Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 89, No. 1
doi:10.1007/s11524-011-9621-2

Neighborhood Urban Form, Social Environment, and Depression

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ABSTRACT *We examined whether neighborhood urban form, along with the social environment, was associated with depressive symptoms in a sample of Miami residents. Using a validated measure of depressive symptoms, we found that living in neighborhoods with higher housing density was associated with fewer symptoms. A larger acreage of green spaces was also linked to fewer depressive symptoms but did not reach significance in the full model. Our results suggest that how residents use the environment matters. Living in neighborhoods with a higher density of auto commuters relative to land area, an indicator of chronic noise exposure, was associated with more symptoms.*

KEYWORDS *Urban form, Depression, Social environment, Mental health, Miami*

INTRODUCTION

Cities have long been seen as playing a powerful role in shaping the health of populations. The recent spike in studies linking neighborhood environments and population health, have focused mainly on physical health, with relatively few focusing on mental health. A substantial literature has established the association between neighborhood social environments and mental health[1] and depression in particular.[2] However, there are far fewer studies that address potential links between aspects of the built environment and mental health. Features of neighborhood environments may function as stressors or buffers of personal sources of stress related to mental illness.[2] Neighborhood economic deprivation or chronic exposure to neighborhood noise may function as stressors. Neighborhood-based social connections and access to green spaces on the other hand, may be protective of mental health.[2]

There is a need for further studies expanding our knowledge of potential benefits and harm to mental health associated with particular neighborhood environments and the policy and planning decisions that help shape them. In recent decades, a number of movements have emerged with the overall aim of creating more sustainable and livable communities. The neighborhood environments considered desirable by the Smart Growth and New Urbanist movements in particular reflect a return to valuing traditional features such as higher density, connected street networks, a mix of land uses, and access to public transit and parks.

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These characteristics promote livability and sustainability by supporting walking, offering opportunities for meeting neighbors, and allowing many daily errands to be done without driving, thus potentially reducing automobile dependence.[3,4] Advocates of these kinds of environments claim mental health benefits,[5,6] and there is some evidence for this claim. Casual social interactions in neighborhoods have been found to occur more frequently while walking,[7] and a lack of social networks is a risk factor for depression.[8] In addition to facilitating social interactions that can lead to improved mental health, walking as a form of physical activity can have an ameliorative effect on depression.[9–11] The presence of parks or green spaces has also been found to be associated with mental health benefits.[1]

In this paper we examine the understudied association between neighborhood urban form, along with the social environment, and depressive symptomology, i.e. the prevalence of depressive symptoms in the study population. A major strength of our study is that we are able to use a validated measure of depressive symptoms as the outcome of interest. Our analysis is innovative in that we also seek to determine the importance of how residents use the environment by examining the link between level of depressive symptoms and living in a neighborhood with a higher density of auto commuters relative to land area,* an indicator of chronic noise exposure.

Depression is a major illness which also leads to other illnesses and death. It is associated with reduced quality of life, social functioning, and excess disability, as well as significant expense, both public and private. Depression is now the third leading cause of the global disease burden world-wide and the leading cause for both middle and higher-income countries.[12] In high-income countries like the United States, unipolar depressive disorders are estimated to account for 8.2% of lost disability-adjusted life years.[12(p44)] Recent data from the 2005–2006 National Health and Nutrition Examination Survey found that more than one in 20 Americans 12 years of age and older suffered from current depression.[13] Approximately 80% of those who met diagnostic criteria for depression reported some level of functional impairment because of their depression, and 27% reported serious difficulties in work and home life.[13]

For this study, we take advantage of a sample survey carried out in Miami, Florida, and we link the information on survey respondents with data on their neighborhood of residence. The former are from a sample of individuals screened for disability and a matched sample of persons without a self-reported physical disability, and the latter are from the US Census, a parcel-level database, or a public land file. These data allow us to investigate the contribution of neighborhood urban form and social environment to depressive symptomology.

BACKGROUND

A substantial literature addresses links between the neighborhood social environment and mental health, with a concentration of studies documenting an association between neighborhood socioeconomic status and mental health in general[1] and depression in particular.[2] There is also some evidence of the importance of other attributes of the social environment. Places vary in their level of social integration, i.e., the extent to which residents maintain social ties with their neighbors, and the

*We are grateful to the anonymous reviewer who suggested this measure instead of the one we originally included.

extent to which they are willing and able to exercise control over public spaces in their neighborhood, and in particular to reduce physical and social disorder such as graffiti, vandalism, abandoned buildings or lots, broken glass, public drunkenness, or displays of prostitution.

Neighborhood residential stability and age concentration are two aspects of social integration that have been linked to depression. Several studies found that neighborhood residential instability, an indicator of low social integration, was associated with depression.[14–17] One of them, however, found that neighborhood instability was only associated with reduced psychological well-being in more affluent neighborhoods, not in high poverty areas.[17] The study's results indicated this was because neighborhood residential stability did not reduce physical and social disorder in neighborhoods, and it was the latter that affected mental health. Another study found that a lack of social networks was a risk factor for depression;[8] however, the extent to which these social ties are neighborhood based varies.

A high concentration of older adult residents may be an indicator of the presence of services such as medical care and public transportation or of increased opportunities for social activity and social support from neighbors.[18] Existing evidence is limited and mixed, with one study finding that residents of neighborhoods with a high concentration of older adults had increased knowledge of and access to services and other people, whereas others found that having many neighbors who are older was negatively associated with well-being.[18]

A substantial literature addresses the association between one aspect of urban form, well-maintained green areas, and mental health. However, the burgeoning literature investigating links between urban form, transportation systems, and physical activity has not yet extended into consideration of associations with mental health. To the extent that urban form and transportation systems support more walking in the neighborhood and more social interaction, they have the potential to enhance mental health.

