a larger positive influence on cognition in the rural than in the urban region? One likely explanation is that within the context of a low average in years of education in the rural sample, any increase in years of education would have a larger impact in the cognitive functioning of rural older adults, than in the urban region. In simpler words, having more years of education brings larger health advantages in underprivileged regions.

These education-related findings are consistent with the socioecological model (Kaplan, Everson & Lynch, 2000) and the bioecological model (Bronfrenbenner, 2005). Following from these models, Zimmerman, Wolf and Haley (2015) suggest that education has a strong influence in the development of an individual (the microsystem), which exert a driving force on each of the other ecological levels, the mesosystem, exosystem, macrosystem. In this way, education ends up becoming inter-dependent with the environmental context, resources and experiences that positively impact an individual's social network, access to health services, living conditions and culture. Thus, if the regions and environmental contexts in which individuals grow and age are disadvantaged, it could be expected that even the smallest increase in years of education will have a positive impact in their health and overall development.

Research and Clinical Significance

Identification of the factor model and assessment of the measurement invariance model has important implications for the clinical and scientific understanding of pathological and normal cognition of older adults in the LA region. This issue is particularly important considering that most of the neuropsychological measures used in the LA region have been developed in other outside countries and translated and adapted into Spanish. Studies in this and other regions around the world have examined the disparity in cognitive health by region, age and education, without assessing or questioning the equivalency of the cognitive measures used. The present study examined whether some of the most widely used neuropsychological measures can be used and compared in a sample of urban and rural older adults in Costa Rica. Even though the sample was limited to one urban and rural region of one LA country, this study represents an important step toward the ongoing process of examining construct validity and reliability of neuropsychological measures. And, therefore, this study contributes to the recent, but growing, area of cultural neuropsychology (see Cagigas & Manly, 2014) and the call to action that clinical neuropsychologists have expressed to increase cultural awareness in research and clinical services (Rivera-Mindt, Byrd, Saez & Manly, 2009).

The model identification, measurement invariance testing, and group comparisons conducted in this study also contributes the growing literature on measurement invariance of neuropsychological measures in older adults. As of now, there are no previous studies examining measurement invariance of a neuropsychological battery across regions (urban and rural) in a sample of older adults or, even, across any other grouping variable (e.g., gender, age groups, educational level) in a sample of LA older adults. Most of the studies focusing on measurement invariance testing of neuropsychological measures (cognitive measures) in older adults have been conducted in the United States (Blankson & McArdle, 2013; Gavett et al., 2018; Mungas et al., 2011; Park et al., 2012; Siedlecki et al., 2008), Canada (Brewster et al., 2014; Tuokko et al., 2009), Australia (Bowden et l., 2004), and Portugal (Moreira et al., 2018). Several of these studies have examined invariance across time, ethnicity/race, gender, education and cognitive statuses. Yet, despite the well-known effect that region/geography has on health disparities (Healthy People 2020, 2008), the study of measurement invariance in cognitive tests across rural and urban samples of older adults was inexistent until the present study.

The question of measurement invariance should be considered in all health disparities research in which analyses are directed at showing that measured attributes (e.g., cognition, depression, quality of life, etc.) are different for diverse groups of people based on race/ethnicity, gender, region, language, level of education, etc. The use of univariate and multivariate statistics (e.g., t tests, correlations, ANOVAs, etc.) is frequent in the health disparities literature, with an implicit assumption that the scales and measures used are comparable (invariant) across groups.

Studies examining the factor structure and measurement invariance are important so that when disparities are found, they are not the result of biased measures, as opposed to true mean scores. The same rationale applies to the administration of neuropsychological tests in clinical practices. Caution is advised in the administration and interpretation of Logical Memory I and Spatial Relations in LA older adults. Importantly, clinicians and researchers should consider designing norms that adjust scores by age and years of education when assessing older adults in rural Costa Rica.

Finally, the findings of the present study have practical significance for the EDAD project itself. With the established partial measurement invariance, future analysis in EDAD can test the associations between the cognitive factor model and any other socio-cultural constructs (e.g., health behaviors). With the purpose of continuing contributing to the field of cultural neuropsychology and aging in the Americas, future studies should test the measurement invariance of the factor model across time (i.e., testing of time invariance cognitive constructs) and/or across new samples of urban and rural regions in Costa Rica and other Central American countries.

Limitations and Future Directions

There are some limitations of this study that should be noted. First, only the EDAD neuropsychological measures are being studied. Evidence of invariance found in the present study does not consider other forms of cognitive functions (e.g., attention/working memory, episodic memory, executive functions) and may not generalize to constructs or cognitive tests that were not part of the EDAD neuropsychological battery. Future research should consider a broader range of cognitive ability measures (e.g., digit span).

Even though the model was identified, and measurement and structural invariance was established, the present study was just one step toward establishing construct validity of the model. Therefore, the results of this study cannot be generalized to all older adults living in rural and urban regions of LA as the present study was limited to the cognitively healthy older adults of the urban and rural regions sampled in Costa Rica. Because this model was not intended for applied use, and values of its latent factors have not been cross-validated in other independent samples (i.e., urban and rural older adults from other provinces in Costa Rica), further testing and replication is warranted. Comparison of the identified model with conceptually different older adult groups would help evaluate the construct validity of the latent factors (see Delis, Jacobson, Bondi, Hamilton & Salmon, 2003).

