Published in final edited form as:

Curr Opin Psychiatry. 2019 May ; 32(3): 210–217. doi:10.1097/YCO.0000000000000490.

Impact of Urbanization on Cognitive Disorders

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Abstract

Purpose of review—Cognitive disorders remain a major global burden with an estimated 47 million people living with dementia worldwide. Rates of cognitive disorders are expected to grow, especially as the global population ages. Global trends also indicate that about half of the global population lives in urban settings. To help guide future research, as well as the development of targeted and tailored interventions to prevent and care for people living with cognitive disorders, we present an up-to-date review and summary of the literature examining cognitive disorders and urbanization.

Recent findings—We reviewed the literature between January 2017 and September 2018 on cognitive disorders and urbanization. We found that rates of dementia among urban dwellers tends to be lower than those of rural dwellers. Leading theories explaining this difference tend to focus on better access to higher quality education, as well as public and health services among urban dwellers. We also found that greater exposure to air and noise pollutants may negatively impact cognition.

Summary—The reasons why older adults living in urban settings appear to have lower rates of dementia and better performance on cognitive measures are not well understood. Furthermore, the definitions of urban and rural and, cognitive disorder, as well as how they are measured vary greatly between studies, making comparisons difficult.

Keywords

Dementia; cognitive disorders; cognitive impairment; urbanization

INTRODUCTION

Cognitive disorders, also known as neurocognitive disorders, typically affect the abilities of learning, memory, perceptual-motor function, language, attention, and problem solving. Classified as mental health disorders in the Diagnostic and Statistical Manual of Mental

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Conflicts of interest.

None.

Disorders [1], neurocognitive disorders include delirium, mild neurocognitive disorder, and major neurocognitive disorder (i.e., dementia).

Globally, an estimated 47 million people are living with dementia, over half of whom live in low-and-middle income countries (LMICs) [2]. The number of people living with dementia is expected to increase three-fold by 2050 [2]. This is also the case for mild cognitive impairment, where prevalence rates have been estimated to range from 1% to 38% across countries and different studies [3–5]. The worldwide cost of dementia alone, in 2015, was estimated to be 818 billion US dollars [6].

Dementia and mild neurocognitive impairment typically affect older adults with the risk of having either greatly increasing at 65 years of age and older [2,7]. Mild and major neurocognitive disorders also can occur as a consequence of other disease processes. For example, neurocognitive impairment is commonly observed in people living with HIV. Prevalence rates of HIV-associated neurocognitive disorders have been estimated to occur in about 50% of people living with HIV [8].

While prevalence of cognitive disorders is on the rise globally, there is strong evidence to support a variety of prevention strategies. Recent studies and review articles have identified a range of modifiable risk factors for dementia [2,9–12]. The most commonly identified and studied modifiable risk factors are: cardiovascular/cerebrovascular factors (reducing: hypertension, smoking, obesity, and hyperhomocysteinemia); metabolic factors (controlling: diabetes and metabolic syndrome symptomology); dietary factors (increasing: folate and vitamin B12 levels); psychiatric factors (reducing: depression and social isolation); lifestyle factors (increasing physical activity, particularly among those with low activity levels); and educational factors (increasing education) [2,9–12]. Non-modifiable factors include: age, genetics (e.g., APOE4) and family history of dementia.

It is now estimated that over half of the world's population lives in urban settings [13]. Research on urbanization indicates that there is a global shift towards the rapid development and expansion of urban centers [14,15]. This rapid expansion often leads to more densely populated areas with closer proximity to industrial facilities and transportation infrastructure (e.g., motorways and bus depots) with high rates of poverty, poor environmental conditions (e.g., contaminated water sources, poor sewage management, and housing adjacent to major motorways), and a lack of social services for its residents [16,17]. Research indicates that living in such conditions can negatively impact individual health [17,18].

The relationship between urbanization and cognitive disorders, however, mostly suggests the opposite – people living in urban centers are less likely to develop cognitive disorders (i.e., dementia) compared to those in rural areas [19–26]. However, there are some caveats. Evidence has established a relationship between greater exposure to air pollution (i.e., particulate matter) and traffic related pollutants to higher risk of developing dementia [27,28]. Exposure to these pollutants tends to be higher in urban centers [16,17]. The purpose of this review was to examine the most recent research on the relationship between cognitive disorders and urbanization.