There are decades of empirical work revealing a positive relationship between mental health and contact with nature, and a number of studies finding that the absence of well-maintained green areas contributes to stress and negative mental well-being.[19–24] "Contact with nature" has a wide variety of mental health benefits: It is associated with a more positive outlook on life and higher life satisfaction, and it enhances one's ability to cope and recover from stress and mental fatigue.[24] These studies generally conceptualize contact with green spaces or "natural settings" in two ways: (1) being able to view them or (2) being immersed in them, such as in taking a walk in a park. Furthermore, green space has been found to be important to people whether or not they use it.[24]

Existing studies also measure different aspects of "contact with nature." Some focus on proximity of green spaces to place of residence or percentage of area of residence devoted to green spaces. Findings are mixed regarding the association between proximity of one's residence to a park and park use and levels of physical activity; one study found a positive association,[25] whereas another found no relationship between either dichotomous sedentary/non-sedentary behavior or meeting/not meeting recommended levels of physical activity and proximity to parks.[26] Although it addresses self-reported health rather than physical activity, another study used the percentage of green space in respondents' area of residence as their indicator of access to green spaces and found a significant association with self-reported health.[27]

We are not aware of any studies examining the role of amount (area) of green space in one's area of residence on either depression or mental health in general. In theory, a larger amount of green space near one's residence increases opportunities for observing nature or being actively immersed in it. Particularly in urban and urbanizing environments, everyday contact with nature is dependent upon the abundance and distribution of green spaces. A study exploring what characteristics influence park use found that easy access to larger and more attractive public open space was a significant determinant of people achieving high levels of walking in these places.[28] It also found that once access was considered, size was more important than attractiveness in determining use. This is in line with a more recent finding that more park area close to home increased the odds of more strenuous physical activity.[29] However, there are also findings which show no relationship.[30,31]

A substantial literature in the transportation and public health fields documents a positive association between urban form, physical activity, and reduced vehicular travel. Neighborhood features that influence the ease with which people can stroll, walk, or cycle in neighborhoods—housing density, land-use diversity, connected street networks, availability of public transportation options—have been found to be associated with greater non-motorized travel in numerous studies.[32] Land-use diversity is hypothesized to be associated with neighborhood walkability because having more destinations nearby increases the prevalence of walking.[33,34] Higher density and connected street networks bring destinations closer to residents, making it more likely they will engage in non-motorized travel.[35] Because walking leads to more neighborliness,[7] it is plausible that both neighborhood housing density and land-use diversity will be associated with fewer depressive symptoms.

However, land-use diversity can also indicate a higher number of non-residents and their vehicles passing through and therefore creating more noise; existing studies have found chronic noise exposure to be associated with mental health in general[1] and with depression in particular.[2] In addition, a high density of auto commuters in a neighborhood, relative to land area, may be associated with more noise. An indicator of how residents live in and use the environment, it is related to the composition of the neighborhood and may act as a stressor. Traffic generated by a greater diversity of land uses and higher auto commuter density may keep residents from strolling or walking in the neighborhood due to concerns about safety.

STUDY HYPOTHESES

In this study, our primary purpose was to examine the association between urban form and depression which has received little attention in the literature to date. Because of the extensive literature establishing the importance of the neighborhood social environment for mental health, we also included indicators of economic deprivation, residential stability, and age concentration in the analysis.

Based on substantial evidence of links between urban form, physical activity and vehicular travel, and a plausible association between walking and neighborliness, we expected that two of our measures of urban form—housing unit density and land-use diversity—would be associated with fewer depressive symptoms, and our measure of how residents use the environment—auto commuter density—would be associated with more depressive symptoms, in models that adjust for individual-level covariates. We also expected that living in an area with fewer acres of green space would be associated with more depressive symptoms, given the numerous studies

that find that an absence of well-maintained green areas contributes to stress and negative mental well-being.

Prior studies also led us to expect that high neighborhood economic deprivation, a measure of the social environment, would be strongly associated with depressive symptomology, with residents of high economic deprivation neighborhoods showing significantly more depressive symptoms. On the other hand, residential stability and a concentration of older adults, both also measures of the social environment, may be associated with fewer depressive symptoms although prior studies yield varying results.

METHODS

Data Sources

Individual-level data were taken from a survey carried out in Miami, Florida in 2004. We obtained data to create our measures of the neighborhood social environment, housing unit density, and auto commuter density, from US Census 2000. However, the census does not include data relevant to the other important aspects of urban form. We therefore created our measure of land-use diversity based on data from a 2002 parcel-level database kept by the Miami-Dade Department of Revenue. To create our measure of access to green space, we used data on accessible green spaces from a 2009 public land file obtained from the Florida Geographic Data Library.*

Study Population

The population we focused on in this study is a stratified, case-comparison sample of 2,000 community-residing individuals in Miami, Florida, 1,000 of whom were screened as having limitations in activity and 1,000 others who were of the same age, gender, race/ethnicity group, and area of residence but did not have activity limitations. Individuals were sampled to achieve equal representation of four racial-ethnic groups within both the activity-limited and comparison samples. The four racial-ethnic groups together compose approximately 95% of the Miami-Dade County population; these are Cuban, other Hispanic, African-American, and non-Hispanic White. According to the 2000 US Census, 29% of Miami-Dade residents report being of Cuban origin, 23% self-report as other Hispanic or Latino, and 20% as black or African-American.

