Introduction

As the U.S. population ages, understanding the characteristics of neighborhoods with changing older adult populations is increasingly important, especially as the percentage of older adults living in cities increases over time (U.S. Department of Health and Human Services [USDHHS], 2013). Several dimensions of the neighborhood environment may affect health outcomes, including factors particularly relevant to older adults, such as residential density, walkability, housing prices, neighborhood amenities, and green space (Yen, Michael, & Perdue, 2009). Policies that target the neighborhood environments of older adults can be used to create age-friendly communities that promote active, independent, healthy lifestyles for older adults, in particular for those residing in metropolitan areas.

While prior work has described age structure across U.S. cities from 1940 to 1970 (Cowgill, 1978), little is known about more recent changes in demographic structure due to aging of the baby boomer generation. In particular, very little research has examined concomitant changes in age structure and neighborhood characteristics over time, despite associations between age composition and social engagement, and utilization of resources (Cagney, 2006; Moore et al., 2010; Vogelsang & Raymo, 2014). Resources related to neighborhood physical infrastructure may play a key role in reducing health burdens of older adults by promoting increased physical activity and overall mobility (Yen et al., 2009).
In addition, neighborhood socioeconomic disadvantage has been shown to be associated with obesity and poor self-rated health among older adults (Bell, Hamer, & Shankar, 2014; Yen et al., 2009). Therefore, it is critical to identify classes of neighborhood age structure to understand how the social and physical environment of U.S. older adult populations is changing relative to other age groups, and to anticipate the needs of older adults living in those areas.

Few studies have detailed, time-varying data describing multiple characteristics of neighborhood environments with growth in older adult populations. Using 30 years (1980-2010) of longitudinal neighborhood-level data, we characterized the age structure of neighborhoods in four U.S. cities by identifying distinct, a priori neighborhood trajectory classes of older adult populations, and sought to compare the physical and socioeconomic characteristics of these classes at baseline and over time. We hypothesized that neighborhoods with increasing (vs. “stable”) older adult percentages would be less likely to have higher street connectivity and higher socioeconomic advantage at baseline and over time. Conversely, we hypothesized that neighborhoods with declining (vs. “stable”) older adult percentages would have lower street connectivity and lower socioeconomic advantage at baseline and over time.

**Method**

**Older Adult Population**

Using U.S. Census data from 1980, 1990, and 2000, and American Community Survey (ACS) 5-year estimates from 2005 to 2009 and 2007 to 2011 (normalized to 2010 census tract boundaries), we created variables to represent the number and percentage of older adults (65 years or older) within neighborhoods located in four metropolitan areas (Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; Oakland, California). We selected these four cities to capitalize on a range of existing geographic information system data, and because these locations are emblematic of different types of urban areas in the U.S. neighborhoods for Chicago, Illinois, Oakland, California, and Minneapolis, Minnesota, were defined using socially constructed boundaries from Zillow (Tzeng, Teng, Chen, & Opricovic, 2002) and neighborhoods for Birmingham, Alabama, were obtained from the Regional Planning Commission of Greater Birmingham (Figure 1).

**Neighborhood-Level Characteristics**

To characterize the neighborhoods of older adults, we used detailed, time-varying neighborhood-level data from several administrative and geographic information sources, including multiple measures related to socioeconomic status (education, median household income, and poverty), home ownership and housing price, and built environment features (parks, food and physical activity density, population density, street network). All neighborhood-level variables were harmonized to fit neighborhood geographic boundaries within city limits across the four U.S. cities. When data source boundaries did not align with neighborhood boundaries, we created a geographically weighted estimate of neighborhood-level variables, assuming an equal distribution of variables. Because our goal was to characterize macro-level changes in characteristics of neighborhood environments across the United States, we combined neighborhood units from each city for a total of 392 neighborhoods in five study periods (observations = 1,962).
From the U.S. Census 1980, 1990, and 2000 and ACS 5-year estimates from 2005 to 2009 and 2007 to 2011, we obtained data related to the percentage of adults (25+) with education less than high school or greater than or equal to college, median household income, and the percentage of people with household incomes less than 150% of the federal poverty level. We linearly interpolated these values across the censuses to derive a continuous change in characteristics across the full period.

