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Destinations That Older Adults Experience Within Their GPS Activity Spaces Relation to Objectively Measured Physical Activity

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Abstract

Identifying the relevant geography is an ongoing obstacle to effectively evaluate the influence of neighborhood built environment on physical activity. We characterized density and diversity of destinations that 77 older adults experienced within individually representative GPS activity spaces and traditional residential buffers and assessed their associations with accelerometry-measured physical activity. Traditional residential buffers had lower destination density and diversity than activity spaces. Activity spaces based only on pedestrian and bicycling trips had higher destination densities than all-mode activity spaces. Regardless of neighborhood definition, adjusted associations between destinations and physical activity generally failed to reach statistical significance. However, within pedestrian and bicycling-based activity spaces each additional destination type was associated with 243.3 more steps/day (95% confidence interval (CI) 36.0, 450.7). Traditional buffers may not accurately portray the geographic space or neighborhood

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resources experienced by older adults. Pedestrian and bicycling activity spaces elucidate the importance of destinations for facilitating active transportation.

Keywords

Global Positioning Systems (GPS)/Geographic Information Systems (GIS); Activity Space; Mobility; Walkability; Neighborhood Attributes; Destinations; Physical Activity

Introduction

As we age, it becomes increasingly imperative to maintain our mobility and quality of life and, in turn, our independence. These factors are inextricably linked and the World Health Organization suggests "mobility… is the best guarantee of retaining independence and being able to cope" (Heikkinen & World Health Organization Ageing and Health Programme, 1998). Being physically active is also closely linked with aging well (Chodzko-Zajko, 2014) as it effectively increases functional mobility (Gretebeck, Ferraro, Black, Holland, & Gretebeck, 2012), quality of life (Rejeski, Brawley, & Shumaker, 1996; Rejeski & Mihalko, 2001), and psychological wellbeing (Aenchbacher III & Dishman, 2010; McAuley & Rudolph, 2010; O'Connor, Aenchbacher III, & Dishman, 1993). While a myriad of individual-level factors influence older adults' physical activity levels, contextual factors, such as neighborhood built environments, play important roles to positively influence older adult physical activity and independent mobility (Clarke, Ailshire, & Lantz, 2009; Cunningham & Michael, 2004; Northridge, Sclar, & Biswas, 2003; Schulz & Northridge, 2004). A growing literature supports that neighborhood built environments, including physical features such as destinations, street layout, transportation and aesthetics (S. L. Handy, Boarnet, Ewing, & Killingsworth, 2002) support or inhibit physical activity (Lovasi, Grady, & Rundle, 2012; Marquet & Miralles-Guasch, 2015; Saelens & Handy, 2008; Saelens, Sallis, & Frank, 2003; Van Cauwenberg et al., 2011; Van Holle et al., 2012; Wendel-Vos, Droomers, Kremers, Brug, & Van Lenthe, 2007). Specifically, destinations such as shopping, grocery stores, malls, and restaurants (Chudyk et al., 2015; Davis et al., 2011) provide opportunities for older people to accomplish daily errands on foot. Access to commercial destinations (measured as density or a composite walkability index) has been associated with higher amounts of walking (Glazier et al., 2014; S. Handy, 2005; Yvonne L Michael, Beard, Choi, Farquhar, & Carlson, 2006; Nagel, Carlson, Bosworth, & Michael, 2008) and walking for transportation (Giles-Corti et al., 2013; Hirsch, Moore, et al., 2014; Hirsch, Moore, Evenson, Rodriguez, & Roux, 2013; McCormack, Giles-Corti, & Bulsara, 2008; Sallis, Floyd, Rodríguez, & Saelens, 2012). Recreational destinations within neighborhoods were also positively associated with physical activity (Diez Roux et al., 2007; Ranchod, Diez Roux, Evenson, Sánchez, & Moore, 2014) and recreational walking (Chaix et al., 2014; Fisher, Li, Michael, & Cleveland, 2004; Giles-Corti et al., 2013; Li, Fisher, Brownson, & Bosworth, 2005; Yvonne L Michael et al., 2006; Sallis et al., 2012). Research identifying destinations that older adults encounter throughout their daily life would help us better understand the potential role these locations play to promote physical activity.

Yet throughout this literature, a persistent challenge is identifying the optimal geographic scale to effectively capture the role of neighborhood built environments for older adult physical activity (M.-P. Kwan, 2012a, 2012b; M. P. Kwan, 2000). The majority of previous work has relied upon administrative boundaries (e.g. counties, census tracts) or residential buffers (i.e. Euclidean or network street distances from participants' homes) (Leal & Chaix, 2011). However, neighborhoods represented by these approaches may not accurately reflect environmental exposures individuals experience. Additionally, conventional buffer distances may not be the appropriate scale to assess physical activity in older adults, given that distances older adults walk and cycle are both longer and shorter than commonly used buffers (Morency, Paez, Roorda, Mercado, & Farber, 2011; Prins et al., 2014). The focus on residential neighborhoods may miss other salient environments, such as work locations, yet fewer than 5% of studies evaluated non-residential locations (Chaix, 2009).