Further analyses are needed to understand the use of *Logical Memory I and II, Verbal Fluency Vegetables, Boston Naming Test, Trails Making Test* and *Paper Folding* in the neuropsychological assessment of Costa Rican older adults. From the findings of the present study, it is recommended that these measures should be used and interpreted with caution. It was out of the scope of this study to analyze the psychometric properties of each individual measure and, thus, more analysis are warranted.

The present study had a sample size above the rule of thumb typically used for ensuring precision of model parameters estimates (i.e., sample size of at least 100 cases; case-to-parameter ratio of 3:1) (Brown, 2015); however, having a larger sample size would allow the EDAD project to improve the model identification steps. With a larger sample size, the urban and rural samples could be split in half, with one half used to form an EFA and the other half of the samples could be used to confirm the identified model (see Fabrigar et al., 1999). Another option is to use exploratory structural equation modeling approach (ESEM; Muthén & Muthén, 1998-2017, see Brown 2015 for an explanation of the ESEM approach), which is a method that integrates EFA and CFA models within the same solution; that is, ESEM could reduce the repeated procedures used to identify the baseline model.

Despite these limitations, the present study is a step toward the understanding of health disparities by region in the cognitive functioning of CR older adults, and the contribution of age and education in the study of regional disparities in cognition among older adults. This study can serve as a push to advance the research of cognition in older adulthood in the Central American region.

Conclusions

Studies have identified dimensions of neuropsychological test performance in different linguistic, gender, racial/ethnic groups and examined their measurement invariance. However, such studies have not been conducted for regional groups in Central America, LA and other regions of the world. The current study was unique in that a comprehensive evaluation of measurement invariance was conducted across rural and urban groups of older adults in Costa Rica. An important strength in this study was its ability to test partial measurement invariance models. For the EDAD study, this approach revealed that the EDAD neuropsychological tests could be used to measure the verbal memory, spatial reasoning and cognitive flexibility abilities in Costa Rican older adults, and results could be similarly interpreted across regions. Only Logical Memory I and Spatial Relations were the exceptions of this finding, as their absolute levels of performance may not be comparable across groups and may give rise to misleading interpretations of their test scores. Comparisons of the latent means of the cognitive constructs across regions resulted in a rural disadvantage for Spatial Reasoning and Cognitive Flexibility abilities. However, the cognitive disparities were not present when age and education were included as covariates in the model. Future research in health disparities in cognitive functioning (and other areas of mental health) should examine measurement invariance to test if the measures are appropriate and unbiased for group comparisons.

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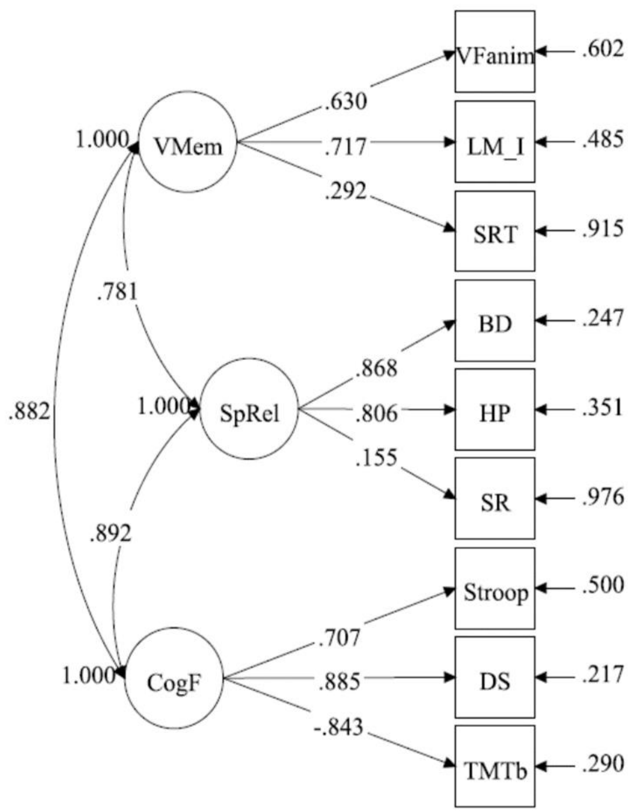
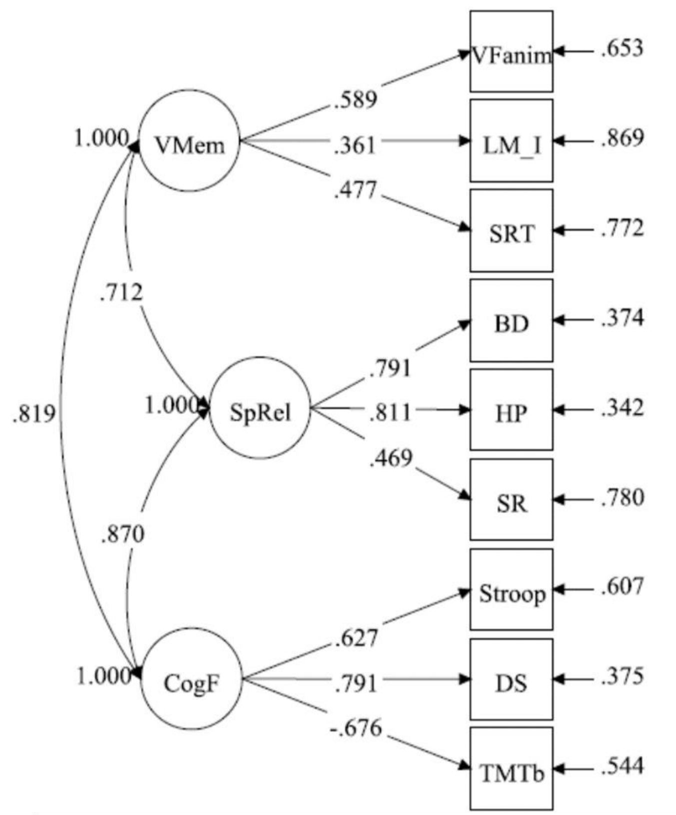
Figures and Tables