The sample population represents the substantial majority of individuals with disabilities who have physical limitations in normatively expected activities; their physical limitation had to be of at least 3 months duration to be included in the sample.[36] As might be expected, the sample population over-represents older individuals: 13% of the Miami-Dade county population as a whole are 65 years of age or older whereas in the study sample, 40% are 65 or older. The disabled population in this study therefore is representative of the non-institutionalized disabled population of south Florida. The non-disabled population in the study might not represent the general population in all aspects if they were matched

*Consistent with the generally slow progress of any public land acquisition, we determined that there were no significant green space acquisitions or sales within the study area between 2002 and 2009 that could have altered our results.

to a disabled population that is different from the general population in ways other than disability.[36]

Survey respondents were linked to a census tract of residence using address-matching software. The census tract ID was linked to the land-use data in a spatial overlay procedure where all parcels within the tract were given the ID of that tract. This process yielded a study sample of 1,980 individuals in 178 census tracts out of a total of 347 tracts.

Measuring Neighborhood Environments

Urban Form We include three measures of neighborhood urban form in our models predicting levels of depressive symptoms: housing unit density; number of acres of green space, and land-use diversity; and auto commuter density, a measure of how residents use the environment.* Housing unit density was calculated as number of occupied housing units per acre in the census tract; auto commuter density was created by dividing the number of resident workers 16 years and older who commute to work by automobile (as opposed to public transit or walking), by the number of acres in the tract. These measures were entered into the statistical models as continuous variables.

For each tract in the sample, we created an indicator of access to green spaces consisting of the number of acres of green spaces within the tract or within a quarter-mile border around the tract. These data included all state and national forests and parks, wildlife conservation areas and preserves, and city and county parks. This database is the best approximation of a statewide inventory of accessible green space in Florida. Excluded from the green space variable in this study were golf courses and land used for agricultural purposes. Distance from tract boundaries was measured as straight line or Euclidean distance.†

The distribution of accessible green spaces is highly skewed in the Miami-Dade County context, with over half of sample tracts having no green spaces and several tracts featuring a large acreage of green space. For the statistical models we therefore created a categorical variable where a code of "1" indicates a tract with no green spaces within its boundaries or within a quarter-mile border around the tract, a "2" indicates a tract with an amount of green space greater than zero but less than the 80th percentile, determined to be 38 acres for this distribution, and a "3" indicates a tract with an acreage of green space greater than the 80th percentile.

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*As with most other studies, data availability constrained the measures we could include. If data had been available, we would have liked to include other important built environment characteristics of neighborhoods such as: internal and external housing conditions, and number of structural fires in the neighborhood.

†We created a second indicator of access to green spaces: proximity to green space measuring the distance between the census tract centroid and the nearest accessible green space. The findings were consistent with those using the acreage of green space within the tract and within a quarter-mile border of the tract, so we report only the latter here. Green space area within defined distances of where people live appears to hold up better than distance to nearest green space when measuring the effect of green space on mortality (Coutts et al.).[37]

The land-use diversity variable was calculated using 2002 Miami-Dade Department of Revenue data which contain land-use codes at the parcel level. These data were aggregated to calculate the percent area that each land use accounted for in each census tract within the sample. The land uses were recorded into the standard categories of: single family residential, multi-family residential, commercial, industrial, agricultural, institutional, governmental, and parks or recreational open space. Calculating the sum of squares of the percent area of each of these land uses in a tract resulted in a numerical index of land-use diversity. This Herfindahl–Hirschman Index[38] is an improvement over simply counting the number of land uses because it accounts for the respective weight, in area, each land use carries in shaping the environment. For ease of interpretation, we divided the index values by 1,000 and reversed the coding such that larger values indicated greater diversity. Our values range from 1.4 (least diverse mix, single land use dominant) to 8.2 (most diverse mix).

Social Environment Much of the empirical work on the neighborhood social environment and mental health uses indirect, census-based measures[2,39,40] and ours is no exception.* Following Land et al.,[41] we create composite measures of the socioeconomic dimensions of neighborhoods using principal factor analysis because the social environment indicators are strongly correlated with one another.† The factor analysis includes all Miami-Dade census tracts (n=347). We enter into the factor analysis indicators of low levels of participation in the labor market (percent unemployed), high dependence on public programs of income support (percent on public assistance), a high proportion of non-traditional family structures (percent female-headed households with small children), high level of educational achievement (percent with a college degree), residential stability (percent in same house for 5 or more years), percent households living below the federal poverty level, and median household income (Table 1).

The two dimensions that emerge represent well the chronic social stressors in the local residential environment.[14] The first factor is dominated by high to moderate (>70) loadings on median household income, percent with a college degree, percent female-headed households with small children, percent of households below the poverty level, percent on public assistance, and percent unemployed. This factor is essentially a measure of *economic deprivation*. The negative sign on the factor loadings for median household income and percent with college degree indicate these are inversely associated with *economic deprivation*, as expected. This measure of the resource poverty dimension of neighborhoods represents more than income poverty; it represents a more entrenched poverty that has been found to be associated with high neighborhood crime and violence.[41,42] The second factor is dominated by a single

*Data availability constrained the measures we could include. Had they been available, we would have liked to include other neighborhood social indicators and in particular measures of the different forms of social capital.

†Varimax is used to maximize the variance of the squared loadings. Varimax is an orthogonal rotation method which simply rotates the axes of the first factor to a variable or group of variables and then rotates the subsequent factors to be at right angles (uncorrelated) with the first. It thereby removes the effects of variables which could be highly loaded on the first factor. Compared with the unrotated factor solution, an orthogonal rotation minimizes the number of samples needed to account for the variation of distinct groups of variables.

