Built environment and physical activity: measurement and analysis using (mostly) objective approaches

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Abstract

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Much of what is known about the relationship between built environment and physical activity has come from self-reported data using limited spatial frames. This talk will present recent developments in measurement of built environment and physical activity using largely objective data, with focus on 'activity space' based approaches.

What this talk is (and is not)

IS

- A description of data sets
- Details on how the data were prepared
- Brief description of how the data have been used
- Presented in the hopes of generating interest for collaboration in the use/analysis of the data
- Hopefully of use to people dealing with similar data

NOT

- A synopsis of a study (but will briefly refer to some projects)

Contents I

Contents II

Walking

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- The most common type of physical activity

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- Locomotion on foot, with at least one foot on the ground at any time
- An essential human behavior
- The most common way of moving from place to place
- The most common type of physical activity
- Can be done by most people with no special equipment or training

History

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- Streets were originally pedestrian thoroughfares

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- US 1908, Model T popularized the car for the middle class
- By 1925, crashes accounted for 25% of deaths in cities with population $>$ 25,000

Vanderbilt (2008); Norton (2008)

History

By 1930s, cars had won right-of-way, relegating pedestrians to sidewalks (where they existed)

Benefits of walking

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- Social benefits
- Personal benefits

Social benefits of walking

- More walking means less driving

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- Fewer greenhouse gas emissions

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- More walking means less driving
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- Fewer pollutants
  - hydrocarbons
  - $NO_x \rightarrow O_3$
  - fine particulates

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- "Eyes on the street"

Personal benefits of walking

- Increased physical activity

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- Increased physical activity
- Lower spending
  - car payments
  - gas payments
  - insurance payments