Figure 1. Map of Costa Rica. A red arrow is pointing the city of San Jose and Liberia.





a. Rural sample b. Urban sample

Figure 2. CFA baseline model with three cognitive latent factors and nine neuropsychological tests. Latent variables: VMem = Verbal memory; SpRel = Spatial relations; CogF = Cognitive flexibility. Neuropsychological tests: VFanim = Verbal fluency animals; LM_I = Logical memory immediate recall; SRT = Selective reminding test total score; BD = Block Design; HP = Hidden Pattern; SR = Spatial relations; Stroop = Stroop Color-word interference; DS = Digit Symbol; TMTb = Trail Making Test b time.

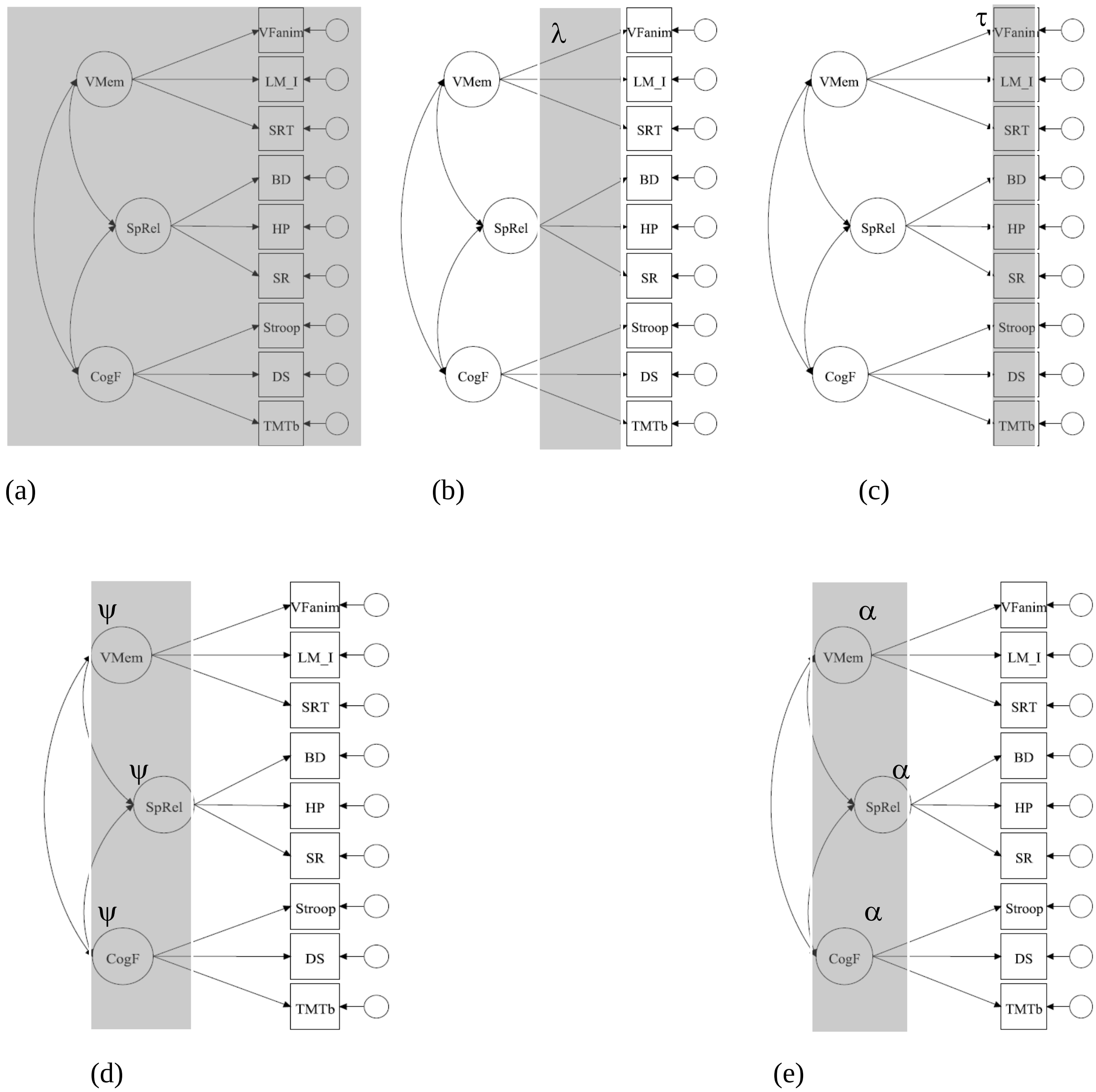


Figure 3. Schematic view of the multiple-group confirmatory factor analysis (MGCFA) models used to test measurement and structural measurement invariance across urban and rural regions. Shaded areas indicate the focus of comparison in each model. (a) Configural invariance, (b) Metric invariance, (c) Scalar invariance, (d) Variance invariance, and (e) Mean invariance.