One potential strategy to better capture neighborhood parameters is to use "activity spaces." Activity spaces are individual-based measures of spatial behavior derived from data acquired using Global Positioning Systems (GPS) (Hirsch, Winters, Clarke, & McKay, 2014; Matthews & Yang, 2013; Perchoux, Chaix, Cummins, & Kestens, 2013; Sherman, Spencer, Preisser, Gesler, & Arcury, 2005; Starnes, 2012; van Heeswijck et al., 2015; Zenk et al., 2011). These represent opportunities to more closely examine health and behavior outcomes as they relate to characteristics within individually-generated neighborhood boundaries. Previous work examining the influence of opportunities found within activity spaces and physical activity outcomes has been limited, and with conflicting results (Starnes, 2012; van Heeswijck et al., 2015; Zenk et al., 2011). No studies have examined activity spaces of older adults, despite older people being highly dependent on their local environments (Cunningham & Michael, 2004; Day, 2008; Marquet & Miralles-Guasch, 2015; Yvonne L. Michael, Green, & Farquhar, 2006). The substantial time spent in their residential neighborhoods, as well as potential mobility or resource limitations may confine this group to smaller activity spaces, with greater overlap with traditional buffers. Additionally, no previous work has teased apart activity spaces by different modes of travel. Characterizing mode-specific activity spaces can further our understanding of the types of built environments people choose to walk and bicycle in. These specific choices can then be compared with areas individuals experience across all travel (including car trips).

Therefore, our overall aim was to understand neighborhood opportunities experienced by older adults beyond traditional buffers. To do so, we created GPS activity spaces for 77 low-income older adults who reside in Metro Vancouver, Canada. We address three central objectives: 1) assess density and diversity of destinations (Cervero & Kockelman, 1997) within participants' individually representative activity spaces, as compared to traditional definitions of neighborhoods; 2) compare destinations present in activity spaces based on all travel, versus activity spaces based only on pedestrian and bicycling travel; and 3) evaluate whether destination landscapes within these neighborhoods is associated with participants' objectively measured physical activity. We assert that destinations within activity spaces will vary from destinations within traditional buffers, as people will travel far to access destinations that support their daily needs. Further, we hypothesize that higher density and more diverse destinations within all types of neighborhood will be positively associated with physical activity.

Methods

Sample

We used participant data from Walk the Talk (WTT), a cross-sectional study (January–May 2012) evaluating the association between built environments and mobility and health of 161 low-income older adults (≥65 years) residing in Metro Vancouver. Methods for WTT are described elsewhere (Chudyk et al., 2015; Hirsch, Winters, et al., 2014). Briefly, WTT base population consists of 5806 households that receive a Shelter Aid for Elderly Renters (SAFER) rental subsidy from BC Housing and with a head of household aged ≥ 65 years. Households were sampled using a random stratified design within deciles of Walk Score® (www.walkscore.com) to ensure a range of neighborhood settings. Individuals were excluded if they were diagnosed with dementia, left their home less than once in a typical week, were unable to understand or speak English, were unable to walk more than ten meters with or without a mobility aid (e.g. cane, walker), or participate in a mobility assessment involving a four meter walk. A subgroup (n=107) of participants received GPS (QStarz BT-Q1000XT, 1s epoch), accelerometers (ActiGraph GT3X+, ActiGraph LLC, FL; 30 Hz sampling rate) and travel diaries and were instructed as to their use for a 7 day period. The study was approved by University of British Columbia’s Clinical Research Ethics Board. Participants were included in this analysis if they had valid data for GPS (n=95) and were not missing information on objectively measured physical activity (n=16) or destination densities (n=2) leaving a final sample size of 77.

Neighborhoods

We cleaned GPS data and generated activity spaces using methodology detailed elsewhere (Hirsch, Winters, et al., 2014; Voss, Winters, Frazer, & McKay, 2015; Voss, Winters, Frazer, & McKay, 2014). In short, GPS data were downloaded as .csv files (QStarz data viewer). Using a custom-built tool (MS Access), imprecise/invalid data points were excluded (‘no fix’ and HPOD ≥10), and GPS data were time-aligned with accelerometry files (1s epoch, .csv). Then GPS data were processed using ArcGIS Tracking Analyst in concert with travel diaries to define start and end points of trips, and mode, based on trip speed, distance, duration, and accelerometry-defined activity level. We removed trips outside Metro Vancouver so as to represent regional travel. We selected trip-related GPS point data (n= 1,392,347) and processed them using Python 2.7.2 (Python Software Foundation, www.python.org) and ArcPy for ArcGIS 10.1 (ESRI, Redlands, CA, USA).