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  - legal fees

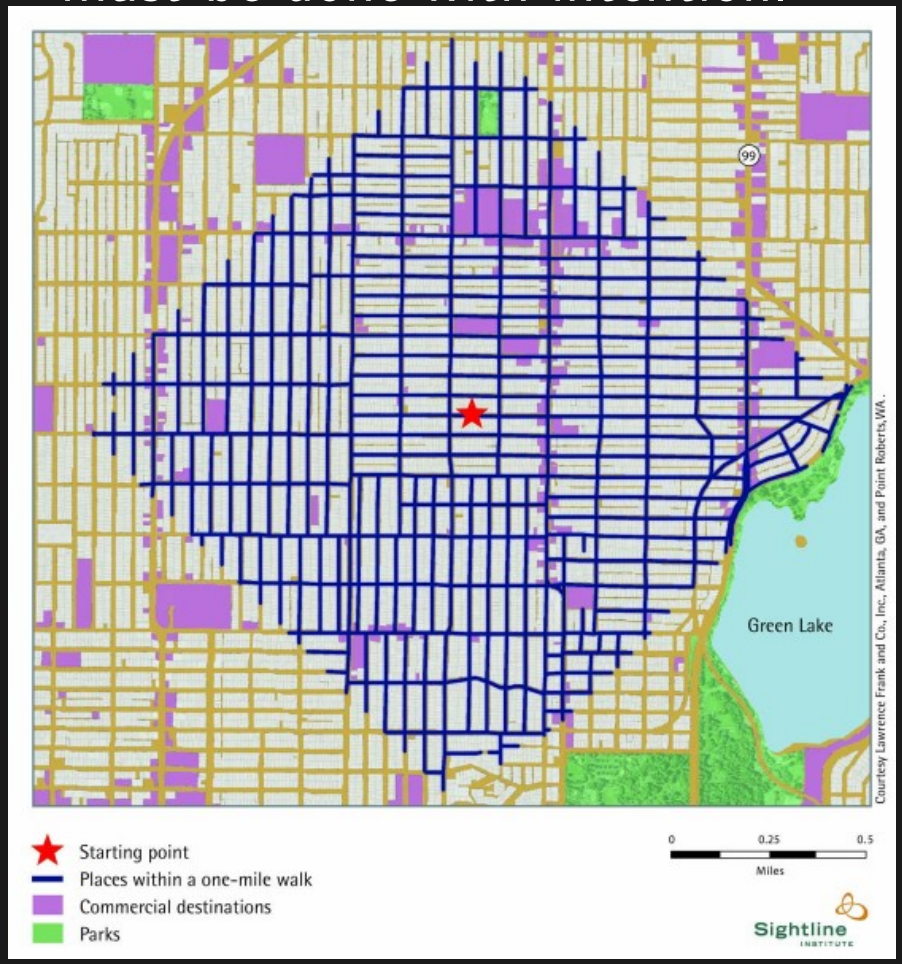
Personal benefits of walking

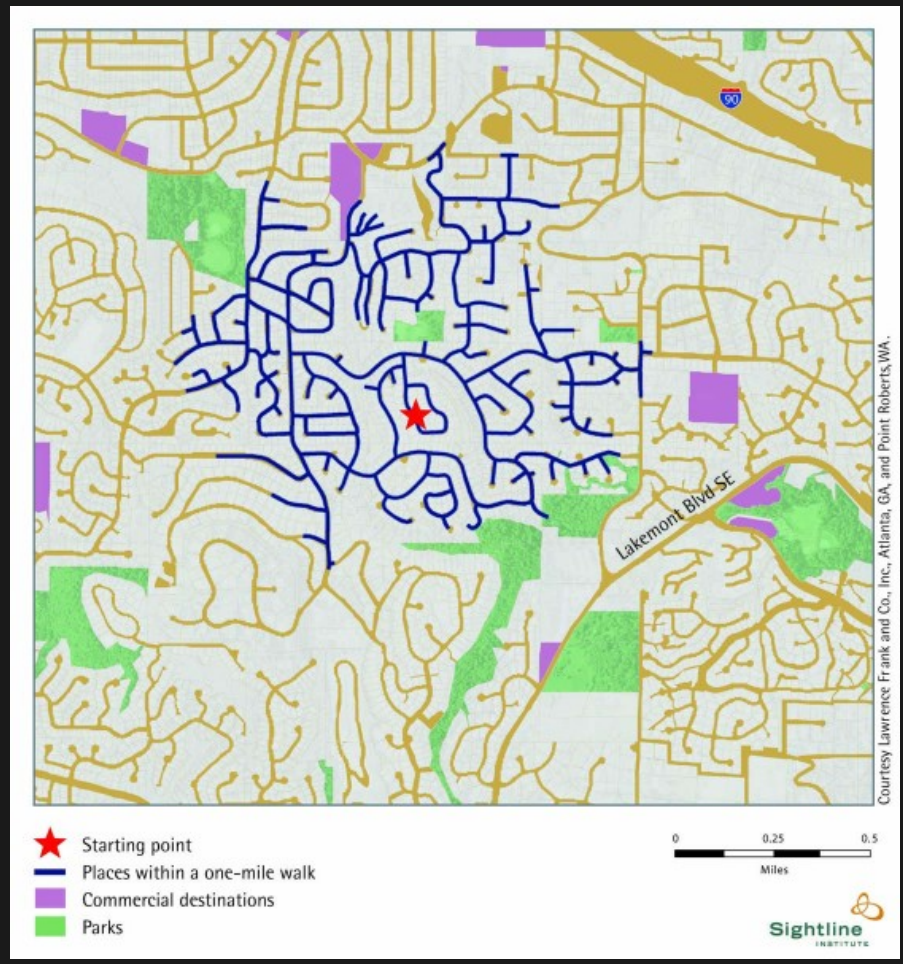
- Increased physical activity
- Lower spending
  - car payments
  - gas payments
  - insurance payments
  - legal fees
- Pleasure!

Planning for walking

Necessary infrastructure, i.e., streets and sidewalks

With current car-dominated environments, planning for walking must be done with intention.