Table 1

Summary of Studies Examining Rural and Urban Disparities in Cognition and Dementia

Authors	Year	Country	Type of study	Sample	Definition of settings	Outcome variables	Findings
Cassarino et al.	2015	Ireland	Cross-sectional study	N = 3,765 50+ years	Urban = Dublin Other settlements = [1,500 – 200,000] habitants Rural = <1,500 habitants	Comprehensive neuropsychological battery	Poorer cognition for rural, but faster RT. Childhood rural residence related to poorer cognition.
De Souto Barreto et al.	2014	France	Cross-sectional study	N = 6,275 Mean age = 86.0 (8.2) years	Rural < 2,000 inhabitants Low urban [2,000 – 10,000] Intermediate urban [10,000 – 100,000], or High urban >100,000 inhabitants.	Behavioral and psychological symptoms of dementia (BPSD) scale.	High-urban areas had the highest prevalence of dementia and BPSD, while rural had the lowest prevalence of BPSD.
Gonçalves-Pereira et al.	2017	Portugal	Cross-sectional study (10/66 Dementia Research Group)	N = 1,405	Rural and urban defined by geographic location: Rural near Evora, and Urban near Lisbon.	Geriatric Mental State, Cognitive test battery, physical and neurological examination, informant interview, NPI-Q Dementia diagnosis with 10/66 and DSM-IV	Higher prevalence of dementia with the 10/66 DRG algorithm then with the DSM-IV. Using 10/66 criteria, dementia prevalence was similar in both regions, but with DSM-IV

						research criteria	criteria, urban prevalence was double that in the rural region.
Guerchet et al.	Poster abstract	Central African Republic; Congo EPIDEMCA (Epidemiology of Dementia in Central Africa)	Cross-sectional study (10/66 DRG)	N = 2,004	Rural and urban defined by geographic location (for both CAR and Congo)	10/66 diagnostic algorithm and DSM-IV criteria	Using DSM-IV criteria, there was a higher prevalence of dementia in the rural CAR, compared to the urban site.
Hall et al.	2000	U.S.A.	Cross-sectional study	N = 223 African American only	Combination of self-report and US Census criteria (rural < 2,500 and urban > 2,500 inhabitants). Childhood residence: report of rural/urban residence to age 19.	Community Screening Interview for Dementia (CSI "D")	Individuals with low education (less than 7 years) and rural residence in childhood had the highest risk of developing AD. Low education did not increase risk in the urban area, while it was a significant risk factor in the rural area.
Jia et al.	2014	China	Cross-sectional survey	N = 10, 276	Rural and urban defined by geographic location (census data)	Neuropsychological battery, DSM-IV diagnostic criteria	Higher prevalence of dementia and AD in the rural population. Identified risk factors were manual labor and nonsmoking in urban population, and being a woman, illiteracy and living in the

							south for rural population.
Lin, Lai, Tai et al	1998	Taiwan					
Ma	2016 Poster	China	Cross-sectional study	N = 7,900	Rural and Urban communities in Shanghai	Mini-mental state examination	No differences between rural and urban prevalence rates of cognitive impairment. However, the risk factors associated to CI differed by region (urban: age, lack of physical activities, diabetes; rural: women, exposure to pesticides, encephalitis/meningitis, head truma.
Maillet et al.	Poster abstract	France	Cross-sectional study	N = 2,129, illiterate and low education individuals	By geographic region	Episodic memory tests with no written language	Rural and urban differences were found among the cognitively normal and demented groups. No indication of the direction of the findings.
Radford et al.	2015	Australia	Cross-sectional study	N = 336 Aboriginal Australians	Urban (metropolitan Sydney) and Remote (coast of New South Wales) areas defined by the	Dementia screening tests; consensus panel for diagnosis	Aboriginal prevalence rates of dementia were higher than those previously found for general Australian population. Comparable rates of

					census data (Australian Bureau of Statistics).		dementia between urban/regional and remote population.
Raina et al.	2014[a]	India	Cross-sectional study	N = 2,000	Migrant, Urban, Rural and Tribal areas	Hindi cognitive screening battery	Urban population had higher prevalence of dementia than rural population. The tribal rate of dementia was low. Less urbanized areas have lower dementia prevalence.
Raina et al.	2014[b]	India	Cross-sectional study (follow-up study)	N = 2,000	Migrant, Urban, Rural and Tribal areas	Hindi cognitive screening battery	Literacy was not a predictor of dementia. Dementia was more prevalent in urban than in rural areas.
Sharma et al.	2013	India	Cross-sectional study	N = 400	Urban and rural defined by geographic location.	MMSE	Prevalence of cognitive impairment has higher in rural than in urban, but not significant. Age, widowhood and illiteracy increased risk for cognitive impairment.
St. John et al.	2016	Canada	Longitudinal study, with cross-sectional analysis	N = 3,223	By census data: urban areas (>19,999 inhabitants); rural areas (< 20,000 inhabitants).	Modified Mini-Mental State Examination, with DSM-III criteria	3MS scores were not different between the rural and urban groups, after adjusting for confounding factors. No effect of rurality on the

