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Convergent validity of an activity-space survey for use in health research

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Abstract

We explored the validity of a survey measuring activity spaces for use in health research in a racially/ethnically diverse adult sample (n=86) living in four Chicago communities. Participants reported on the location and visit frequency of 64 activities and wore a GPS data logger. We assessed the spatial congruence of survey- and GPS-derived convex hull measures and the number of GPS points within 100m and 1000m of survey locations. The survey-derived convex hull measures captured a small percentage (median=35.9%) of the GPS-derived convex hull area. However, most GPS points were located within 100m or 1000m of home or reported survey locations (median=73.4% and 92.6%, respectively).

Keywords

Activity Space; Global Positioning System; Validity; Neighborhood; Environment

Introduction

Growing research seeks to determine whether the environments of people's activity space, or the area in which an individual travels when conducting activities (Golledge and Stimson, 1997), affect their health behaviors or outcomes. Inconsistent findings for whether residential neighborhood environments affect health behaviors and outcomes is one motivation for this research (den Braver, et al, 2018, Besser, et al, 2017, Mayne, et al, 2015, Cobb, et al, 2015). Another motivation is that people spend appreciable time outside of their

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residential neighborhood where they encounter other potentially salubrious or health-damaging exposures (Cummins, 2007, Kwan, 1999, Zenk, et al, 2011).

Surveys are one popular approach for assessing locations where people spend time and ultimately their activity space (Chaix, et al, 2012, Shareck, et al, 2014, Vallée, et al, 2010). Survey measures have several strengths including that questions of why (purpose), when (frequency, duration, and timing), how (travel mode), and with whom can all be asked. However, little is known about their validity, or how well survey-derived activity-space measures capture where people conduct activities and spend time. Without sufficient validity, there is a strong possibility of misclassification of environmental exposures which can weaken or bias environment-health associations. Fortunately, recent research has begun to shed light on this important issue through comparisons with GPS location tracking data (Kestens, et al, 2018, Shareck, et al, 2013).

Building on this research, the purpose of this study was to explore the convergent validity of a survey for measuring activity spaces for use in health research. Specifically, we examined to what extent activity locations reported in a survey encompassed where people subsequently traveled, visited, or spent time over 14 days based on GPS tracking data. Because some activity-space surveys restrict most activities participants report on to those visited once a week or more (Chaix, et al, 2012), we also explored how restricting locations to those visited at least once per week affected results. Data are from the Activity Space and Contextual Measures of Environmental Exposures (ASCMEE) study.

Methods

Sample and data collection procedure

We recruited a non-probability sample of 101 adults (ages 18-64) from four neighborhoods in Chicago's west side. Participants completed an activity-space survey, and were then asked to wear a GPS data logger (Qstarz BT-Q1000XT) for 30 days. The analytical sample is based on 86 participants with at least fourteen valid days of GPS data—the minimum number needed to capture routine activity space (Zenk, et al, 2018).

Measures

Survey measures.—Participants could report on the locations of up to 64 activities in which they engaged in the past 30 days (see Appendix). We drew on VERITAS (Chaix, et al, 2012) and Los Angeles Family and Neighborhood Study (Inagami, et al, 2007) items and supplemented with activities relevant for our study population. For each reported activity (“Did you go to _____ in the last 30 days?”), we asked the participant to provide the name (e.g., store name) and location (e.g., street address, intersection). Self-reported visit frequency was measured using a single item (“How often did you go to _____ in the last 30 days?”), with participants allowed to answer the number of times per day, week, or month.

We geocoded home and activity locations using ArcGIS 10.2.1. Out of over 5400 reported activity locations, 3.6% lacked information and 3.9% were outside a 50-mile radius of the study area (selected to exclude trips not likely to be part of the routine activity space). Of the remaining, less than 1% were not able to be geocoded, 1.7% were geocoded to the ZIP code

or neighborhood level, 20.0% to the closest street intersection, and 77.3% to the street address.

Based on the geocoded survey data, we constructed two convex hull measures to represent a participant's activity space based on their home and (a) all reported activity locations regardless of visit frequency and (b) activity locations they reported visiting at least weekly. A convex hull is the minimum area convex polygon that encompasses all activity locations (Sherman, et al, 2005).