TABLE 1 Neighborhood social environment indicators: rotated factor loadings (pattern matrix) and unique variances (all census tracts, $n=347$)

Variable	Economic deprivation	Residential stability	Uniqueness
Median household income	−0.8624	0.1454	0.2352
Percent college degree	−0.8661	−0.1835	0.2161
Percent female household head	0.7142	0.1661	0.4623
Percent household below poverty	0.9087	−0.162	0.148
Percent public assistance	0.8983	−0.0359	0.1917
Percent unemployed	0.8837	−0.0952	0.2099
Percent in same house for 5 or more years	−0.0535	0.977	0.0426

loading on the percentage of residents who were living in the same house 5 years prior to the Census. It is a measure of *residential stability*.

In the analyses that follow, the social environment measures that we include are the factor scores associated with the *economic deprivation* factor, a single variable indicating residential stability: the percentage of residents who lived in the same house 5 years prior to the census (since it is the only variable that loaded highly on the second factor), and an indicator of age concentration: the percentage of residents over the age of 65 years. All of these were entered into the statistical models as continuous variables

Measuring Extent of Depressive Symptoms

To measure extent of depressive symptoms, we employed the Center for Epidemiological Studies-Depression (CES-D) scale, a widely used 20-item instrument originally developed by the National Institute of Mental Health to measure current depressive symptomology in community settings; it has been shown to have good validity and reliability.[43–45]

Statistical Analysis

Our main analyses involved examining correlations between the different aspects of urban form and the social environment to better understand the extent to which they are related, and carrying out a series of regression models to determine the association between neighborhood urban form and the social environment and level of depressive symptoms. We used OLS regression models due to the very small sample sizes within most of the sampled census tracts, rather than multilevel models. Cluster-based robust standard errors were used to estimate standard errors that accounted for the potential correlation in depressive symptoms between individuals in the same census tract. All models were analyzed using Stata/SE v. 11.0 (Stata, College Station, TX, USA). We accepted p values at or less than 0.05 as statistically significant.

We characterized the bivariate association between attributes of urban form and the social environment and extent of depressive symptoms in separate OLS regression models using cluster-based robust standard errors and adjusting for individual-level covariates: age, sex, race/ethnicity, marital status, disability status, education in years, employment status, and home ownership.

We examined the association between urban form and extent of depressive symptoms in OLS regression models that also included the social environment

indicators. The CES-D score was our outcome measure. These models also included the individual-level covariates. We analyzed models with and without auto commuter density to show the importance of considering how residents use the environment.

FINDINGS

Description of Neighborhoods in the Sample

Figure 1 shows that the tracts linked to survey respondents are well-distributed across Miami-Dade County. The distribution of accessible green spaces however is highly skewed (Figure 1). As indicated earlier, over half of the census tracts have no green spaces within their boundaries or within a quarter-mile border around the tract.

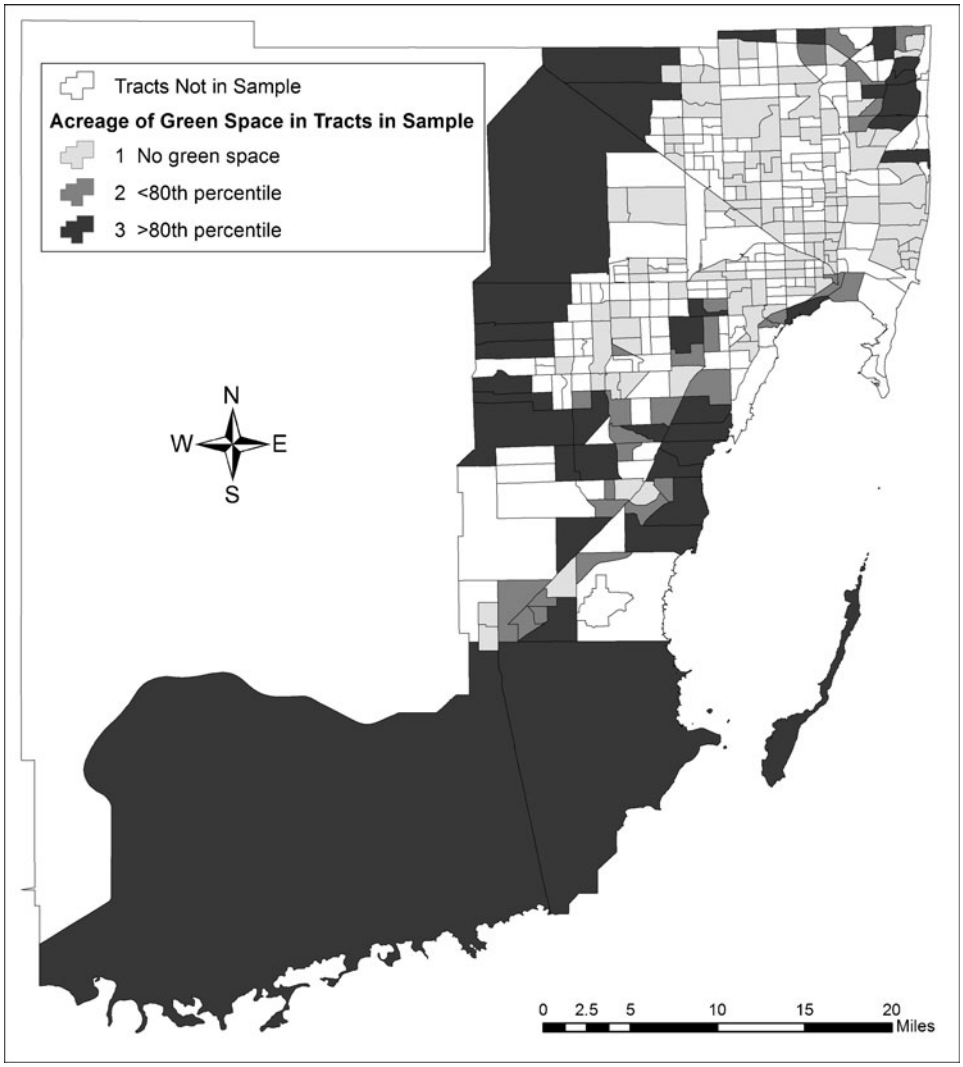

FIGURE 1. Distribution of acreage of green space in census tract.