We developed activity spaces using Daily Path Areas (DPA). This approach builds 200 meter buffers around all of an individual’s trips, resulting in a geographic area that most closely represents destinations a participant would actually encounter during trips. To capture the geographic extent of active travel, pedestrian and bicycling activity spaces were derived using the DPA method only for trips coded as walking or bicycling. Pedestrian and bicycling activity spaces existed only for the sample subset that took these modes (n=59). Sensitivity analyses were performed using two additional types of activity space approaches (Standard Deviation Ellipse (SDE) and Minimum Convex Polygon (MCP)).

Traditional residential buffers (Euclidean 400 meter and 800 meter) were created in ArcGIS 10.1 (ESRI, Redlands, CA, USA). An example of overlap between traditional residential buffers and DPA activity spaces can be found in Figure 1. We conducted sensitivity analyses on activity spaces with and without water; areas were highly correlated (Spearman's ρ >0.99, p<0.0001) and results were consistent across measures with and without water (not presented).

Destinations

We obtained destination point data from Environics Analytics business data (Toronto, ON, Canada, March 2013) and classified using North American Industry Classification System (NAICS) codes into 16 mutually exclusive categories (ambulatory health care services, banks/credit unions, community center/neighborhood house, convenience stores, entertainment, food stores, gyms and fitness centers, library, malls, museum, nature/parks/ botanical gardens, pharmacies/drug stores/personal care, religious organizations, restaurants, retail shopping, and services, see Table S1). We calculated density (count per km^2) and diversity (number of different destinations) of destinations using ArcGIS 10.1. Due to the non-normal distribution of densities, we log-transformed all destination densities for regression analyses.

Physical Activity

We used ActiGraph GT3X + triaxial accelerometers (ActiGraph GT3X+, ActiGraph LLC, Pensacola, FL) without low-frequency extension to objectively quantify total physical activity, step counts, and meeting daily recommended step counts. We converted raw .gt3x files to 60s epochs .agd files for analysis using ActiLife v. 6.5.4. (ActiGraph LLC, FL). We defined non-wear time as intervals of ≥60 consecutive minutes of zero activity counts, allowing spikes of ≤2 min of ≤100 counts per minute (Troiano et al., 2008). We deemed a day valid if there were ≥600 min of wear time (mean 813.6 min/day; median 811.7 min/ day), and included participants if they had a minimum of 3 valid days (mean 6.4 valid days; median 7 valid days), as is recommended (Hart, Swartz, Cashin, & Strath, 2011). We did not adjust our analyses for accelerometer wear time because we did not find a large association between daily wear time and daily physical activity measures. We extracted total steps and total acceleration counts for valid days. We calculated mean daily steps as total steps divided by valid accelerometry days. Meeting recommended step counts was defined as ≥7100 steps per day, a recommended threshold for health benefits for older adults (Tudor-Locke et al., 2011). We calculated mean daily minutes spent in light physical activity (100–1951 counts per minute) and moderate-to-vigorous physical activity (MVPA; ≥1952 counts per minute) relative to valid accelerometry days (Freedson, Melanson, & Sirard, 1998). We focus on total physical activity (light plus MVPA) given the health benefit of any activity in older populations (Buman et al., 2010; Simonsick, Guralnik, Volpato, Balfour, & Fried, 2005; Sparling, Howard, Dunstan, & Owen, 2015). Sensitivity analyses examining MVPA, or sedentary time, found similar results (not shown).

Sociodemographic and Resource Characteristics

We assessed participants' self-reported sociodemographic and resource characteristics via questionnaire, including age, race, education level, marital status, cohabitation with someone, dog ownership, current valid driver's license, vehicle at their disposal, length of time in their current neighborhood, support for going outside, enjoyment of walking outside, confidence to walk outside, falls in the past 6 months, and use of a mobility aid. We assessed neighborhood walkability using Street Smart Walk Score® (www.walkscore.com), a single measure that accounts for distance to popular amenities and street design and has been shown to be associated with walking (Hirsch, Moore, Evenson, Rodriguez, & Diez Roux, 2013; Hirsch, Moore, Evenson, Rodriguez, & Roux, 2013). Categorization of all of these variables is described elsewhere and was guided by meaningful cut points and distribution (Hirsch, Winters, et al., 2014).

Analyses

We described density and diversity of destinations using medians and interquartile range (IQR) and mean and standard deviation (SD), respectively, for each activity space and traditional buffer. We compared density and diversity of destinations across traditional residential buffers and activity spaces using Spearman's and Pearson's correlation coefficients (ρ), respectively. Linear and logistic models were used to assess associations between destinations and physical activity (PA) (total PA, daily step count, and meeting recommended steps) as appropriate. We selected model covariates (age, gender, education, having access to a vehicle) using a Directed Acyclic Graph (DAG) and a priori knowledge on sociodemographic and resource characteristics that act as confounders (Greenland, Pearl, & Robins, 1999; Textor, Hardt, & Knüppel, 2011). We back-transformed and scaled results for destination densities so that regression estimates represented a change in physical activity for a 10% increase in destination density. We conducted all statistical analyses using SAS software, Version 9.3 (SAS Institute Inc., Cary, NC, USA).