Recent Reports on Dementia, Urbanization, and Pollutants

Studies published between January 2017 and September 2018 are presented for review and summarized below (see Table 1). These investigations examined the relationship between urbanization and cognitive disorders spanning seven middle to high income countries: Canada [29,30], China [31], England [32], Ireland [33], Mexico [34*], Spain [35] and USA [36–38]. There are no recent data from low-income settings. With the exception of Chen *et al.* [30] who assessed the effects of pollutants on cognition, all the above studies assessed the relationship between urban and rural dwelling, and cognitive outcomes, but varied in how they defined urbanization and cognition, as well as the statistical methods used to analyze this relationship.

Urbanization

How urbanization was operationalized and measured varied greatly between studies and it is not clear whether specific factors of urbanization are relevant to the incidence or progression of cognitive disorders (such as pollution, over-crowding, or stress) or a combination of these factors. One of the more common approaches to define urban versus rural was to describe communities with >2500 residents as urban [29,34*,36]. Other methods included a range of densities from very low to very high based on persons per hectare [33]. Yet another approach considered cities, and bordering and outlying areas (i.e. geographical contiguity) combined with minimum population size, to define densely populated areas (cities and large urban areas), and intermediate-thinly populated areas (towns, suburbs and rural areas) [35]. Other studies used governmental definitions based on Census data of rural and urban and also examined migration patterns (rural-to-urban, and urban-to-rural) [31,37].

Cognitive Disorders

We noted that most studies did not explicitly define cognitive disorder. Studies referred to: probable dementia and cognitive impairment without dementia [37], dementia [30,36], Alzheimer's disease [36], possible/probable Alzheimer's disease, vascular dementia or other types of dementia, non-demented [29], cognitive function [31,32,34*], cognitive impairment [32,35], mild cognitive impairment (MCI) [38], and cognitive health [33]. Measurement of cognition was highly varied. Assessments ranged from brief screening instruments, full neuropsychological test batteries, telephonic assessment, and database-driven methods (see Table 1 for details). Six studies relied primarily on screening tools: Mini-Mental State Examination (MMSE) [31–33,35], Modified Mini Mental State (3MS) examination [29], and the Montreal Cognitive Assessment and the Color Trails Test [33]. Two studies utilized neuropsychological test batteries [36,38]. Weden *et al.* [37] used a 27-point modified Telephone Interview for Cognitive Status. Saenz *et al.* [34*] used the Cross-Cultural Cognitive Examination assessing five cognitive domains. One study determined dementia incident diagnosis using validated databases as opposed to cognitive testing [30]. The wide variety of cognitive disorder and impairment definitions and the range of tools used make comparison and summary challenging.

Relationship between Urbanization and Cognitive Disorders

Findings regarding the relationship between neurocognitive status and urbanization were varied, although many studies suggest an association between worse cognition or increased rates of dementia in non-urban (or rural) persons. Some of these associations were complicated by moderating and mediating factors. Hendrie *et al.* [36] found that overall, older individuals with higher education were protected against Alzheimer's disease. There was an interaction effect whereby higher education was protective for persons growing up in rural areas, but had no effect in urban upbringing. Weden *et al.* [37] found higher risk for dementia and cognitive impairment without dementia in rural participants at baseline, but similarly to Helmes and Van Gerven [29] these findings did not reach significance in the 10-year follow-up. Educational attainment may have served as a protective factor; larger gains in rural adults' cognitive functioning was associated with increased educational attainment. However, adjustment for sociodemographic and health factors revealed persistent rural disadvantages for dementia and cognitive impairment among rural groups. Similarly, Cassarino *et al.* [33] found that, after controlling for demographic, health, and lifestyle factors their middle age to older adult participants in medium to very high urban areas had better cognitive functioning than those living in very low urban areas. Saenz *et al.* [34*] found that respondents living in rural areas performed worse across five cognitive domains and that historical educational disadvantage in rural areas may account for this. Xu *et al.* [31*] assessed rural-to-urban and urban-to-rural migration. They found that rural-to-urban migrants and rural residents had higher levels of cognitive functioning at baseline, but rural-to-urban migrant residents demonstrated faster cognitive decline than urban residents. Overall, compared to urban residents, rural residents had better cognitive functioning at baseline but faster rates of cognitive decline. There were no differences between urban-to-rural migrants and urban residents in terms of cognitive decline or function.