Our calculations indicate that the median housing density for Miami-Dade census tracts is about 4 units per acre, suggesting a relatively low-density metropolitan area. Indeed, further descriptive analyses show that 94% of tracts have densities less than 12 units per acre. This is the cut-off for identifying "healthy" densities that was incorporated into the 1920 Ministry of Health Housing Manual in Britain, based on the work of influential engineer/planner Raymond Unwin.[46] Our results also suggest that land-use diversity in Miami-Dade on average is moderate (median score of 6.4 and ranging from 1.4 to 8.2).

Residential stability varies widely across Miami-Dade census tracts, as might be expected in an area experiencing high levels of immigration. On average, 54% of neighborhood residents were in the same house as 5 years prior, ranging from a low of 5% to a high of 74%.

Prior studies find that among the 102 largest metropolitan areas in the United States, Miami has the second highest poverty rate in its central city (28.5%) and the fifth highest in the suburbs of its central city (16%). High city poverty rates are not unexpected as they are found in every part of the country. More unusual is Miami's high rate of suburban poverty. Some of the suburbs with high poverty rates, Miami among them, were in metropolitan areas that are home to historically high levels of immigration and Hispanic population such as Los Angeles, El Paso, Miami, and McAllen-Edinburg-Mission, Texas.[47] Rather than being concentrated in central cities, minority populations in these metropolitan areas are more evenly distributed between cities and suburbs than in the rest of the country.[47]

Correlations Between Measures of Urban form and Social Environment

An analysis of correlations shows that higher housing density was significantly associated with most of the other urban form indicators and with all of the measures of neighborhood social environment (Table 2). Higher housing density was also associated with higher auto commuter density ($r=0.84$) and the chronic noise exposure this entails. However, the correlation between housing unit density and land-use diversity did not reach statistical significance ($r=0.04$), indicating that in this Miami study population, higher density neighborhoods did not necessarily have a greater mix of land uses (Table 2).

In contrast, greater land-use diversity was associated with lower auto commuter density ($r=-0.07$) as was a higher acreage of green spaces ($r=-0.38$). This suggests that participants living in neighborhoods with a mix of land uses or more green spaces were not likely to be exposed to the chronic noise associated with higher auto commuter density. Land-use diversity like housing density was highly correlated with economic deprivation and with a high concentration of older adults. Residents of places with high land use diversity were also less likely to live near accessible green spaces ($r=-0.32$ and $r=-0.11$, respectively). However, those living in neighborhoods with higher land-use diversity were no more or less likely to experience the benefits associated with neighborhood residential stability ($r=-0.49$).

Regression Analyses

In separate regressions adjusting for individual-level covariates: age, sex, race/ethnicity, marital status, disability status, education in years, employment status and home ownership, the only urban form feature that was significantly

TABLE 2 Correlation matrix: urban form and social environment characteristics of neighborhoods of residence (study population = 1,944)

	Housing density	Diversity	Green space	Commuter density	Economic deprivation	Stability	Age concentration
Urban form							
Housing density	1.00						
Land-use diversity	0.04*	1.00					
Acres green space	−0.32***	−0.10***	1.00				
Auto commuter density	0.84 ***	−0.07***	−0.38***	1.00			
Social environment							
Economic deprivation	0.14***	0.37***	−0.40***	0.04*	1.00		
Residential stability	−0.49***	0.17***	0.20***	−0.48***	−0.05**	1.00	
Age concentration	0.36***	0.12***	−0.14***	0.12***	−0.04*	0.12***	1.00

*$p<0.10$;**$p<0.05$; ***$p<0.01$

TABLE 3 Ordinary least squares (OLS) separate regressions predicting depressive symptoms (CES-D; $n = 1{,}944$)

Model no.	Independent variables	Dependent variable: depressive symptoms (CES-D)
	Urban form	
1	Housing density	0.005
2	Land-use diversity	0.030
3	Acres green space (reference category = 1)	
	2	−0.299***
	3	−0.115
4	***Auto commuter density***	0.015
	Social environment	
5	Economic deprivation	0.093**
6	Residential stability	−0.006**
7	Age concentration	0.006

N.B. Models used robust standard errors and adjusted for age, sex, race/ethnicity, marital status, disability status, education in years, employment status, and home ownership

*$p<0.10$; **$p<0.05$; ***$p<0.01$

associated with depressive symptoms was acreage of green space; those living in areas with between 0.1 and 38 acres of green space displayed significantly fewer depressive symptoms than those living in neighborhoods with no green spaces (Table 3). However, those living in areas with the greatest amount of green space did not display significantly fewer symptoms than those living where there was no green space (Table 3). Living in a higher density neighborhood was not significantly associated with depressive symptoms, and neither was living in an area with a greater mix of land uses or residing in a neighborhood with a higher density of auto commuters relative to land area (Table 3).

In contrast, two of the three indicators of neighborhood social environment displayed a significant association. Living in a tract with higher economic deprivation was associated with more depressive symptoms than living in a less resource-poor area (Table 3). And residence in an area with greater residential stability was associated with fewer depressive symptoms compared to an area where more people were moving in and out. Living in an area with a concentration of older adults however made no difference.

In multivariate models we first examined the association between the urban form and social environment indicators and level of depressive symptoms, adjusting for individual-level covariates (Table 4, Model 1). Associations found in separate regressions (Table 3) remained very similar in the multivariate context, except in the case of neighborhood economic deprivation; it lost significance due to confounding, i.e., to its correlation with the outcome measure as well as with the other neighborhood environment indicators in the model (Table 4, Model 1).