GPS measures.—We pre-processed the GPS data using a multistep protocol (Zenk, et al, 2018). The first 14 valid days of GPS data were used. Consistent with a prior study (Kestens, et al, 2018), we counted the number of GPS points within 100 meters (m) and 1000m of each reported activity location. Because the GPS was set to record location each minute, this provided an estimate of the amount of time participants spent at each reported activity location. We assigned GPS points within 100m or 1000m of multiple activity locations to the closest reported activity location. In addition, we constructed a convex hull measure to represent each participant's 14-day activity space.

Data analysis

Descriptive statistics summarize the sample's characteristics, activity-space sizes, and the percentage of a participant's GPS points that were located within 100m and 1000m of each reported activity location. We examined spatial congruence by calculating what percentage of the GPS-derived convex hull was located inside each survey-derived convex hull. For data that were skewed, we relied on medians and interquartile ranges (IQR) to convey the results.

More information on the methodology is provided elsewhere (Zenk, et al, 2018). The study was approved by the University of Illinois at Chicago Institutional Review Board (protocol number 2015-0164).

Results

Table 1 presents descriptive information on the study participants. On average, participants reported 22.0 activities (SD 6.2; range 11-45) in the past month. Participants reported an average of 9.4 activities (SD 4.1; range 1-23) that they visited at least weekly.

Over the 14-day GPS period, half the sample spent at least 61.3% of their time within 100m of their home (i.e., median=61.3; IQR 41.7, 75.0) and 66.5% of their time within 1000m of their home (IQR 47.0, 86.3) (Table 2). Excluding average sleep time of 7 hours, this is equivalent to 52.2% of their non-sleep time within 100m of their home (and 47.8% beyond 100m of their home) and 55.8% of their non-sleep time within 1000m of their home (and 44.2% beyond 1000m of their home).

Half the sample spent at least 6.2% of their total time (IQR 3.7, 12.1) within 100m of a reported non-home activity location, and at least 19.1% of their total time (IQR 7.2, 36.0) within 1000m of a reported non-home activity location, regardless of visit frequency (Table 2). Half spent at least 92.6% of their total time (IQR 87.6, 96.3) within 1000m of their home

or other reported activity location regardless of visit frequency. Applying the minimum weekly time filter generally decreased the amount of time spent within 100m and 1000m of reported non-home activity locations (Table 2).

For half the sample, survey-derived activity spaces were at least 56.6 km² (IQR 30.2, 91.6) for all reported activity locations regardless of reported visit frequency and 11.0 km² (IQR 2.1, 31.7) when restricted to activity locations visited at least weekly. For half the sample, GPS-derived activity spaces were at least 119.9 km² (IQR 63.2, 337.4). For spatial congruence between GPS- and survey-derived activity spaces, the survey-derived activity space captured a median of 35.9% of the GPS-derived activity space (IQR 13.1, 56.6) regardless of visit frequency, but only 6.9% (IQR 1, 21) when restricted to locations visited at least weekly.

Discussion

To inform emergent research on activity spaces and health, this study examined the convergent validity of a survey approach for activity-space measurement through comparisons with GPS data. However, limitations of our research should be kept in mind when considering the results. First, we were not able to geocode some of the reported activity locations and there is imprecision in other geocoded locations. We do not know to what extent these errors are random. Second, our sample is small and from a single area. Therefore, our results should be taken as suggestive and future research should consider the extent to which these and other validation study results apply to particular populations. Third, we employed a convex hull as our activity-space measure because it is commonly used, including in prior validation studies (Kestens, et al, 2018, Shareck, et al, 2013), even though it can contain sizeable areas that are not actually experienced by the participant. It is not possible to create several other activity-space measures based on survey data without making numerous assumptions (e.g., utilized travel routes between locations for route buffer measures).

For the majority of the sample, we found the activity-space survey locations captured much of the area where participants spent most of their time but not the full spatial extent of their activities over a subsequent 14-day GPS period. Half the sample spent 50.6-82.2% of their time within 100m and 87.6-96.3% of their time within 1000m of survey locations including their home. These results support the validity of the survey measure. Still, approximately one in four participants spent only 1-50% of their total time within 100m and 26-87% of their total time within 1000m of the reported survey locations. Moreover, the survey-derived activity space poorly covered the GPS-derived activity space: the survey-derived activity space at most covered 35.9% of the GPS-derived activity space for half the sample. These discrepancies may reflect that convex hull measures include considerable area with which participants do not come into contact, some key activity hubs may be missing from the survey, and travel paths between activity locations separated by more than 2000m are not fully captured.