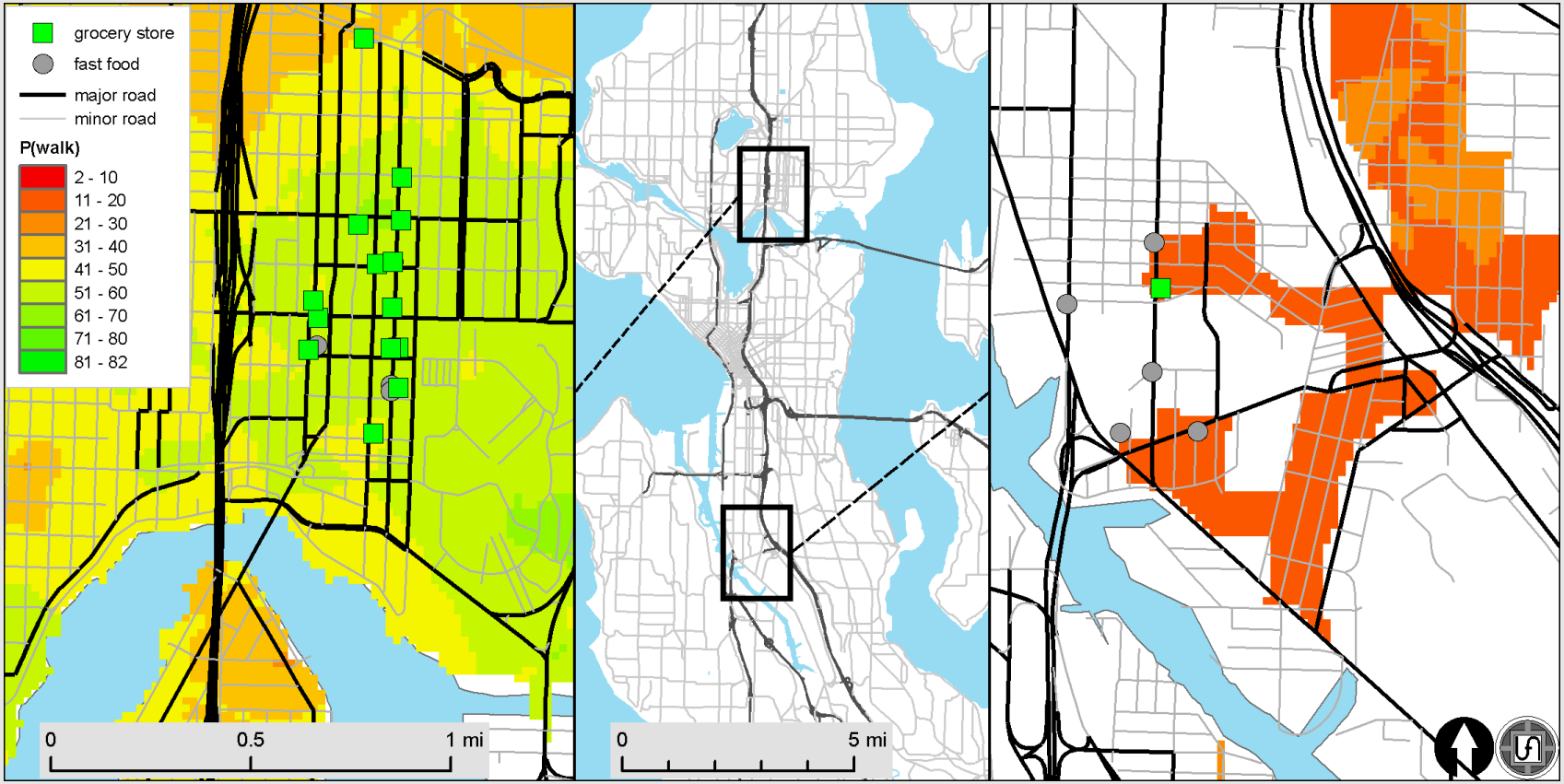




Lawrence Frank and Co., Inc.