We used U.S. Census and ACS data to obtain information on the percentage of owner-occupied housing units with a mortgage, home equity loan, or similar debts. We obtained home price index values for neighborhoods in the four cities from Moody's Analytics (Chen, Carbacho-Burgos, Mehra, & Zoller, 2011). Moody's provides Case-Schiller data for Chicago, Minneapolis, and Oakland for each quarter of each year between 1975 and 2012, where price data are index values relative to a value of 100 for the first quarter of the year 2000. In contrast, Moody's offers Lender Processing Service data for Birmingham for each quarter from 1991 to 2012, measured in the thousands of dollars. We used multilevel mixed-effects linear regression to predict housing price values for 1980 in Birmingham; thus, we used data corresponding to years 1980, 1991, 1995, 2000, 2005, and 2010 for all four cities.

Using current and historic geospatial data, our team collected key built environment features of the four cities (retrospectively and currently). The methods for this study are detailed elsewhere (under review). Briefly, data collected in the retrospective audits were then processed using ArcGIS 10.3 (ESRI, Redlands, California) and Python 3.4 (Python Software Foundation, Beaverton, Oregon). We calculated the park area (m²) within a neighborhood (km²) for each of the four U.S. cities corresponding to years 1985, 1990, 1995, 2000, 2005, and 2010.

We obtained food and physical activity resources from Dun & Bradstreet, a commercial dataset of U.S. businesses (Dun & Bradstreet, Inc, 2013). We calculated the count of each type of food outlet or physical activity facility per neighborhood area (km²) corresponding to years 1986, 1993, 1996, 2001, 2006, and 2011. The types of food outlets examined in this study included fast food restaurants, convenience stores, and grocery stores/supermarkets. We classified food outlets and physical activity facilities according to 8-digit Standard Industrial Classification codes. Eight-digit codes were unavailable for 1986, so 4-digit codes and matched business names were used to classify resources.

To describe neighborhood street connectivity, we used StreetMap Pro datasets corresponding to years 1999, 2003, 2005, and 2010 to calculate intersection density, defined as the number of three-way, four-way, and higher intersections per kilometer square. Population density (persons per kilometer square) came from the U.S. Census and ACS.

### Statistical Analyses

Using PROC TRAJ in SAS (Version 9.3), we estimated a discrete mixture model to create distinct longitudinal groups of older adult populations. We ran a series of models where we modified the number of classes (range = 2-5 classes) and the order of each equation for each class (i.e., linear, quadratic, cubic). In all iterations of the model, we specified a censored normal distribution for the dependent variable (percentage of older adults within a neighborhood measured at each time period). For each model, we evaluated the fit (Akaike information criterion [AIC] and Bayesian information criterion [BIC]), interpretability, and uniqueness of class assignment. Each neighborhood was then assigned to a particular trajectory class based on the highest posterior probability.

For each neighborhood trajectory class, we calculated the mean baseline values for each neighborhood characteristic of interest, as well as the mean change in each neighborhood characteristic (the difference between the baseline measure and the end of follow-up). Using a pairwise t test, we compared whether the mean baseline values or change in characteristics were statistically significantly different between neighborhood trajectory classes of older adult populations. To determine whether the changes in relative age composition across classes were due to changes in older adult populations themselves or changes from other age groups, we also tested whether the count of older populations was statistically significantly different across trajectory classes.

### Sensitivity Analyses

Using the same series of models utilized in the main analysis, we performed sensitivity analyses to examine whether other age groups experienced similar trajectories of change in residential neighborhoods over time, including children (<5 years), young adults (18-29 years), and middle-aged adults (45-54 years). As data corresponding to baseline values varied by source, we also conducted sensitivity analyses using data corresponding to baseline values varied by source.

### Results

The final model included second-order polynomial terms for each trajectory class, with two trajectory classes characterized by an increasing and declining percentage of older adult populations, and a third class with a minimal increase in the percentage of older adult populations (relative to other classes), that we refer to as “stable” (Table 1). The AIC and BIC showed no noticeable improvement when adding a cubic term or specifying a four-class model. The highest posterior probabilities also suggested a good fit to the data, with a posterior probability of 22.2% (SD = 2.5) for neighborhoods...
Table 1. Baseline and Change Characteristics of Four Cities Neighborhoods From 1980 to 2007-2011, by Trajectory Classes of Demographic Change in Older Adult Populations (≥65 Years of Age).