							risk of having dementia, over a 5-year period.
Tang et al.	2016	China	Cross-sectional study	N = 7,900	Geographic location	MMSE, and risk factors (BMI, waist-to-hip ratio)	No difference between rural and urban prevalence of cognitive impairment. Risk factors for the rural population were: female gender, exposure to pesticides, head trauma, encephalitis/meningitis; while for the urban region: diabetes, having more than 2 children and physical inactivity.
Wackerbarth et al.	2001	U.S.A.	Cross-sectional study	N = 956	Geographic location. Rurality was defined by patients seen in a satellite clinic of the Kentucky ADRC.	MMSE, IADLs, ADLs, Blessed Dementia Rating Scale, Revised Memory and Behavior Problems Checklist.	Adjusted MMSE scores and ADLs/IADLs were equivalent in urban and rural regions. Urban family members reported more memory and personality changes.
Weden et al.	2017	U.S.A.	Cross-sectional multicohort study (Health and Retirement Study)	N = 16,386 (time 1) N = 16,311 (time 2)	Based on geographic location and population density requirements from the U.S. Census Bureau	Telephone Interview for Cognitive Status	Dementia was more prevalent in rural than urban regions. Rural/urban differences in race/ethnicity and educational attainment may explain the disparity.

Table 2

List of Neuropsychological Tests Administered in the EDAD Study

Cognitive Measure	Operationalization
Global cognition	
MMSE	Total score (0-30)
BNT	Total (0-30)
Attention	
TMT-A	Completion time (in seconds)
Crossing off	Completion time (in seconds)
Memory	
LM Immediate recall	Number of words (0-25)
LM Delayed recall	Number of words (0-25)
Selective Reminding Test	
Free recall	Number of words from trial 1 to trial 3
Cued recall	Number of words from trial 1 to trial 3
Visuospatial processing	
Space relations	Number of correct responses
Paper folding test	Number of correct responses
Hidden patterns	Number of correct responses
Block design	Number of correct responses
Executive functions	
Verbal Fluency	Number of animals and vegetables provided
Digit Symbol	Number of correct responses
TMT-B	Completion time (in seconds)
Stroop	Number of correct responses (interference)
Identical pictures	Number of correct responses

Table 3

Demographic Characteristics and Descriptive Statistics of the Neuropsychological Battery.

Sample	Urban (N = 181)	Rural[a] (N = 114)	Skewness (SE)	Kurtosis (SE)	Shapiro-Wilk p-value	
					Urban	Rural
Characteristic, mean (SD)						
Age, years	67.6 (5.54)	70.51 (6.34)**				
Education	13.96 (6.52)	10.2 (5.57)**				
Female (%)	136 (75.1%)	91 (79.8%)[b]				
MMSE	28.98 (1.45)	27.70 (1.92)**				
Observed variables, mean (SD)						
LM – I	9.88 (3.24)	8.34 (2.88)**	.587 (.142)	.725 (.283)	.001	< .001
LM – II	9.87 (3.89)	6.99 (2.96)**	.874 (.142)	1.412 (.283)	< .001	.005
VF – Ani	19.48 (4.35)	18.57 (5.10)	.107 (.142)	-.228 (.284)	.153	.159
VF – Veg	14.23 (3.98)	12.94 (3.90)*	.307 (.142)	.612 (.284)	.094	.052
BNT	26.03 (3.54)	22.86 (4.40)**	-.928 (.142)	.585 (.283)	< .001	.001
SRT	46.81 (2.30)	46.99 (2.43)	-1.724 (.142)	7.095 (.283)	< .001	< .001
TMT-A	55.85 (21.71)	83.94 (37.6)**	1.649 (.142)	4.087 (.284)	< .001	< .001
TMT-B	140.09 (68.9)	172.8 (67.7)**	.884 (.153)	.079 (.306)	< .001	< .001
DS	35.70 (10.18)	24.23 (11.4)**	-.005 (.142)	-.593 (.283)	.314	.012
BD	26.17 (10.22)	19.20 (9.29)**	.663 (.142)	.691 (.284)	< .001	.007
Stroop	29.91 (9.71)	23.78 (9.18)**	.774 (.142)	2.919 (.284)	< .001	.020
Crossing	59.87 (26.40)	72.69 (29.5)**	2.618 (.142)	8.306 (.283)	< .001	< .001
SR	8.74 (3.56)	6.75 (2.95)**	.312 (.144)	-.244 (.287)	.013	.005
HP	45.82 (23.53)	32.43 (22.3)**	.854 (.145)	.880 (.288)	< .001	< .001
PF	4.33 (2.49)	2.83 (1.53)**	1.261 (.152)	2.472 (.303)	< .001	< .001
IP	30.36 (9.01)	21.93 (7.72)**	1.223 (.142)	7.770 (.284)	< .001	.246

Note. Skewness and kurtosis values above the cutoffs indicate the measures have non-normal distribution (in boldface). For the Shapiro-Wilk test, p-values < .05 suggest that the data are not normally distributed.