Our results when applying the minimum weekly time filter are remarkably similar to a Paris study (Kestens, et al, 2018), although it is important to keep in mind we did not use the same

survey and half our participants were not currently employed. Our estimate that half the sample spent 66% of their total time within 1000m of their home falls between Kestens's estimates of 62% for employed and 75% for unemployed persons. Our participants spent an average of 23% of their total time (median=13) within 1000m of a reported non-home activity location compared to 24% for employed and 7% for unemployed persons in their study. Moreover, half our sample spent 88% of their total time within 1000m of home or a non-home reported activity location compared to 89% in their study. Finally, our estimate that the survey-derived activity space (based on locations visited a minimum of once per week) captured a median of 6.9% of the GPS-derived activity space is lower than their 10% estimate and higher than in a Montreal study (4%)(Shareck, et al, 2013).

Limiting activities to those visited weekly decreased the time people spent within 1000m of a reported non-home activity location although not appreciably for 100m. It also substantially reduced spatial congruence between the survey-derived and GPS-derived activity-space measures. Based on one's conceptualization of activity space, this may be desirable, although we caution that limiting activity spaces to those locations visited at least weekly could miss environmental exposures with potential health implications (Zenk, et al, 2018). Either way, whether to restrict activities to those visited at least weekly is an important decision for researchers as it is not inconsequential.

In conclusion, participants spend appreciable amounts of time outside their residential neighborhood, an estimated 34% of their total time (44.2% of their non-sleep time, assuming 7 hours of nightly sleep) beyond 1000m of home in our study. Valid measures of people's activity spaces are needed to accurately estimate total (residential and non-residential) environmental exposures and their associations with health behaviors and outcomes. Use of invalid measures of activity spaces risks further mischaracterizing the role of the environment in health behaviors and outcomes and perhaps inflating the importance of the residential environment (Chaix, et al, 2017). If corroborated by other studies in different samples and settings, our results suggest the survey we tested can provide a valid estimate of activity space for use in health studies. However, our results also have implications for the design of activity-space surveys, underscoring the need to further consider what activities and locations should be asked about and the need to collect data on time (duration and frequency of visits) at survey locations.

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Appendix.: Non-home activities assessed in the activity-space survey

Second residence
Primary job

Second job
 (Respondent's) school, college, or university *
 Place where purchased groceries 1
 Place where purchased groceries 2
 Bakery
 Butcher or meat store
 Produce or fruit/vegetable store
 Outdoor market or farmer's market
 Convenience or corner store *
 Liquor store *
 Pharmacy or drug store *
 Big box store like Walmart or Target *
 Discount or dollar store *
 Mobile vendor (e.g., fruit truck or cart) *
 Food pantry or other emergency food source *
 Nonfood store (e.g., clothing) *
 Other place where purchased tobacco
 Restaurant 1
 Restaurant 2
 Restaurant 3
 Bar or club
 Coffee shop
 Start of outdoor exercise (e.g., run, walk, bike) route 1 *
 Start of outdoor exercise (e.g., run, walk, bike) route 2 *
 Place to play/participate in the following physical activities (up to 3 activities):

- Aerobics, cardio, strength training
- Baseball, softball *
- Basketball
- Bowling
- Boxing
- Climbing
- Dance, Zumba
- Football *
- Golf
- Gymnastics
- Hockey, ice skating
- Horseback riding
- Indoor cycling
- Martial arts
- Rowing, kayaking, canoeing
- Skateboarding, inline skating, rollerblading
- Soccer
- Swimming

- Tennis, badminton, squash
- Track and field
- Ultimate frisbee *
- Volleyball
- Yoga, Qi Gong, Tai Qi
- Other

Other park, playground, or recreation area

Hair salon or barber shop

Nail salon

Post office

Bank or ATM

Currency exchange *

Laundromat or dry cleaners *

Gas station *

Library *

Health center, clinic, or doctor's office *

Social service office [e.g. Special Supplemental Nutrition Program for Women, Infants and Children (WIC), unemployment, family services] *