| Characteristics                        | Stable older adult populations (n = 157 neighborhoods) | Decreasing older adult populations (n = 153 neighborhoods) | Increasing older adult populations (n = 86 neighborhoods) |
|----------------------------------------|--------------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------------|
| Age structure                          |                                                        |                                                           |                                                          |
| Population ≥ 65 (%)<sup>a</sup>        | 10.0                                                   | -1.8                                                      | 16.6                                                     |
| Population ≥ 65 (count)                | 1,220                                                  | -208                                                     | 1,505                                                    |
| Socioeconomic environment              |                                                        |                                                           |                                                          |
| Education at age 25: <HS (%)           | 37.7                                                   | -13.4                                                    | 32.7<sup>**</sup>                                        |
| Education at age 25: ≥college (%)      | 14.5                                                   | 37.5                                                     | 19.7<sup>**</sup>                                        |
| Median household income ($)            | 13,461                                                 | 30,348                                                   | 16,105<sup>**</sup>                                       |
| % population <150% FPL                 | 34.5                                                   | 4.7                                                       | 25.1<sup>***</sup>                                       |
| Housing Price Index<sup>b</sup>        | 33.4                                                   | 104.3                                                     | 34.5                                                     |
| Percentage of housing debt<sup>c</sup> | 65.0                                                   | 11.0                                                      | 58.4<sup>**</sup>                                        |
| Built environment                      |                                                        |                                                           |                                                          |
| Intersection density<sup>d</sup>       | 54.9                                                   | 22.3                                                      | 52.1                                                     |
| Population density (per km<sup>2</sup>)| 4,135                                                  | 124.2                                                     | 3,111<sup>***</sup>                                       |
| Park area (m<sup>2</sup>) within neighborhood (per km<sup>2</sup>) | 0.04                                                  | 0.002                                                     | 0.07<sup>**</sup>                                        |
| PA facilities (per km<sup>2</sup>)     | 1.7                                                    | 5.5                                                       | 1.6                                                      |
| Fast food restaurants (per km<sup>2</sup>) | 0.9                                                   | 1.6                                                       | 0.8                                                      |
| Convenience stores (per km<sup>2</sup>) | 0.8                                                   | 0.7                                                       | 0.8                                                      |
| Grocery stores/supermarkets (per km<sup>2</sup>) | 3.0                                                   | 0.1                                                       | 1.7<sup>***</sup>                                        |

Note. n = 392 neighborhoods across the four cities (Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; Oakland, California). FPL = federal poverty line.

<sup>a</sup>Values are unique based on the intercepts and slopes calculated for each class by PROC TRAJ.

<sup>b</sup>Birmingham in thousands ($); Chicago, Minneapolis, Oakland are index values.

<sup>c</sup>Percentage of owner-occupied housing units with a mortgage, home equity loan, or similar debts.

<sup>d</sup>Intersection density represents the number of three-way, four-way, and higher intersections per km<sup>2</sup>; collected beginning in 2000.

<sup>e</sup>Indicates that the values between stable and increasing trajectory classes are statistically significantly different (p < .05).

<sup>**</sup>Indicates that the values between decreasing and stable trajectory classes are statistically significantly different (p < .05).

caracterized as having an increasing trajectory of older adult populations, 37.8% (SD = 3.4) for neighborhoods assigned to the declining trajectory class, and 39.9% (SD = 3.3) for neighborhoods assigned to the class with “stable” older adult population (Figure 1). The change in the count of older adults in the increasing trajectory class was statistically significantly different from the change in the count of older adults in the “stable” trajectory class (Table 1); the same was true for the count of older adults in the declining (vs. “stable”) trajectory. Neighborhood trajectory classes were distributed with approximately equal proportions throughout the four cities (Figure 2).

**Differences Across Increasing and “Stable” Neighborhood Trajectory Classes**

Neighborhoods with an increasing (vs. “stable”) percentage of older adults had a statistically significantly lower percentage of population with household incomes less than 150% of the federal poverty level at baseline (Table 1). They also experienced a significantly greater decrease in the percentage of population with an education less than high school, as well as a greater increase in median household income and the percentage of population with an education greater than or equal to college over time. Neighborhoods with increasing percentages of older adults also had a statistically significantly lower increase in housing price index values and the percentage of housing units with debt over time.

Neighborhoods with an increasing (vs. “stable”) percentage of older adults had statistically significantly lower population density and intersection density at baseline, with a statistically significantly smaller increase in intersection density and the count of convenience stores per neighborhood area (km<sup>2</sup>) over time. Neighborhoods with increasing percentages of older adults also became statistically significantly less densely populated over time. We observed no differences in the availability of other types of food outlets or physical activity destinations, or park area, across “stable” and increasing trajectory classes.

**Differences Across Declining and “Stable” Neighborhood Trajectory Classes**

With a few critical exceptions, the results for neighborhoods with a declining versus “stable” percentage of older adults were similar to those for increasing versus “stable” percentages of older adults. For example,
neighborhoods with declining (vs. “stable”) percentages of older adults had a lower percentage of housing units with debt, but statistically significantly higher increases in housing price index values and the percentage of housing units with debt over time (Table 1).