Results

Participants were primarily female and Caucasian, and lived across diverse walkability settings (Table 1). While 75.3% had valid driver's licenses, only 59.2% had access to a vehicle. On average, participants took 5149.5 steps/day (SD 2941.3 steps/day) and 246.5 min/day (SD 80.7 min/day) of total physical activity comprised of 20.2 min/day MVPA (SD 20.8 min/day) and 226.3 min/day light activity (SD 71.3 min/day). Of 77 participants, only 14 (18.2%) met recommended daily step counts for older adults.

Across all destination categories, traditional residential buffers had lower destination densities and a lower mean number of destination types (diversity) than activity spaces (Table 2; supplemental Table S2). While activity spaces encompassed a mean of 14.66 of 16 destination types (SD 1.59), traditional buffers only encompassed 6.83 (SD 3.94) and 10.13 (SD 3.73) destination types for 400-m and 800-m buffers, respectively. In analyses of specific destination types, many traditional buffers did not encompass convenience stores, entertainment, libraries, malls, museums, and nature/parks/botanical gardens, while most activity spaces still encompassed these locations, albeit at low densities. For 59 participants who had pedestrian and bicycling activity spaces, these spaces covered between 0.4% and 100% of their activity spaces based on trips by all modes, with an average overlap of 23.6% (SD 31.8%). Activity spaces based on pedestrian and bicycling trips only had higher destination densities than activity spaces for trips by all modes. However, activity spaces from all trips encompassed 4/16 additional destination types, on average (mean diversity 14.66, SD 1.59 for all modes; mean diversity 10.46, SD 3.95 for pedestrian and bicycling only).

Similarly, density of destinations within activity spaces was poorly correlated with density of destinations within traditional buffers (Figure 2, supplemental Table S3). Associations were somewhat higher between activity spaces and 800-m traditional buffers than between activity spaces and 400-m buffers. When we compared all-mode activity spaces and pedestrian and bicycle activity spaces, correlations of destination densities were higher, although Spearman's correlation coefficients were below 0.66. Similarly, correlation coefficients between the two traditional buffer distances were higher (Spearman's ρ 0.51 to 0.87) but still indicated disagreement between these definitions of neighborhood. Correlations between neighborhood types for destination diversity demonstrated patterns similar to what we observed for destination densities.

Regardless of neighborhood geography definition used, adjusted associations between total destination density and diversity and total physical activity, daily step count, or odds of meeting recommended daily step counts were generally positive, although they failed to reach statistical significance (Table 3). Results were similar for other definitions of activity space (supplemental Table S4). However, diversity of destinations found in pedestrian and bicycling activity spaces was significantly associated with daily step count; for each additional destination type, 243.34 more daily steps were taken, on average (95% confidence interval (CI) 35.97, 450.70). Similar patterns emerged for specific destination densities (supplemental Tables S5–S6). Few specific destination densities in traditional buffers or all-mode activity spaces were associated with measures of physical activity. However, specific destination densities within pedestrian and bicycling activity spaces were associated with physical activity outcomes. Of particular note, density of convenience stores within pedestrian and bicycling-based activity spaces was associated with increases for all three measures of physical activity. Finally, density of banks/credit unions within pedestrian and bicycling-based activity spaces was associated with increased total physical activity and daily step count.

Discussion

We extend the sparse body of literature that investigates neighborhood opportunities experienced by older adults, beyond the traditional buffer approach. We noted stark differences between destinations older adults experience within their traditional residential buffers and activity spaces assessed using GPS. As anticipated, traditional residential buffers had lower destination density and diversity compared with activity spaces. Further, activity spaces representing travel by pedestrian and bicycling had higher destination densities than did activity spaces representing travel by all modes. We noted associations between diversity of destinations and densities of convenience stores and banks within pedestrian and bicycle activity spaces and daily step count. However, there were few other significant associations between these destination landscapes and objectively measured physical activity.