Second, we added to the model our indicator of the way residents use the environment: number of tract residents who commute to work by automobile rather than by mass transit or walking, relative to land area (Table 4, Model 2). The inclusion of the measure of auto commuter density improved the predictive validity of housing density and reduced the association between acreage of green spaces and depressive symptoms such that it was no longer statistically significant due to confounding. The results of the full model suggest that living in a neighborhood

TABLE 4 OLS regression coefficients: urban form, social environment, and auto commuter density on depressive symptoms (CES-D; $n=1,944$)

	Model 1	Model 2
Urban form		
Housing density	−0.013	−0.060***
Land-use diversity	0.025	0.033
Acres green space (reference category = 1)		
2	−0.229**	−0.205*
3	−0.050	0.081
Auto commuter density		0.072***
Social environment		
Economic deprivation	0.066	0.113**
Residential stability	−0.007**	−0.008**
Age concentration	0.012*	0.022***
R-squared	0.088	0.093

N.B. Models used robust standard errors and adjusted for age, sex, race/ethnicity, marital status, disability status, education in years, employment status, and home ownership

*$p<0.10$; **$p<0.05$; ***$p<0.01$

with higher unit density was associated with fewer depressive symptoms (Table 4, Model 2). Living in a neighborhood with a higher auto commuter density on the other hand, was linked to more depressive symptoms; auto commuter density is an indicator of chronic exposure to traffic-related noise.

Furthermore, although it did not reach statistical significance in the full model, the association between living in an area with a moderate acreage of green space compared to none was negative as expected, with participants living near a moderate amount of green space showing fewer depressive symptoms than those living in a neighborhood with no accessible green spaces (Table 4, Model 2). The link between living near the largest amount compared to no green space, and level of depressive symptoms, remained negative and non-significant in the full model (Table 4, Model 2), with participants living near the largest amount of green space showing fewer symptoms of depression. The association between land-use diversity and depressive symptoms was not significant in any of the models.

The link between higher neighborhood economic deprivation and more depressive symptoms was enhanced by the inclusion of auto commuter density in the model and reached statistical significance in the full model (Table 4, Model 2), and a significant association between age concentration and extent of depressive symptoms was revealed in the full model (Table 4, Model 2). Living in a neighborhood with a higher percentage of older residents was linked to more depressive symptoms.

The association between residential stability and fewer depressive symptoms was stable across both models (Table 4, Models 1 and 2). Because of the findings of Ross and colleagues,[17] we tested for a possible interaction between neighborhood economic deprivation and residential stability. However, unlike their results, we did not find that residential stability was negatively associated with depression for residents in economically deprived areas and positively associated for those in more affluent areas. Our results indicate that living in a more stable neighborhood was beneficial regardless of the economic deprivation of the neighborhood of residence.

Our results suggest that auto commuter density acted as a suppressor variable in these analyses given that its inclusion led to an increase in the contribution of

housing density, economic deprivation, and age concentration respectively to predicting extent of depressive symptoms in the full model. A suppressor variable is defined as a variable which is correlated with other independent variables and increases the predictive validity of another variable (or set of variables) by its inclusion in a regression equation.[48] Irrelevant variance is removed from the suppressed variable(s) (housing density, economic deprivation, and age concentration in this case) when it is included.[48]

DISCUSSION

In this study, we examined the association between urban form and depressive symptomology since little work has been done in this area to date. Building on previous research, we also considered key features of the social environment along with a host of individual-level covariates. A major strength of this research is its use of a validated measure of depressive symptoms. We hypothesized that housing density, probably the most important single aspect of urban form because it is a general summary measure,[49] would be associated with fewer depressive symptoms. We hypothesized that a greater diversity of land uses and larger acreage of green spaces would also be associated with a lower level of depressive symptoms. Furthermore, recognizing the importance of how people live in and use the environment, we hypothesized that the density of auto commuters in a neighborhood, relative to land area, would be associated with more depressive symptoms. We expected that higher auto commuter density would act as a stressor because of the chronic noise exposure associated with it.

Our results suggest that living in a neighborhood with higher housing density is associated with fewer depressive symptoms. In the Miami context, it is important to note that housing densities overall are moderate, with 94% of census tracts featuring fewer than 12 housing units per acre. Higher densities may influence the ease with which people can stroll or walk in neighborhoods, thereby facilitating greater non-motorized travel.[32] Walking as a form of physical activity can have a positive influence on depression.[9–11] Higher density may also be associated with greater access to services and facilities and make it more likely people will meet each other on the street compared to lower density areas.[49] Further research is needed to determine whether densities that are substantially higher than the moderate densities characteristic of Miami are also associated with fewer depressive symptoms.

Our finding that land-use diversity is not significant in models predicting depressive symptoms is also important. Our results may be partly due to measurement error, i.e., the lack of specificity of our measure in terms of number and types of destinations within walking distance of residences. However, our inconclusive results also may arise from the fact that greater land-use diversity has conflicting effects on mental health. On the one hand, researchers coming from an urban form and active travel perspective would expect neighborhood land-use diversity to be associated with fewer depressive symptoms. In this literature, land-use diversity along with housing density has been found to be associated with neighborhood walkability, presumably because proximity to more destinations increases the prevalence of walking,[33,34] which in turn leads to more neighborliness.[7] However, in our study population, living in a higher density neighborhood is not significantly correlated with living in a place with greater land-use diversity. In this context, the effect of land-use diversity is neither positive nor negative for level of depressive symptoms.