More complex relationships were identified when defined aspects of urbanization were explored in the Wu *et al.* [32] study. Individuals living in low and higher land use areas had increased odds of cognitive impairment, suggesting that factors associated with both under- and over-stimulation might be detrimental. Chen *et al.* [30] reported that closer proximity to heavy traffic was associated with higher dementia incidence, suggesting an effect of noise and pollution.

Three studies did not find a significant relationship between degree of urbanization, and cognitive status [29,35,38], although in one [35] there was a delayed onset of disorder from symptoms. In this study, the construct of "occupational cognitive demand" was protective against the development of dementia, but the authors note that factors such as education need to be considered.

The impact of urbanization on cognition is complex and may be mediated by several variables, for example sociodemographic factors [36] such as education and quality of education [34*,37,39,40], allocation of- and access to public resources [35] and childhood and adulthood living environments [31]; environmental factors such as air pollution and noise pollution [30]; health factors such as allocation of- and access to health care facilities and better cardiovascular treatment [36,41]; occupation [35]; and environmental conditions/design [32]. Regarding education, the most common variable reported within the context of

urbanization across studies - some suggest that higher education is protective against dementia [42] and that investment in education should be prioritized, especially in rural areas, however, it has also been suggested that promoting a healthy lifestyle may be a more successful approach to preventing cognitive decline [29].

CONCLUSION

Consistent with previous research on the relationship between urbanization and cognitive disorders, our review also indicated that living in an urban center appears to reduce risk for developing cognitive disorders, though the exact reasons why are not well understood. Our review indicated that older adults living in rural areas were more likely to have poorer cognition than their counterparts in urban centers. Likely reasons for this relationship are due to differences in education where residents in rural areas: may begin schooling at a later age, receive less or a poorer quality of education, and have limited access to social and health services than those living in urban centers. Yet, there is evidence supporting a link between exposure to pollutants (which may be more common in urban centers) and poorer cognition. One study suggested that highly dense or urbanized living might result in overstimulation and cognitive decline on that basis.

Variability in how urbanization is operationalized and how cognitive disorders are assessed and categorized poses challenges in understanding the relationship between urbanization and cognition. Inconsistent measurement, or lack thereof, of key components of urbanization (e.g., pollution) and cognition (e.g., screening tests vs. full neuropsychological batteries), as well as limited data from LMICs that shoulder the greatest burden of dementia makes the development of causative theories or prevention strategies difficult. Where relevant, future studies should build on existing cohorts and use similar tools for comparative purposes. While factors potentially impacting the relationship between urbanization and cognition are myriad and complex, future research should attempt to account for these factors where possible by using consensus definitions and assessment methods. There is also a need for studies assessing the impact of urbanization on cognition in LMICs.

Acknowledgements

Financial support and sponsorship

Reuben N. Robbins is supported by the National Institute of Child Health and Human Development under Grant R01-HD095256; the National Institute of Child Health and Human Development under Grant R21-HD098035; the National Institute of Mental Health to the HIV Center for Clinical and Behavioral Studies at NY State Psychiatric Institute and Columbia University under Grant P30-MH43520.