One key finding was the difference in destination landscape we observed between traditional residential buffers and activity spaces. This highlights that traditional residential buffers may not accurately portray the geographic space or neighborhood resources experienced by older adults. While previous work indicates that older adults are highly influenced by their local environments (Cunningham & Michael, 2004; Day, 2008; Marquet & Miralles-Guasch, 2015; Yvonne L. Michael et al., 2006), in reality, older adults experience a greater density and wider diversity of destinations in their geographic activity spaces than their traditional residential buffers would suggest. Traditional buffers underestimate resources available to older adults, notably entertainment, parks, and libraries. This finding is in keeping with our previous work where 400-m and 800-m traditional buffers accounted for between 7.8 and 22.3 percent of GPS-based activity spaces (Hirsch, Winters, et al., 2014). In other age groups whose mobility may be less constrained, overlap between activity spaces and traditional residential buffers may be even smaller. Also of note, a number of studies identified a key set of destinations older adults visit as part of their daily routine (Chudyk et al., 2015; Davis et al., 2011). These results highlight the dichotomy between nearby resources for older adults and older adults' abilities to travel to necessary destinations. It seems that if people need to access these destinations for critical daily amenities (e.g. food stores or retail shopping) they will travel to them, away from their immediate neighborhood. In support of this, many destinations (including convenience stores, entertainment, libraries, malls, museums, and nature/parks/botanical gardens) are generally absent from traditional residential buffers but appear in activity spaces. Our observations are consistent with evidence on food environments; shoppers travelled far outside traditional residential neighborhoods to grocery stores (Hirsch & Hillier, 2013) and older adults travelled outside traditional neighborhoods (Prins et al., 2014). However, similar to previous work in Vancouver (Winters et al., 2015), our sample of older adults was fairly active and potentially more able to engage in activities to seek out amenities far from home. Nonetheless, as a low-income sample, this group of older adults may have fewer resources, such as access to a vehicle, to engage in travel outside of their immediate neighborhoods. Further work should continue to better understand the dual roles of local environments and resources or capacity for mobility on access to destinations for older adults. We note a meager association between destinations within activity spaces and traditional residential buffers. However, correlations between traditional buffer distances was not perfect, so some of these discrepancies may also reflect that, in general, destination landscapes are affected by scale issues. This aligns with previous work that reported the influence of built environments on obesity differed based on size and shape of residential buffers (James et al., 2014). Overall, activity spaces can illuminate some limitations of traditional buffers and help inform findings from research using traditional buffers.

Previously, researchers who examined activity spaces treated travel uniformly across all modes. Our study makes a unique contribution to the literature in that we generated mode-specific activity spaces. By creating activity spaces solely from pedestrian and bicycling trips, we were better able to observe the types of places where active travel for older adults occurs. In general, these pedestrian and bicycling activity spaces had higher destination densities than those derived from all modes. It makes conceptual sense that places where people walk or bicycle, rather than drive, have more destinations in close proximity making active travel modes convenient (Hirsch, Moore, et al., 2014; Winters, Brauer, Setton, & Teschke, 2010). Interestingly, the relationship between pedestrian and bicycling activity spaces and all-mode activity spaces varied widely. Across the sample, some participants had geographically constrained pedestrian and bicycle spaces (only 0.4% of their full activity space), while others covered their full activity space by these modes. Investigating individual characteristics or neighborhood features for those whose entire geographic extent is dictated by walking and bicycling trips may illuminate optimal conditions to live an active life.

This work adds to emerging literature linking activity spaces to health outcomes. We did not observe an association between destination densities in activity spaces (all modes) and physical activity. Two studies have reported positive associations between built environment measures and physical activity or active travel (Starnes, 2012; van Heeswijck et al., 2015). In an unpublished dissertation, Starnes reported a positive association between population density and land use mix within activity spaces with daily MVPA in 148 adult trail users (Starnes, 2012). Van Heeswijck et al. constructed activity spaces from a travel survey (based on shortest path, not GPS) and found a positive association between destination density and odds of reporting active transportation (van Heeswijck et al., 2015). However, studies in other age groups and geographies have found no association between recreational opportunities (parks or green space) and physical activity (Starnes, 2012; Zenk et al., 2011). Finally, we did not observe a significant association between destination densities and physical activity for traditional residential buffers, counter to previous literature (Diez Roux et al., 2007; Glazier et al., 2014; Hirsch, Moore, et al., 2014; McCormack et al., 2008; Yvonne L Michael et al., 2006; Nagel et al., 2008; Ranchod et al., 2014). These findings may reflect our relatively small sample size, use of objective measures of physical activity, or characteristics of this older adult sample (e.g. transit access or urbanicity).

The directionality of the associations we observed between destination diversity within pedestrian and bicycling-based activity spaces and daily step counts are not straightforward. People who walk more may have larger pedestrian and bicycling activity spaces which, in turn, captures more destinations. However, in compact environments where many daily trips are within short distances, walking more may not translate directly to bigger activity spaces. Previous work showed higher walkability translated to smaller, more compact spaces (Hirsch, Winters, et al., 2014). Importantly, some specific destinations (convenience stores and banks/credit unions) were associated more physical activity when they were within pedestrian and bicycling activity spaces. This highlights the importance of these types of destinations to encourage a physically active lifestyle.