Movie theater

Place to participate in the following cultural activities (up to 2 activities)

- Drawing, sculpture, pottery, painting
- Learning a language
- Music lessons or musical group
- Theater, drama, spoken word, or poetry
- Book club or reading group
- Photography, film, or audiovisual production
- Another cultural activity

Other entertainment or cultural event facility (e.g. theater, concert hall, museum) 1 *

Other entertainment or cultural event facility (e.g. theater, concert hall, museum) 2 *

Place to participate in an association, club, or group (up to 2)

- Neighborhood group or association [e.g., Chicago Alternative Policing Strategy (CAPS) meeting, homeowners association]
- Place you volunteer
- Community or cultural center
- Bible study or religious group meeting
- Another organization or social club [e.g., Veterans of Foreign Wars (VFW), support group]

Place of worship

Child's school or daycare 1

Child's school or daycare 2

Child's school or daycare 3

Child's school or daycare 4

Child's school or daycare 5

Child's school or daycare 6

Other place you often took a child (e.g., his/her activities, practices, or another parent's house) 1

Other place you often took a child (e.g., his/her activities, practices, or another parent's house) 2
 Other place you accompanied an adult relative (e.g., doctor's office, grocery shopping) 1
 Other place you accompanied an adult relative (e.g., doctor's office, grocery shopping) 2
 Family member or friend's home 1
 Family member or friend's home 2
 Public transit stop near home 1
 Public transit stop near home 2
 Other location 1 *
 Other location 2 *

Primary residence was assessed as part of the demographics survey

* Not included in the VERITAS survey (Chaix, et al, 2012)

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Highlights

- Half the sample spent 33% of their time beyond 1000m of their home.
- Half spent 93% of their time within 1000m of home or non-home activity location
- The survey activity space covered a median of 35.9% of the GPS activity space
- Limiting survey activities to those visited at least weekly affected the results.

Table 1.

Sample characteristics (N=86)

	Mean	SD
Age (in years)	46.0	13.4
Residency in current neighborhood (in years)	12.5	12.6
	n	%
Women	46	53.5
Race/ethnicity		
Non-Hispanic white	22	25.6
Hispanic/Latino	14	16.3
Non-Hispanic Black/African American	50	58.1
Highest level of education completed		
No high school diploma or GED	11	12.8
High school diploma or GED only	22	25.6
Trade/vocational school, associate's degree, or some	26	30.2
Bachelor's degree or higher	27	31.4
Employment status		
Working now	37	43.0
Annual household income		
Less than \$15,000	26	31.7
\$15,000 - \$29,999	27	32.9
\$30,000 or more	29	35.4
Own or lease a car	33	38.4
Receive government assistance	43	50.0
Own home	22	25.6
Marital status		
Single or never married	48	55.8
Married/living with partner	20	23.3
Separated/divorced	17	19.8
Widow/widower	1	1.2

Table 2.

Percentage of total time based on the GPS period spent within 100m or 1000m of home, reported non-home activity locations, and all reported activity locations

	Mean	SD	Min	Q1	Med	Q3	Max
100m							
Home	53.2	28.7	0	41.7	61.3	75.0	95.8
Non-home survey locations visited regardless of visit frequency	11.6	16.5	0.6	3.7	6.2	12.1	84.1
Non-home survey locations visited at least weekly	10.3	16.7	0	2.1	4.7	9.4	83.9
Home + non-home survey locations regardless of visit frequency	64.8	25.7	1.2	50.6	73.4	82.2	98.0
Home + non-home survey locations visited at least weekly	63.5	26.1	0	50.2	72.5	81.9	96.4
1000m							
Home	61.6	29.0	0	47.0	66.5	86.3	100
Non-home survey locations visited regardless of visit frequency	28.2	27.6	0	7.2	19.1	36.0	98.6
Non-home survey locations visited at least weekly	23.2	26.9	0	3.2	13.1	32.2	98.6
Home + non-home survey locations regardless of visit frequency	89.8	11.0	25.9	87.6	92.6	96.3	100
Home + non-home survey locations visited at least weekly	84.7	16.6	4.9	83.0	88.4	93.6	100