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Key Points

- Cognitive disorders, in particular dementia, are a major burden that affect upwards of 47 million people, most who residing in low- and middle-income countries. Cognitive disorders typically affect older adults (>65 years), though other disease factors (such as HIV) can impair cognition at any age.
- Global trends indicate rapid expansion and development of more densely populated areas with closer proximity to industrial facilities and transportation infrastructure (e.g., motorways and bus depots) with high rates of poverty, poor environmental conditions (e.g., contaminated water sources, poor sewage management, and housing adjacent to major motorways), and a lack of health and public services for its residents.
- Older adults living in rural areas tend to perform worse on measures of cognitive functioning than those in urban areas, with rates of dementia being higher in rural areas. The reasons for this are not well understood, but less and poorer education, less access to health care and other public resources are considered risk factors for dementia.
- There is evidence linking air and noise pollution to worse cognition.
- Additional research with more consistent definitions of urbanization and and consistent definitions and measurements of cognitive disorders is need, particularly in low and middle income countries, to better understand how our rapidly urbanizing world is impacting our cognitive functioning.

Table 1.

Studies on the impact of urbanization on cognitive disorders from 2017–2018.

Author, Date	Location	Participants (N, Age, Years Education, Gender)	Purpose	Assessment of Urbanization	Cognitive Measure Used	General Findings	Limitations
Cassarino et al. 2018	Ireland	4127 Irish adults aged 50 and older Age: $M = 62.5$ years Education: $M = 46\%$ secondary education attainment Gender: 49.8% female.	To examine geographical variations in cognitive skills in older adults based on urbanization and disability status.	Six groups based on categories used in the Irish Census: (1) Very low: Less than 0.5 persons per hectare (i.e., less than one person every two hectares); (2) Low: Between 0.5 and 1 person per hectare; (3) Medium Low: Between 1 and 10; (4) Medium High: Between 10 and 25; (5) High: Between 25 and 50; (6) Very High: More than 50 persons per hectare.	Montreal Cognitive Assessment Test (MoCA); Mini Mental State Examination (MMSE); Color Trails 1 and 2.	After controlling for socio-demographic, health and lifestyle covariates, participants living in urban areas had better cognitive performance in all domains measured than those living in very low urban areas.	Young participants lacking important measures (e.g., of environmental accessibility or stressors) that might contribute to findings. Cross-sectional study that does not directly assess risk of future dementia.
Hendrie et al. 2018	USA, Indianapolis	African Americans aged 70 and older residing in Indianapolis, Indiana from 1992 ($n = 1,440$) and 2001 ($n = 1,835$). Age: 70 years old Education: $M = 9.3$ years (1992); $M = 11.4$ (2001) Gender: 66% female (1992 and 2001).	To explore possible association of childhood residence, education levels, and occupation with declining incidence rates of dementia in two cohorts of elderly African Americans.	Childhood residence: $>2500 =$ Urban; $<2500 =$ rural.	Community Screening Interview for Dementia (CSID) for initial screen. CSID evaluates the following cognitive domains: language, attention and calculation, memory, orientation, praxis, comprehension, and motor response. Full neuropsychological battery from Consortium to Establish a Registry of Alzheimer's Disease used to make the diagnosis of dementia along with neurologic and physical exam, structured interview, and consensus diagnostic conference.	Higher education level is significantly associated with reduced Alzheimer's disease risk in participants with childhood rural residence, but no association was found in those with urban residence.	Observational study that occurred in a very specific sample of African Americans who lived through a time of social and political upheaval. Did not account for several important variables: childhood family income, years of age at migration, and diet. Possible selection bias due to 2001 cohort having higher refusal rates than the 1992 cohort.
Saenz et al. 2018	Mexico	$N = 15,723$ Mexican older adults. Age: $M = 65.4$ years. Education: $M = 5.5$ years. Gender: 57% female.	To describe the differences in cognitive functioning across rural and urban areas among older Mexican adults.	Cut points based on standard values used by the Mexican statistical bureau to categorize rurality into four levels based on community size of residence: (a) 100 000+ residents as urban, (b) between 15 000 and 99 999 residents, (c) between 2500 and	Cross Cultural Cognitive Examination assessing five domains: verbal learning, verbal memory, verbal fluency, orientation, and attention.	Rural participants performed worse across 5 cognitive domains compared to urban participants.	Study did not examine role of rural to urban migration in present findings; and cognitive functioning over time.