Our study illustrates advantages of an activity space approach, but users must also be cognizant of limitations. These GPS methods are at the forefront for assessing environmental exposures with high sensitivity and accuracy(Jankowska, Schipperijn, & Kerr, 2015), in that they characterize neighborhoods at the individual level, which may reduce misclassification bias related to time away from residential locations. However, creating GPS-derived activity spaces can be expensive for researchers and taxing on participants (Zenk et al., 2012). We may see GPS used in subsets of large cohort studies, to inform findings from traditional buffer-based analyses or alternatively, with technological developments we may see new methods of GPS collection (e.g. cell phone traces). Additionally, GPS-based activity spaces do not reflect duration of time in any area, or give insight into what locations individuals visit most frequently, or how they traveled there. Potential for selective daily mobility bias (Chaix et al., 2013) must be considered when using GPS to examine location-specific physical activity. Finally, use of activity spaces as individual neighborhood boundaries may make it hard to identify salient locations or scales for policy interventions. Despite these limitations, activity spaces bring value as indicators of mobility over time and can provide insight into how geographic extents change during different life transitions. Activity spaces may also have important implications for outcomes including quality of life or social connections.

Strengths and Limitations

To our knowledge, this is the first study to utilize activity spaces to characterize destinations older adults experience and potential associations with physical activity. Unlike previous work, we utilized both GPS-based measures of geographic extent and objectively measured physical activity. Furthermore, we examined mode-based activity spaces (not previously tested) and from this were able to understand geographic features of active travel. While we only used one type of activity space (DPA), results from sensitivity analyses with two additional types showed no substantial differences. Our sample of older adults with low-incomes allowed us to understand differences between traditional buffers and activity spaces among those whose mobility may be restricted by physical, cognitive, or financial limitations. However, future studies would benefit from a comparative assessment of the value of activity spaces in different age groups. We also acknowledge study limitations, including a small sample size and a cross-sectional design that limits our ability to draw causal inference. Further, we did not examine aspects of built environments beyond density. Objective physical activity measured with accelerometry does not accurately capture physical activity gained during bicycle travel, although these were rare in this dataset (16 of more than 2100 trips). While our sample was drawn across diverse walkability settings, results may not be generalizable to less urban samples or other geographic locations.

Conclusion

To better serve the needs of an aging demographic we must first understand where older people choose to go to meet their daily needs, and how they get there. We used a novel approach, mode-specific activity spaces, and shed some light upon the role destinations play to facilitate active transportation. However, there is much yet to do. Larger studies might further explore the relation between destinations and objectively measured physical activity, and the relation between activity spaces and key outcomes such as social isolation and psychological well-being.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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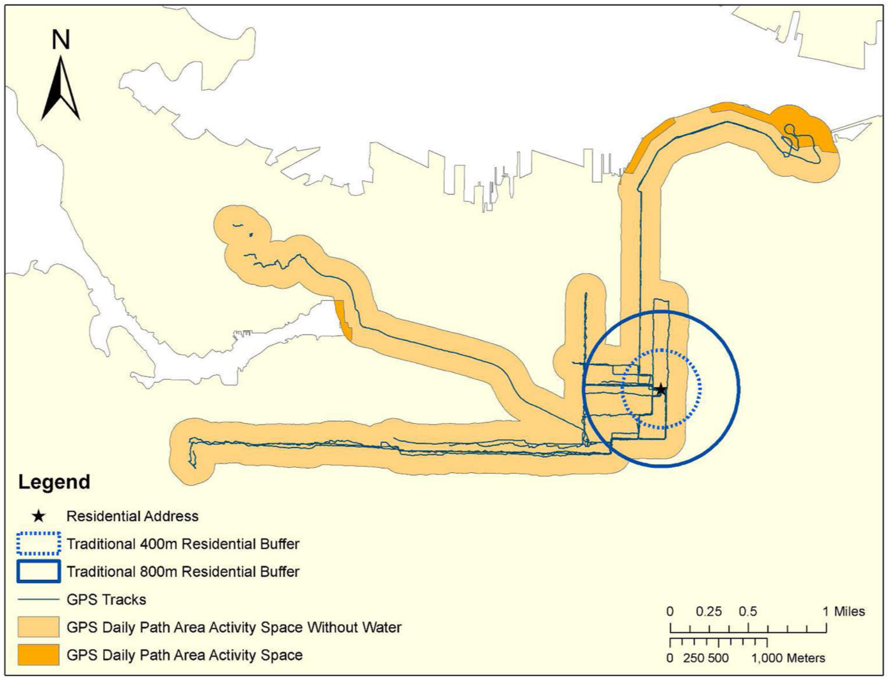

Figure 1.

Example of traditional residential buffers (shown in solid and dotted line) with a Daily Path Area (DPA) activity space (shown as solid polygon). Residential home address indicated with a star, GPS tracks shown with thin solid lines.