[a]Asterisks indicate p-values for t-test comparisons of urban vs. rural. [b]The X^2 statistic was used to compare the number of female vs. male participants by region, $X^2 = .87$, p > .05

* p <.05. ** p <.001

Table 4

Correlation Matrix of Neuropsychological Tests, by Urban and Rural (in cursive) Regions

	1.	2.	3.	4.	5.	6.	7.	8.
1. BNT	1	*.448***	*.399***	*.463***	*.249***	*.211**	*.298***	*-.290***
2. LMI	.233**	1	*.865***	*.453***	*.218**	*.09*	*.181*	*-.144*
3.LMII	.170*	.636**	1	*.414***	*.292***	*-.024*	*.169*	*-.270***
4. VF ani	.351**	.263**	.216**	1	*.281***	*.145*	*.291***	*-.331***
5. VF veg	.119	.079	.07	.324**	1	*.013*	*.044*	*-.05*
6. SR	.155*	.096	-.042	.172*	-.032	1	*.016*	*-.049*
7. PF	.202**	.082	.131	.310**	-.149	.469**	1	*-.161*
8. Crossing	-.146*	-.149*	-.131	-.133	.003	-.03	-.184*	1
9. BD	.359**	.227**	.105	.355**	-.052	.393**	.493**	-.186*
10. HP	.381**	.225**	.176*	.358**	.008	.391**	.460**	-.258**
11. IP	.334**	.077	.071	.291**	-.009	.314**	.401**	-.153*
12. DS	.401**	.187*	.089	.340**	.051	.281**	.306**	-.243**
13. Stroop	.402**	.114	.085	.347**	.199**	.243**	.290**	-.053
14. TMT-A	-.346**	-.09	-.041	-.199**	.034	-.270**	-.273**	.181*
15. TMT-B	-.535**	-.168*	-.143	-.288**	-.12	-.271**	-.287**	.196**
16. SRT	.317**	.146	-.063	.255**	.147*	.132	.082	-.044

Note. Pearson correlations between all neuropsychological measures for the rural sample are presented in cursive in the upper-right side of the table.

* p < .05

** p < .001

Table 4

Continued

	9.	10.	11.	12.	13.	14.	15.	16.
1. BNT	*.538****	*.463****	*.536****	*.639****	*.457****	-*.577****	-*.440****	*.290****
2. LMI	*.510****	*.338****	*.431****	*.555****	*.544****	-*.449****	-*.427****	*.203***
3.LMII	*.508****	*.348****	*.420****	*.550****	*.531****	-*.478****	-*.419****	*.230***
4. VF ani	*.423****	*.437****	*.228***	*.445****	*.344****	-*.407****	-*.471****	*.183*
5. VF veg	*.172*	*.168*	*.247****	*.339****	*.128*	-*.223***	-*.141*	*.266****
6. SR	*.101*	*.159*	*.207***	*.078*	*.016*	-*.231***	-*.187*	*.084*
7. PF	*.270***	*.368****	*.283***	*.302****	*.173*	-*.234***	-*.251***	*.184*
8. Crossing	-*.313****	-*.263****	-*.402****	-*.444****	-*.309****	*.446****	*.13*	-*.119*
9. BD	1	*.697****	*.586****	*.681****	*.499****	-*.556****	-*.612****	*.273****
10. HP	.635**	1	*.566****	*.649****	*.538****	-*.561****	-*.467****	*.185*
11. IP	.460**	.540**	1	*.743****	*.551****	-*.660****	-*.596****	*.172*
12. DS	.546**	.588**	.627**	1	*.629****	-*.740****	-*.693****	*.231***
13. Stroop	.467**	.457**	.474**	.472**	1	-*.542****	-*.450****	*.161*
14. TMT-A	-.451**	-.426**	-.497**	-.494**	-.340**	1	*.698****	-*.297****
15. TMT-B	-.413**	-.454**	-.449**	-.524**	-.417**	.497**	1	-*.066*
16. SRT	.276**	.213**	.151*	.343**	.221**	-.245**	-.361**	1

Note. Pearson correlations between all neuropsychological measures for the rural sample are presented in cursive in the upper-right side of the table.

* p < .05

** p < .001

Table 5

Factor Structure for the Three-Factor Model Identified with EFA

Variable	Factor 1	Factor 2	Factor 3
BNT	0.551	**0.710**	**0.537**
LM-I	0.402	0.434	**0.467**
VF – Ani	0.463	0.434	**0.582**
SRT	0.214	0.305	**0.316**
BD	**0.820**	0.673	0.396
SR	**0.472**	0.382	0.103
PF	**0.630**	0.438	0.215
HP	**0.831**	0.646	0.345
DS	0.752	**0.829**	0.407
Stroop	0.623	**0.623**	0.401
TMT – A	-0.635	**-0.831**	0.262
TMT – B	-0.658	**-0.865**	-0.461

Table 6

CFA Baseline Three-Factor Model

CFA model	χ^2	*df*	*p*	RMSEA [CI 90%]	TLI	CFI
Overall Sample	17.65	24	0.82	0.000 [0.000-0.030]	1.01	1.00
Urban Sample	18.54	24	0.10	0.000 [0.000-0.042]	1.02	1.000
Rural Sample	37.77	24	0.04	0.071 [0.018-0.112]	0.945	0.963

Note. RMSEA = root mean square error approximation; TLI= Tucker-Lewis index; CFI = comparative fit index.