The association we found between living in an area with a moderate amount of accessible green space and depressive symptomology, compared to living in a

neighborhood with no green space, fell just short of statistical significance in the full model but was consistent with prior studies showing the importance of contact with nature for mental health. Respondents living in tracts with a moderate number of acres of green space displayed fewer symptoms of depression than those living where there was no accessible green space. However, respondents living in tracts with the most acreage of green space did not display significantly fewer symptoms of depression than those living where there was no accessible green space in any of the models. We suspect that given the highly skewed distribution of acreage of accessible green spaces in our sample, we did not have the statistical power to reliably identify the effect of living in an area with the largest amount of green space.

Our results provide new evidence of the importance of how people live in and use the neighborhood environment. We found that living in a neighborhood with a higher density of auto commuters relative to land area was associated with more depressive symptoms than living in areas with lower auto commuter density. The mechanism for such an effect is likely to be related to the traffic and noise produced by motor vehicles. A prior study found that individuals who lived in areas with greater vehicular burdens reported more perceived traffic stress and displayed more depressive symptoms.[50] Auto commuter density therefore acts as a stressor related to the composition of the neighborhood.

We also provide new evidence of an association between social integration in neighborhoods and depressive symptomology, while further confirming the significance of neighborhood economic deprivation found in a wide range of other studies of neighborhoods and mental health. Like Matheson et al.,[14] we found that participants who lived in residentially stable neighborhoods displayed fewer depressive symptoms, regardless of the level of neighborhood economic deprivation. However, the effect of age concentration was the opposite of what we expected. We found that living in a neighborhood with a high percentage of older adults was associated with more depressive symptoms. This is consistent with another study that found that having many neighbors who were older was negatively associated with well-being.[18] Further research is needed into the mechanism for this association.

Two limitations of this research are important to bear in mind. First, this study is based in Miami. Our findings are not necessarily generalizable to other parts of the United States or to other countries. Research is needed in other settings, and in particular in large cities with higher housing densities, and in medium-sized urban areas and rural areas. Second, our study is cross-sectional. This is a significant limitation of the literature on neighborhoods and health in general. It is hard to determine causality in cross-sectional studies where omitted variables and selection issues are likely. Opportunities for longitudinal studies however are rare in this line of inquiry.

In conclusion, this research provides preliminary evidence that urban form has an important effect on depression and that how residents live in and use the environment matters. It also reveals that aspects of the neighborhood social environment beyond economic deprivation play an important role. Many cities today are changing local ordinances to encourage more compact urban form and to permit a mix of destinations within proximity to residences. Our findings suggest that in order to protect and promote mental health in the process, it may be necessary for such policies to incorporate strategies designed to reduce vehicular travel as well, and to seek ways to address the negative consequences of neighborhood economic deprivation, residential instability, and age concentration.

REFERENCES

1. Clark C, Myron R, Stansfeld SA, Candy B. A systematic review of the evidence on the effect of the built and physical environment on mental health. *J Public Mental Health*. 2007; 6(2): 14–27.
2. Mair C, Roux AVD, Galea S. Are neighbourhood characteristics associated with depressive symptoms? A review of evidence. *J Epidemiol Community Health*. 2008; 62 (11): 940–946.
3. Congress of New Urbanism. *New Urban Projects on a Neighborhood Scale in the United States*. Ithaca, NY: New Urban News; 2002
4. Creating Livable Neighborhoods Web Site. http://www.newurbanism.org. Accessed August 10, 2010.
5. Duany A, Plater-Zyberk E, Speck S. *Suburban Nation: the Rise of Sprawl and the Decline of the American Dream*. New York, NY: Farrar, Straus & Giroux; 2001.
6. Frumkin H, Frank L, Jackson R. *The Public Health Impacts of Sprawl*. Washington, DC: Island Press; 2004.
7. Lund H. Testing the claims of New Urbanism: local access, pedestrian travel and neighboring behaviours. *J Am Plann Assoc*. 2003; 69: 414–428.
8. Kawachi I, Berkman LF. Social ties and mental health. *J Urban Health*. 2001; 78: 458–467.
9. Babyak M, Blumenthal J, Herman S, et al. Exercise treatment for major depression: maintenance of therapeutic benefit at 10 months. *Psychosom Med*. 2000; 62(5): 633–638.
10. Ross C, Hayes D. Exercise and psychological well-being in the community. *Am J Epidemiolog*. 1988; 127: 762–771.
11. Stephens T. Physical activity and mental health in the United States and Canada: evidence from four population surveys. *Prev Med*. 1988; 17: 35–47.
12. World Health Organization. Global Burden of Disease: 2004 Update. http://www.who.int/healthinfo/global_burden_disease/2004_report_update/en/index.html. Accessed April 11, 2011.
13. Depression in the United States Household Population, 2005–2006. NCHS Data Brief, No.7, September 2008. http://www.cdc.gov/nchs/data/databriefs/db07.pdf. Accessed December 9, 2009.
14. Matheson FI, Moineddin R, Dunn JR, Creatore MI, Gozdyra P, Glazier RH. Urban neighborhoods, chronic stress, gender and depression. *Soc Sci Med*. 2006; 63(10): 2604–2616.
15. Silver E, Mulvey EP, Swanson JW. Neighborhood structural characteristics and mental disorder: Faris and Dunham revisited. *Soc Sci Med*. 2002; 55: 1457–1470.
16. Aneshensel CS, Wright RG, Miler-Martinez D, et al. Urban neighborhoods and depressive symptoms among older adults. *J Geronol B Psychol Sci Soc Sci*. 2007; 62: S52–59.
17. Ross CE, Reynolds JR, Geis KJ. The contingent meaning of neighborhood stability for residents' psychological well-being. *Am Sociol Rev*. 2000; 65(4): 581–597.
18. Glass TA, Balfour JL. Neighborhoods, aging, and functional limitations. In: Kawachi I, Berkman LF, eds. *Neighborhoods and Health*. New York, NY: Oxford University Press; 2003.
19. Guite HF, Clark C, Ackrill G. The impact of the physical and urban environment on mental well-being. *Public Health*. 2006; 120(12): 1117–1126.
20. Kaplan R, Kaplan S. *The experience of nature. A psychological perspective*. Cambridge, England: Cambridge University Press; 1989.
21. Nielsen TS, Hansen KB. Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. *Health Place*. 2007; 13(4): 839–850.
22. Hartig T, Mang M, Evans GW. Restorative effects of natural environment experiences. *Environ Behav*. 1991; 23: 3–26.
23. Ulrich RS, Simons RF. Stress recovery during exposure to natural urban environments. *J Environ Psychol*. 1991; 11: 201–230.