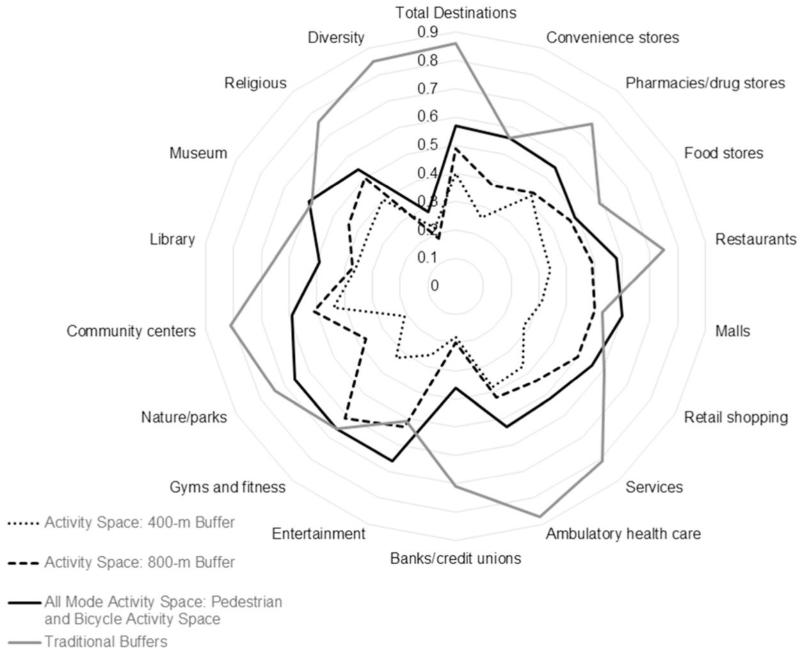

Figure 2.

Correlation between destination densities (count/km^2) and diversity in different types of neighborhoods. Dotted lines represent the correlation between 400-m traditional buffers and activity spaces. Dashed lines represent the correlation between 800-m traditional buffers and activity spaces. Black lines represents the correlation between activity spaces created using trips by all modes and activity spaces created using only pedestrian and bicycling trips. Grey lines represent the correlation between the sizes of traditional buffers (400-m and 800-m).

Table 1

Demographic and resource characteristics of Walk The Talk (WTT) participants with valid GPS, accelerometer and GIS destination data (n=77).

	Percent (n)	Mean (SD)
Female	66.2 (51)	
Age (years)		
65–69	28.6 (22)	
70–74	32.5 (25)	
75–79	24.7 (19)	
80+	14.3 (11)	
White	81.8 (62)	
Education		
Secondary school or less	28.6 (22)	
Some or completed trade/technical school or college	39.0 (30)	
Some university or higher	32.5 (25)	
Married	7.8 (6)	
Living with someone else	15.6 (12)	
Own a dog	11.7 (9)	
Walkability[a]		
Car dependent (0–49)	18.2 (14)	
Somewhat walkable (50–69)	26.0 (20)	
Very walkable (70–89)	28.6 (22)	
Walker's paradise (90–100)	27.3 (21)	
Length of time in neighborhood		
≤ 2 years	26.0 (20)	
Between 2 and up to 6 years	31.2 (24)	
Between 6 and up to 9 years	15.6 (12)	
> 9 years	27.3 (21)	
Have a valid driver's license	75.3 (58)	
Have access to a vehicle	59.2 (45)	
Have social support/companionship to go outside	62.3 (48)	
Have physical support to go outside	54.6 (42)	
Very much like to walk outside[b]	70.1 (54)	
Fall in the last 6 months	18.2 (14)	
Use a mobility aid for walking	15.6 (12)	
Total physical activity (min/day)[c]		246.5 (80.7)
Daily step count		5149.5 (2941.3)
Percent meeting recommended step count[d]	18.2 (14)	

[a]Measured by Street Smart Walk Score for home address.

[b]Less than very much (1–4 on a 5-point scale); Very much (5 on a 5-point scale).

[c] ActiGraph accelerometry (GT3X+, 60s epoch); includes both light physical activity (100–1951 counts per minute) and moderate-to-vigorous physical activity (≥1952 counts per minute) (Freedson et al., 1998).

[d] Meeting recommended steps were calculated as those with greater than 7100 steps per day (Tudor-Locke et al., 2011).

Table 2

Density (count/km^2) and diversity of destinations[a] across traditional residential buffers and activity spaces.