Author, Date	Location	Participants (N, Age, Years Education, Gender)	Purpose	Assessment of Urbanization	Cognitive Measure Used	General Findings	Limitations
Weden et al. 2018	USA	Non-institutionalized U.S. adults from the 2000 ($n=16,386$) and 2010 ($n=16,311$) cross-sections of the Health and Retirement Study Age: 55 years old. Education: mostly high school educated. Gender: Mostly female across all groups.	To analyze rural-urban differences in the prevalence of cognitive impairment and dementia in a nationally representative US sample of older adult population, charting the trends in these urban-rural differentials and their socio-demographic determinants. Rural-urban disparities in the prevalence of probable dementia and cognitive impairment with dementia (CIND).	Determined the percentage urban composition by linking individuals' records in the public use HRS to the restricted-use HRS geographic data file. US Census Bureau and measurement protocols were used to calculate the percentage of the population in the tract that is designated by the Census Bureau as being rural or urban.	27 point modified Telephone Interview for Cognitive Status.	Higher risk for dementia and cognitive impairment without dementia in year 2000 rural participants, but these findings did not reach significance in year 2010 participants. Educational attainment served as a protective factor such that it eliminated rural disadvantage in the 2000 cohort. Adjustment for sociodemographic and health factors revealed persistent rural disadvantages for dementia and cognitive impairment without dementia for rural groups in both cohorts.	This study did not examine residential history and only used current residential status (i.e., rural or urban) at the time of testing. Used a self-report measure of cognitive functioning.
Chen et al. 2017	Ontario, Canada.	Population cohort including all adults aged 20-50 years ($N=4.4$ million) and adults aged 55-85 ($N=2.2$ million) who resided in Ontario, Canada on April 1, 2001. Education: 26% with less than high school (both cohorts). Gender: 50% female (50 cohort); 53% female (55-85 cohort).	To investigate the proximity to major roadways and the incidence of dementia, Parkinson's disease and multiple sclerosis.	Determined Canadian born individual's residential proximity to major roadways in Ontario based on their residential postal code for the year 1996. Using ArcGIS they created five distance categories: Less than 50m from major traffic road, 50-100m, 101-200m, 201-300m and more than 300m.	No measure used.	Living close to heavy traffic associated with higher incidence of dementia but not with Parkinson's disease or multiple sclerosis.	No method to examine undiagnosed cases of dementia, Parkinson's disease, or multiple sclerosis. No information about medication which could impact dementia risk. Postal code address method of determining exposure to higher traffic does not reflect personal exposure. No measure of cognitive status

Author, Date	Location	Participants (N, Age, Years Education, Gender)	Purpose	Assessment of Urbanization	Cognitive Measure Used	General Findings	Limitations
Helmes et al. 2017	Canada	N = 10,263 older Canadians. Age: <i>M</i> = 75.7 years. Education: <i>M</i> = 10.1 years. Gender: 60% female. Also analyzed three subsamples: clinically diagnosed dementia (<i>n</i> = 2,133), clinically confirmed non-dementia (<i>n</i> = 225), both non-demented and clinical status unknown (<i>n</i> = 8,130).	Rural or urban residence was addressed as a new proxy of cognitive reserve and compared with years of education as a predictor of age related cognitive decline.	Rural living was determined as living in a community of 2500 residents.	Modified Mini-Mental State (3MS) examination.	Urban residents and higher educated individuals performed better than rural less educated individuals at baseline, but groups performed similarly at 10 year follow-up.	High levels of attrition. One of only studies to include clinically diagnosed dementia patients. No examination of residential history, only current residence. Quality of cognitive measure (3MS) in detecting cognitive change over time
Lorenzo-López et al. 2017	Galicia, Spain	Representative sample of 65 year old Galician Spanish adults (<i>N</i> = 749). <i>n</i> = 375 densely populated areas (DPA); <i>n</i> = 374 intermediate to thinly populated areas (ITPA). Age: <i>M</i> = 76.3 (DPA); 75.2 (ITPA) Education: 8 years of education 44.8% (DPA); 75.7 (ITPA) Gender: 63.7% (DPA); 57.5% (ITPA).	To estimate the prevalence of cognitive impairment in rural and urban elderly populations and examine the relationship between lifetime occupation and general cognitive performance.	Defined by Task Force on Core Social Variable Group using a criterion of geographical contiguity in combination with a minimum population threshold.	Spanish Mini Mental State Exam adjusted for age and education with 24 being cognitively impaired.	Rural residence not associated with higher risk of cognitive impairment, but trend towards higher cognitive impairment in rural areas (7.8% cognitively impaired compared to 5.3% in urban areas). Only significant finding was lower risk for cognitive impairment in older adults who held occupations with higher cognitive skill.	Childhood residence not taken into account only current residence. Small sample size. Sample was only gathered from senior centers. Overall sample had very low levels of education and especially low levels in the rural group.
Matos et al. 2017	USA	Descriptive sample of older Appalachian adults (<i>N</i> = 289). Age: <i>M</i> = 74.6 years. Education: <i>M</i> = 15.4 years. Gender: 46.7% female.	To compare mild cognitive impairment (MCI) symptom severity among older rural and urban Appalachian adults with MCI at an initial neuropsychological testing visit.	Zip Code.	Neuropsychological composite scores across 4 domains: Memory (Wechsler Memory Scale-R Logical Memory IA – Immediate and Delayed), Language (Boston Naming Test and Category Fluency – animals or vegetables),	No differences found between rural and urban residents in terms of MCI symptom severity, but urban residents reported longer time lapse from symptom identification to	Small sample size. Only older adults who entered Alzheimer's disease centers. Overall sample had very high