Table 7

Model Fit Test Statistics and Indices for Model Comparisons Across Regions

Invariance model	χ^2	*df*	*p*	RMSEA	TLI	CFI	$\Delta\chi^2$ *(df, p)*	ΔRMSEA	ΔTLI	ΔCFI
Measurement Invariance Model										
Model 1 *Configural*	56.3	48	0.192	0.034	0.984	0.989	-	-	-	-
Model 2 *Full Metric*	71.5	54	0.055	0.047	0.970	0.978	15.25 (6, 0.02)	0.013	0.014	0.011[a]
Model 2.1 *Partial metric*	60.6	52	0.193	0.033	0.985	0.989	4.3 (2, 0.11)	0.001	0.001	0.000[b]
Model 3 *Full Scalar*	96.4	59	0.002	0.066	0.942	0.952	35.85 (7, 0.01)	0.033	0.043	0.037[a]
Model 3.1 *Partial scalar*	71.2	57	0.098	0.041	0.977	0.982	10.62 (5, 0.06)	0.008	0.008	0.007[c]
Structural Invariance Model										
Model 4 *Variance Invariance*	77.7	60	0.061	0.045	0.973	0.977	6.55 (3, 0.08)	0.004	0.004	0.005[d]
Model 5 *Mean Invariance*	155.9	63	0.001	0.100	0.865	0.882	78.1 (3, 0.01)	0.055	0.108	0.095[e]
Model 5.1 *VMem invariance*	79.1	61	0.06	0.045	0.973	0.977	1.33 (1, 0.24)	0.000	0.000	0.000[f]

Note. Model 5.1. constrained Verbal Memory only. [a]Model fit is not acceptable, invariance cannot be established. [b]Model fit for the partial metric model is acceptable, invariance can be established. When compared to the full metric model, model 2.1 improved its model fit, $\Delta\chi^2$ (df = 2) = 10.95, p < 0.004 and increased its fit indices (ΔRMSEA = 0.014, ΔTLI = 0.015; ΔCFI = 0.011). [c]Model fit for the partial scalar model is acceptable, invariance is established. When compared to the full scalar model, model 3.1 improved its model fit, $\Delta\chi^2$ (df = 2) = 25.23, p < 0.001 and fit indices (ΔRMSEA = 0.025, ΔTLI = 0.035; ΔCFI = 0.03). [d]Model fit for the structural variance invariance model is acceptable, invariance is established. [e]The mean invariance model is significant. It cannot assume that latent means are equal across groups. [f]Model fit for the Verbal Memory mean invariance model is acceptable, invariance holds. The model fits significantly better than the full mean invariance model. When compared to the full mean invariance model, model 5.1 improved its model fit, $\Delta\chi^2$ (df = 2) = 76.77, p < 0.001 and fit indices (ΔRMSEA = 0.055, ΔTLI = 0.108; ΔCFI = 0.095).

Table 8

Factor Loadings (λ), Intercepts (τ), Latent Means (α), Latent Variances (ψ) and Effect Sizes (R^2) from the Final Structural Invariance Model Tested across Regions.

Latent variable	Observed variable	Urban λ (SE)	Urban τ (SE)	Urban R^2	Rural λ (SE)	Rural τ (SE)	Rural R^2
Verbal Memory	LM-I	0.502 (0.053)	**3.013 (0.172)**	0.25	0.616 (0.066)	3.149 (0.195)	0.38
	VF-anim	0.641 (0.060)	4.323 (0.227)	0.41	0.573 (0.058)	3.867 (0.225)	0.33
	SRT	0.399 (0.067)	20.713 (1.025)	0.16	0.363 (0.060)	18.838 (1.217)	0.13
	α_{VMem}		0.000			0.000	
	ψ_{VMem}		1.000			1.000	
Spatial Reasoning	BD	0.792 (0.032)	2.528 (0.128)	0.63	0.872 (0.032)	2.783 (0.155)	0.76
	HP	0.792 (0.034)	1.987 (0.109)	0.63	0.814 (0.034)	2.044 (0.125)	0.66
	SR	0.473 (0.066)	2.518 (0.154)	0.22	**0.148**^{ns} **(0.101)**	**2.407 (0.194)**	0.02^{ns}
	α_{SpR}		0.000			**-0.764**	
	ψ_{SpR}		1.000			1.000	
Cognitive Flexibility	Stroop	0.602 (0.040)	3.134 (0.145)	0.36	0.675 (0.042)	3.513 (0.193)	0.46
	DS	0.842 (0.028)	3.202 (0.160)	0.71	0.864 (0.032)	3.284 (0.166)	0.75
	TMT-b	-0.704 (0.039)	1.997 (0.121)	0.50	-0.776 (0.044)	2.198 (0.145)	0.60
	α_{CogF}		0.000			**-1.081**	
	ψ_{CogF}		1.000			1.000	

Note. The final structural model was the mean invariance model that constrained the latent mean of Verbal Memory equal across groups, while freely estimated the latent means for Spatial Reasoning and Cognitive Flexibility. Factor loadings (λ), intercepts (τ), and latent means (α) that were freely estimated are bolded. All latent variances (ψ) were set to 1.0 as they were tested to be invariant.

^{ns}Not significant parameters ($p > 0.05$). All other parameters were significant at $p < .001$

Table 9

Model Fit Test Statistics and Indices for Model Comparisons Across Regions with Age and Education as Covariates

Invariance model	χ^2	*df*	*p*	RMSEA	TLI	CFI	$\Delta \chi^2$ *(df, p)*	ΔRMSEA	ΔTLI	ΔCFI
Measurement Invariance Model										
Model 1 *Configural*	82.52	72	0.19	0.032	0.982	0.988	-	-	-	-
Model 2 *Full Metric*	99.25	78	0.053	0.043	0.967	0.976	16.73 (6, < 0.01)	0.011	0.015	0.012[a]
Model 2.1 *Partial metric*	88.00	76	0.16	0.033	0.981	0.987	5.478 (4, 0.24)	0.001	0.001	0.001[b]
Model 3 *Full Scalar*	126.2	83	0.002	0.060	0.938	0.952	38.21 (7, .001)	0.027	0.043	0.035[a]
Model 3.1 *Partial scalar*	96.21	81	0.12	0.036	0.978	0.983	8.21 (5, .145)	0.003	0.003	0.004[c]
Structural Invariance Model										
Model 4 *Variance Invariance*	90.47	83	0.27	0.024	0.989	0.992	5.74 (2, 0.06)	0.012	0.011	0.009[d]
Model 5 *Mean Invariance*	96.55	86	0.205	0.029	0.985	0.988	6.07 (3, 0.108)	0.005	0.004	0.004[e]