	Traditional Residential Buffers		GPS-Defined Activity Spaces	
	400-m Buffer[b]	800-m Buffer[b]	All Modes Activity Space[c]	Pedestrian and Bicycling Activity Space[d]
Destination Measure	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**	**Median (IQR)**
Densities (count/km^2)				
Ambulatory health care services	3.98 (23.86)	8.96 (22.39)	19.21 (24.95)	31.84 (70.75)
Banks/credit unions	0.00 (1.99)	1.00 (2.99)	2.30 (2.24)	4.45 (9.65)
Community center/neighborhood house	0.00 (3.98)	1.49 (3.48)	2.71 (4.04)	4.53 (8.64)
Convenience stores	0.00 (0.00)	0.00 (0.50)	0.28 (0.44)	0.00 (1.13)
Entertainment	0.00 (0.00)	0.00 (0.50)	0.77 (1.54)	0.36 (2.59)
Food stores	1.99 (5.96)	2.49 (5.47)	5.81 (5.91)	8.84 (15.47)
Gyms and fitness centers	0.00 (3.98)	1.00 (1.49)	1.60 (1.55)	2.88 (5.90)
Library	0.00 (0.00)	0.00 (0.50)	0.19 (0.44)	0.00 (1.20)
Malls	0.00 (0.00)	0.00 (0.50)	0.32 (0.66)	0.00 (2.21)
Museum	0.00 (0.00)	0.00 (0.00)	0.12 (0.60)	0.00 (0.00)
Nature/parks/botanical gardens	0.00 (0.00)	0.00 (0.00)	0.03 (0.24)	0.00 (0.00)
Pharmacies/drug stores/personal care	0.00 (5.96)	2.49 (5.97)	5.04 (5.34)	10.24 (15.06)
Religious organizations	1.99 (5.96)	1.99 (2.99)	2.29 (2.27)	3.54 (4.82)
Restaurants	7.95 (23.86)	10.45 (21.89)	22.32 (27.57)	36.88 (65.55)
Retail shopping	1.99 (9.94)	6.97 (19.40)	20.22 (30.56)	30.72 (58.25)
Services	3.98 (17.89)	5.47 (12.94)	11.13 (10.38)	17.64 (32.47)
Total	31.81 (101.39)	51.74 (127.36)	99.72 (107.74)	184.38 (286.78)
Diversity (# of destination types)[e]	6.83 (3.94)	10.13 (3.73)	14.66 (1.59)	10.46 (3.95)

IQR = Interquartile Range

[a]Destinations classified using North American Industry Classification System (NAICS) codes.

[b]Euclidean residential buffers.

[c]Activity space generated using the Daily Path Area method (trip-based lines buffered 200 meters) for all trips by all modes of transportation.

[d]Activity space generated using the Daily Path Area method (trip-based lines buffered 200 meters) for only pedestrian and bicycling trips. These activity spaces were only available for 59 of the 77 participants.

[e]Mean and standard deviation rather than median and IQR. Total types considered n=16.

Table 3

Associations between destinations[a] within neighborhood and objectively measured physical activity.

	Traditional Residential Buffers Neighborhoods		GPS-Defined Activity Spaces Neighborhoods	
	400-m Buffer[b]	800-m Buffer[b]	All Modes Activity Space[c]	Pedestrian and Bicycling Activity Space[d]
Destination Measure	**Mean difference or OR (CL)**	**Mean difference or OR (CL)**	**Mean difference or OR (CL)**	**Mean difference or OR (CL)**
Density (all destination types) (10% difference)				
Total physical activity (min/day)	0.04 (−0.05, 0.13)	0.08 (−0.13, 0.29)	0.07 (−0.83, 0.97)	0.03 (−0.16, 0.22)
Daily step count	1.63 (−1.94, 5.19)	3.83 (−4.33, 11.98)	25.00 (−10.19, 60.19)	3.12 (−4.65, 10.89)
Meeting recommended daily steps	1.00 (1.00, 1.02)	1.01 (1.00, 1.03)	1.02 (0.99, 1.05)	1.00 (1.00, 1.03)
Diversity (1 additional destination type)				
Total physical activity (min/day)[e]	−0.97 (−5.47, 3.53)	3.03 (−1.79, 7.86)	−7.24 (−18.76, 4.28)	3.97 (−1.17, 9.12)
Daily step count	39.32 (−138.51, 217.15)	127.07 (−63.17, 317.30)	−45.68 (−505.59, 414.23)	243.34 (35.97, 450.70)**
Meeting recommended daily steps	1.03 (0.88, 1.20)	1.06 (0.90, 1.26)	0.90 (0.62, 1.35)	1.21 (0.97, 1.59)

CL = 95% Confidence Limits

*p<0.1;

**p<0.05

[a]Destinations classified using North American Industry Classification System (NAICS) codes, 16 types.

[b]Euclidean residential buffers.

[c]Activity space generated using the Daily Path Area method (trip-based lines buffered 200 meters) for all trips by all modes of transportation.

[d]Activity space generated using the Daily Path Area method (trip-based lines buffered 200 meters) for only pedestrian and bicycling trips. These activity spaces were only available for 59 of the 77 participants.

[e]ActiGraph accelerometry (GT3X+, 60s epoch); includes both light physical activity (100–1951 counts per minute) and moderate-to-vigorous physical activity (≥1952 counts per minute) (Freedson et al., 1998).