In addition, we observed a statistically significantly smaller increase in the count of grocery stores per neighborhood area (km²) in neighborhoods with a decreasing (vs. “stable”) percentage of older adults over time. Neighborhoods with a declining (vs. “stable”) percentage of older adults also had a higher total park area at baseline but no differences in changes over time.

Sensitivity Analyses

In sensitivity analyses using other age groups, we found a different or lack of patterning of trajectory classes. For example, the percentage of middle-aged adults (45-54 years) varied across classes, but there were no differences in the patterns of change between 1980 and 2007-2011 (Supplemental Figure 1). In contrast, we observed very little changes in the percentage of children (<5 years) or the percentage of middle-aged adults (45-54 years) across neighborhoods over time, and thus trajectory classes could not be estimated due to overparameterization of the models; unlike the older adult population, the distribution of these age groups did not meaningfully change over time.

We also conducted sensitivity analyses using a different baseline year as data corresponding to baseline values varied by source. Using data corresponding to baseline values from 1990 to 1999, we found similar results to our central findings using data corresponding to baseline values from 1980 to 1999 (Supplemental Table 1). Although all results were in the same direction, several differences in characteristics were statistically significant in sensitivity analyses that had failed to reach statistical significance in the main analysis, and vice versa. This is likely due to differential rates of change in neighborhood characteristics across trajectory classes (e.g., greater relative increases in housing prices between 1980 and 1990 in neighborhoods with an increasing vs. “stable” percentage of older adults).

Discussion

Using 30 years (1980-2011) of longitudinal data from four U.S. cities and a finite mixture model procedure, we identified three types of neighborhoods: those with a “stable,” declining, or increasing older adult population. We found that compared with neighborhoods with a “stable” percentage of older adult populations,
neighborhoods with an increasing percentage of older adult populations were characterized by higher socioeconomic advantage and lower connectivity and population density over time; the same was true for neighborhoods with declining older adult populations. In contrast, neighborhoods with an increasing percentage of older adult populations were characterized by more "stable" housing conditions over time, while the opposite occurred for neighborhoods with declines in older adult population. These findings may have important implications for both the neighborhoods experiencing these changes and the individuals residing in them.

Consistent with our hypotheses, our findings indicated that neighborhoods with an increasing percentage of older adults were characterized by lower initial poverty, larger decreases in poverty, greater increases in education, and greater increases in median household income over time. The same was true for neighborhoods with declining older adult populations. Our findings are encouraging because increases in socioeconomic advantage may attract new businesses, encourage social activities, and promote feelings of safety, which may improve older adults' quality of life (Van Dyck, Teychenne, McNaughton, De Bourdeaudhuij, & Salmon, 2015). Our results also showed that neighborhoods with an increasing percentage of older adults were characterized by lower increases in housing prices and housing debt over time, but neighborhoods with declining older adult populations experienced less stability. As many older adults have fixed incomes (Wu, 2013), living in neighborhoods with stable housing conditions may help reduce economic strain caused by fluctuations in cost of living and economic shocks. Although we were unable to tease apart the contextual versus compositional aspects of demographic shifts (Cagney, 2006), neighborhoods with an increasing percentage of older adults may provide their residents with more stable socioeconomic and housing conditions, and thus support the likelihood of older adults remaining in their homes, whereas less favorable housing conditions in neighborhoods with declining older adult populations may compel older adults living in these neighborhoods to relocate to more affordable areas.

Neighborhoods with an increasing trajectory of older adult populations were characterized by lower initial population and intersection density, and became less dense and connected over time. Our findings are consistent with King and Clarke (2014), which found that census tracts with a higher proportion of older adults had lower walkability. Our results are also consistent with the limited evidence on housing preferences for the baby boomer generation, which suggests that this age group is mixed in their preference for urbanicity, proximity of destinations, compact development, and public transportation options (Urban Land Institute, 2013). It is possible that older generations ("War Babies" and "Silent Generation"), with preferences for connected, walkable neighborhoods, are being replaced by baby boomers with mixed or opposite preferences.