24. Maller C, Townsend M, Pryor A, Brown P, St Leger L. Healthy nature healthy people: 'contact with nature' as an upstream health promotion intervention for populations. *Health Promot Int*. 2006; 21(1): 45–54.
25. Cohen D, McKenzie T, Sehgal A, Williamson S, Golinelli D, Lurie N. Contribution of public parks to physical activity. *Am J Public Health*. 2007; 97(3): 509–514.
26. Witten K, Hiscock R, Pearce J, Blakely T. Neighborhood access to open spaces and physical activity of residents: a national study. *Prev Med*. 2008; 47: 299–303.
27. Mitchell R, Popham F. Greenspace, urbanity and health: relationships in England. *J Epidemiol Community Health*. 2007; 61: 681–683.
28. Giles-Corti B, Brommhall M, Knuiman M, et al. Increasing walking: how important is distance to, attractiveness, and size of public open space? *Am J Prev Med*. 2005; 28(2S2): 169–176.
29. Kaczynski A, Potwara L, Smale B, Havitz M. Association between parkland proximity with neighborhood and park-based physical activity: variations by gender and age. *Leisure Sci*. 2009; 31: 174–191.
30. Hillsdon M, Panter J, Foster C, Jones A. The relationship between access and quality of urban green space with population physical activity. *Public Health*. 2006; 120: 1127–1132.
31. Maas J, Verheij R, Spreewenberg P, Groenewegen P. Physical activity as a possible mechanism behind the relationship between green space and health: a multilevel analysis. *BMC Public Health*. 2008; 8: 206–218.
32. Transportation Research Board (TRB) and Institute of Medicine of the National Academies (IOM). *Does the built environment influence physical activity? Examining the evidence*. Special Report 282 ISBN 0-309-09498-4. Washington, DC: Transportation Research Board; 2005
33. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med*. 2002; 23: 64–73.
34. King WC, Brach JS, Belle S, Killingsworth R, Fenton M, Kriska AM. The relationship between convenience of destinations and walking levels in older women. *Am J Health Promot*. 2003; 18(1): 74–82.
35. Cervero R, Kockelman K. Travel demand and the 3Ds: density, diversity, and design. *Transp Res Part D*. 1997; 2(3): 199–219.
36. Turner RJ, Lloyd DA, Taylor J. Physical disability and mental health: an epidemiology of psychiatric and substance disorders. *Rehabil Psychol*. 2006; 51(3): 214.
37. Coutts C, Horner M, Chapin T. Using GIS to model the effects of green space accessibility on mortality in Florida. *Geocarto Int*. 2010; 25(6): 471–484.
38. Song Y, Rodriguez D. The measurement of the level of mixed land uses: A synthetic approach. Chapel Hill, NC: University of North Carolina; 2004. http://planningandactivity.unc.edu/Mixed%20land%20uses%20White%20Paper.pdf. Accessed December 10, 2005.
39. Raudenbush SW. The quantitative assessment of neighborhood social environments. In: Kawachi I, Berkman LF, eds. *Neighborhoods and Health*. New York, NY: Oxford University Press; 2003: 112–131.
40. Sampson RJ, Morenoff JD, Gannon-Rowley T. Assessing "Neighborhood Effects": social processes and new directions in research. *Annu Rev Sociol*. 2002; 28: 443–478.
41. Land KC, McCall PL, Cohen LE. Structural covariates of homicide rates: are there any invariances across time and social space? *AJS*. 1990; 95(4): 922–963.
42. Miles-Doan R. Violence between spouses and intimates: does neighborhood context matter? *Soc Forces*. 1998; 77(2): 623–645.
43. Radloff L. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977; 1(3): 385–401.
44. Weissman MM, Sholomskas D, Pottenger M, Prusoff BA, Locke BZ. Assessing depressive symptoms in five psychiatric populations: a validation study. *Am J Epidemiol*. 1977; 106 (3): 203.

45. Roberts RE. Reliability of the CES-D Scale in different ethnic contexts. *Psychiatry Res*. 1980; 2(2): 125–134.
46. Hall P. *Cities of Tomorrow*. Oxford, England: Blackwell; 2002.
47. Berube A, Frey WH. A decade of mixed blessings: urban and suburban poverty in census 2000. In: Berube A, Katz B, Lang RE, eds. *Redefining Urban & Suburban America: Evidence from Census 2000*, vol. II. Washington, DC: The Brookings Institution; 2005: 111–136.
48. Conger AJ. A revised definition for suppressor variables: a guide to their identification and interpretation. *Educ Psychol Meas*. 1974; 34(1): 35.
49. Bramley G, Power S. Urban form and social sustainability: the role of density and housing type. *Environ Plann B: Plann Des*. 2009; 36: 30–48.
50. Gee GC, Takeuchi DTDT. Traffic stress, vehicular burden and well-being: a multilevel analysis. *Soc Sci Med*. 2004; 59(2): 405–414.