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					Attention/Psychomotor Speed (Trail Making Test A, Wechsler Adult Intelligence Scale-Revised [WAIS-R] Digit Symbol Substitution Task [DSST], and Digit Span Forward), and Executive Functioning (Trail Making Test B and Digit Span Backwards).	diagnosis and rural adults presented with diagnosis earlier.	levels of education.
Wu et al. 2017	England	Community-based sample of 65 year old adults in UK (N = 7,505). Age: largest age band was 65-69 (n = 1,923). Education: 77.5% < 12 years of education. Gender: 53.9% female.	Cross sectional associations between features of land use and cognitive impairment and dementia, and also explored urban and rural differences in these associations.	Rural/Urban Classification for Small Areas Geographies provided rural/urban categories for all Lower-layer Super Output areas (LSOAs). Three urban categories: Major Conurbation (mean population density [PD]=35.5 people per hectare), Minor Conurbation (PD=22.6), City and Town (PD=16.5); and two rural categories: Town and Fringe (PD=5.9) and Village and Dispersed (PD=0.5).	Mini Mental State Exam (MMSE) 25 defined as cognitive impairment.	Odds of cognitive impairment slightly higher in rural areas than reference group. Living in areas of high land use mix was associated with 30% decreased odds of cognitive impairment and living in areas with high natural environment associated with 30% reduced odds of cognitive impairment. These high natural environment effects were seen only in urban areas.	Did not consider traffic as possible environmental factor. No information on recent relocation but 95% of sample reported living in the same area for > 5 years. Low prevalence of dementia in overall sample limits power to detect more nuanced effects.
Xu et al. 2017	China	Chinese longitudinal study with 5 bands of data (total N = 17,333). Age: M = 77.9 years. Education: M = 52.3% "no education" (<1 st grade). Gender: 49.6% female.	To assess the changes of cognitive function among older adults with different residential status (urban residents, rural-to-urban residents, rural residents, and urban-to-rural residents), over a 12 year period.	Categorical variables used to indicate rural, urban, rural-to-urban, and urban-to-rural residential location based on where participants were born and where they were living at the time the study was being conducted.	Chinese version of Mini Mental State Exam (MMSE) with lower score indicating poorer cognitive functioning	After accounting for above covariates rural to urban migrants and rural residents had higher level of cognitive functioning at baseline, but rural to urban migrant residents demonstrated faster cognitive decline than urban residents. Overall, rural residents had better cognitive functioning at baseline but fastest rate of decline compared to urban residents. There were no differences between urban to	No information about age at migration. Longitudinal nature of the study might mean some areas that were once rural are now urban. Most participants had very limited education (i.e., no education = less than 1 st grade).

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						rural migrant and urban residents in terms of cognitive decline or function.	