Regardless, our findings have implications for the health of older adults: Previous research suggests that less dense, less connected development may be associated with decreased physical activity and increased mobility impairment among older adults (Clarke & Gallagher, 2013; Moran et al., 2014; Rosso, Grubesic, Auchincloss, Tabb, & Michael, 2013; Yen, Flood, Thompson, Anderson, & Wong, 2014). In addition, living in a more sprawling environment may create barriers for social engagement and lead to higher levels of social isolation among older adults (Freeman, 2001), while living in more dense settings may support greater community participation (Leyden, 2003; Richard, Gauvin, Gosselin, & Laforest, 2009). Higher population and intersection density generally reflect higher walkability (Leslie et al., 2007), a key element for independence (Webber, Porter, & Menec, 2010), particularly after driving cessation (Edwards, Perkins, Ross, & Reynolds, 2009). Furthermore, neighborhoods with declines in older adult populations had a higher total park area at baseline, which might encourage physical activity and social interaction among the older adults remaining in those communities. These findings might reflect an influx of younger generations or families with young children, who seek out neighborhoods with greater park area due to increased opportunities for outdoor recreation.

In sensitivity analyses, we did not identify similar trajectory classes in either young adult or middle-aged populations, two groups that play a key role in shaping neighborhood age distributions. The group of neighborhoods with an increasing percentage of older adult populations in our study likely arose from a growing overall older adult population, as well as residential movement of other age groups out of neighborhoods (and vice versa for neighborhoods with a declining percentage of older adults). Despite consistency between changes in the percentage of older adults and changes in the count of older adults across neighborhood trajectory classes, it is important to consider the potential for increased age segregation within the four cities (Cowgill, 1978). In particular, future work should explicitly examine patterns of age segregation across the United States in the context of evolving residential development patterns.

To our knowledge, this is the first study to identify neighborhood trajectory classes of older adult populations in the United States and to examine characteristics of neighborhoods experiencing growth in older adult populations. Unlike the largely cross-sectional literature, we used detailed, time-varying data related to older adults' neighborhood environments, including comprehensive measures of neighborhood-level socioeconomic characteristics and built environment features. Furthermore, we used a longitudinal model to describe population dynamics across 30 years of follow-up, allowing us to examine differences in neighborhood...
Our study is a critical first step in understanding which or declining (relative to “stable”) older adult populations may not be a challenge in neighborhoods with increasing age composition in those communities. In general, we observed no differences in the availability of food outlets affecting declines in older adult populations had less stable housing conditions, which might underlie the changes in housing markets over time, these areas were more stable than less urban neighborhoods or other regions. Finally, we did not measure age segregation within neighborhood units, and thus cannot comment on the distribution of neighborhood-level characteristics in neighborhoods with a highly dissimilar proportion of older adults relative to younger age groups.

The emergence of three distinct trajectory classes of older adult populations across four large U.S. cities reflects the changing landscape of aging in the United States. As the older adult populations in some neighborhoods continue to grow, efforts to create more connected street networks are crucial for encouraging physical activity and mobility among older adult residents. It is also important to provide affordable housing options to promote social interaction and independent living among older adults, especially in neighborhoods with declining older populations. Identifying areas with growing or declining older adult populations is necessary for targeted allocation of community resources and development of strategies to create sustainable, livable communities. Our results emphasize the need to consider built and social environments when planning supportive, livable communities for older adults, especially street network connectivity and housing affordability.

In sum, we found that while neighborhoods experiencing 30-year increases in older adult populations had more stable housing markets over time, these areas were less dense and less walkable than areas with younger populations. We also found that neighborhoods experiencing declines in older adult populations had less stable housing conditions, which might underlie the changes in age composition in those communities. In general, we observed no differences in the availability of food outlets or physical activity facilities across trajectory classes, suggesting that proximity to commercial destinations may not be a challenge in neighborhoods with increasing or declining (relative to “stable”) older adult populations. Our study is a critical first step in understanding which features of the neighborhood environment are experiencing meaningful changes along with changes in the older adult population.

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Characteristics at baseline and changes over time. Despite these strengths, we were unable to examine the mechanisms through which changes in older adult populations influenced changes in neighborhood characteristics over time, and vice versa. In addition, we did not examine how neighborhood characteristics influenced individual-level health behaviors and outcomes of older adults, and therefore cannot comment on whether differences across neighborhood trajectory classes were meaningful. Our measures were collected at different time points, and data were unavailable for some neighborhood characteristics at earlier years (e.g., connectivity); however, sensitivity analyses showed that variation in baseline measurement did not substantively affect our results. Another limitation of this study was a lack of data to describe important aspects of livability, such as community engagement, safety, government services, or the condition of amenities over time. While our sample is geographically diverse, neighborhoods only represent four metropolitan areas, and thus our findings may not be generalizable to less urban neighborhoods or other regions. Finally, we did not measure age segregation within neighborhood units, and thus cannot comment on the distribution of neighborhood-level characteristics in neighborhoods with a highly dissimilar proportion of older adults relative to younger age groups.
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