Note. All measurement (full and partial) and structural models include age and education as covariates. [a]Model fit is not acceptable, invariance does not hold. [b]Model fit for the partial metric model is acceptable, invariance holds. The partial metric model fits significantly better than the full metric model. When compared to the full metric model, model 2.1 improved its model fit, $\Delta\chi^2$ (df = 2) = 11.25, p = 0.004 and increased its fit indices (ΔRMSEA = 0.010, ΔTLI = 0.014; ΔCFI = 0.011). [c]Model fit for the partial scalar model is acceptable, invariance holds. The partial scalar model fits significantly better than the full scalar model. When compared to the full scalar model, model 3.1 improved its model fit, $\Delta\chi^2$ (df = 2) = 11.25, p < 0.001 and fit indices (ΔRMSEA = 0.024, ΔTLI = 0.040; ΔCFI = 0.031). [d]Model fit for the structural variance invariance model is acceptable, invariance holds. [e]The mean invariance model is not significant. It assumes that latent means are equal across groups. Latent mean invariance across regions is established.

Table 10

Factor Loadings, Intercepts (standard errors in parentheses) and Effect Sizes (R^2) from the Final Structural Invariance Model Tested across Regions, with Age and Education as Covariates

Latent variable	Observed variable	Urban			Rural		
		λ (SE)	τ (SE)	R^2	λ (SE)	τ (SE)	R^2
Verbal Memory	LM-I	0.472 (0.056)	**4.208 (0.513)**	0.22	0.676 (0.065)	4.425 (0.595)	0.46
	VF-anim	0.609 (0.072)	5.970 (0.667)	0.37	0.630 (0.061)	4.974 (0.571)	0.41
	SRT	0.308 (0.062)	21.826 (1.086)	0.16	0.353 (0.068)	19.858 (1.297)	0.12
	α_{VMem}		0.000			0.000	
	ψ_{VMem}		1.000			1.000	
Spatial Reasoning	BD	0.769 (0.036)	4.427 (0.624)	0.59	0.890 (0.030)	4.364 (0.623)	0.79
	HP	0.768 (0.037)	3.864 (0.629)	0.59	0.840 (0.033)	3.600 (0.593)	0.71
	SR	0.448 (0.064)	3.597 (0.406)	0.20	**0.115** ^{ns} **(0.116)**	**2.596 (0.358)**	0.01^{ns}
	α_{SpR}		0.000			0.000	
	ψ_{SpR}		1.000			1.000	
Cognitive Flexibility	Stroop	0.526 (0.043)	4.960 (0.447)	0.28	0.722 (0.041)	4.790 (0.441)	0.52
	DS	0.803 (0.033)	6.112 (0.624)	0.65	0.933 (0.020)	4.988 (0.546)	0.87
	TMT-b	-0.651 (0.042)	0.052^{ns} (0.510)	0.42	-0.835 (0.036)	0.047^{ns} (0.460)	0.70
	α_{CogF}		0.000			0.000	
	ψ_{CogF}		1.000			1.000	

Note. The final structural model was the mean invariance model with all latent means constrained equal across groups. Factor loadings (λ) and intercepts (τ) that were freely estimated are bolded. All latent variances (ψ) were set to 1.0 as they were tested to be invariant.

^{ns}Not significant parameters ($p > 0.05$). All other parameters were significant at $p < .001$

Table 11

Regression Coefficients (SE) and Effect Sizes (R^2) of Latent Cognitive Constructs on Age and Education, by Region.

	Age		Education		R^2	
	Urban	Rural	Urban	Rural	Urban	Rural
Verbal Memory	-0.239 (0.080)	-0.237 (0.109)	0.283 (0.098)	0.562 (0.098)	0.152	0.464
Spatial Reasoning	-0.233 (0.063)	-0.212 (0.091)	0.247 (0.078)	0.551 (0.079)	0.128	0.368
Cognitive Flexibility	-0.324 (0.058)	-0.272 (0.068)	0.374 (0.070)	0.688 (0.055)	0.272	0.640

Note. All regression coefficients were significant at a p-value < .05. The effect sizes of each latent cognitive construct include age and education, as they were included simultaneously in the model.

Table 12

Correlations (SE) between the Latent Cognitive Constructs, by Region and Models Tested.

	Verbal Memory		Spatial Reasoning	
	Urban	Rural	Urban	Rural
Region comparison				
Spatial Reasoning	0.711 (0.086)	0.790 (0.095)	-	-
Cognitive Flexibility	0.765 (0.090)	0.907 (0.081)	0.866 (0.046)	0.879 (0.048)
Age and Education as covariates				
Spatial Reasoning	0.616 (0.109)	0.614 (0.148)	-	-
Cognitive Flexibility	0.625 (0.120)	0.743 (0.142)	0.849 (0.063)	0.783 (0.090)

Note. All correlations were significant at a p-value < .001