Planning for walking

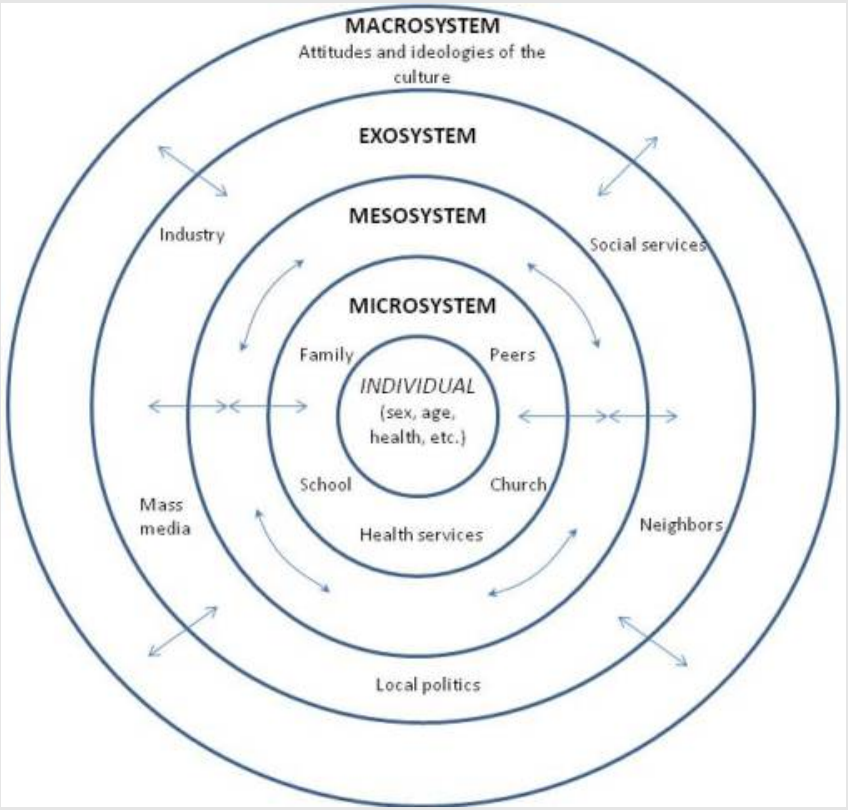
Destinations (i.e., something to walk to)



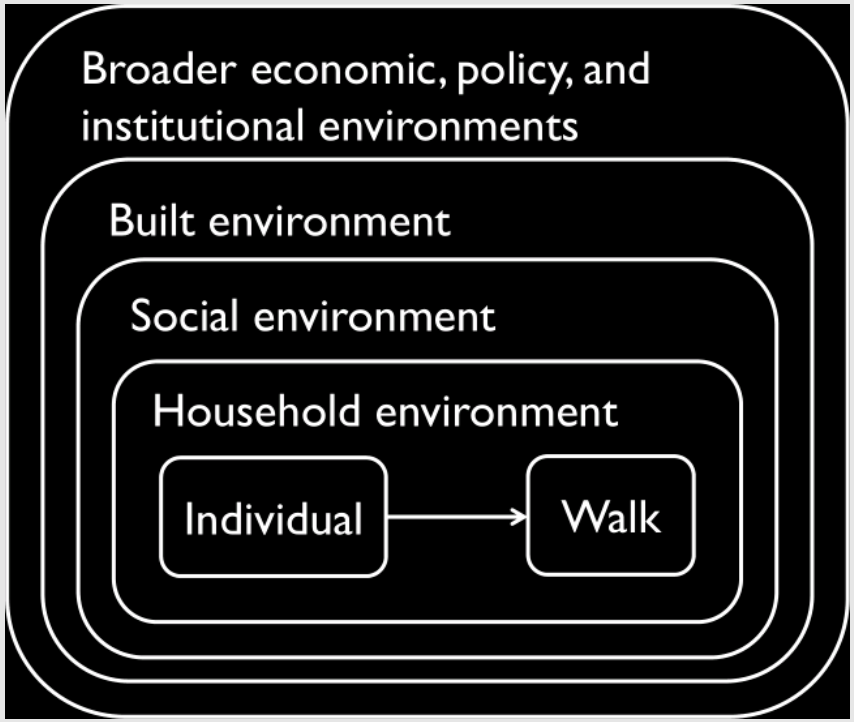
Social ecological model

A framework for understanding the factors influencing behavior

Ecological systems theory, 1970s



SEM for walking



Bronfenbrenner (1979)

Walking characteristics

To differentiate categories of walking trips

Purpose

- **Recreation/leisure** (i.e., for pleasure, exercise, dog walking[?])

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Location

- Home neighborhood
- Work neighborhood
- Commuting

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Frequency, duration, and intensity

- Time (minutes per week)
- Trips (trips per week)
- MET-minutes (intensity and duration)
- Thresholds (low/medium/high, walker/non-walker)

Individual- and household-level characteristics related to walking

Some consistent personal and household characteristics are associated with increased levels of walking:

- Income (high and low)
- Education (high and low)
- Age (older)
- Number of cars (fewer cars)
- Dog ownership (dog present)
- Cognitive constructs: attitude, perceived behavioral control, perceived benefits, self-efficacy

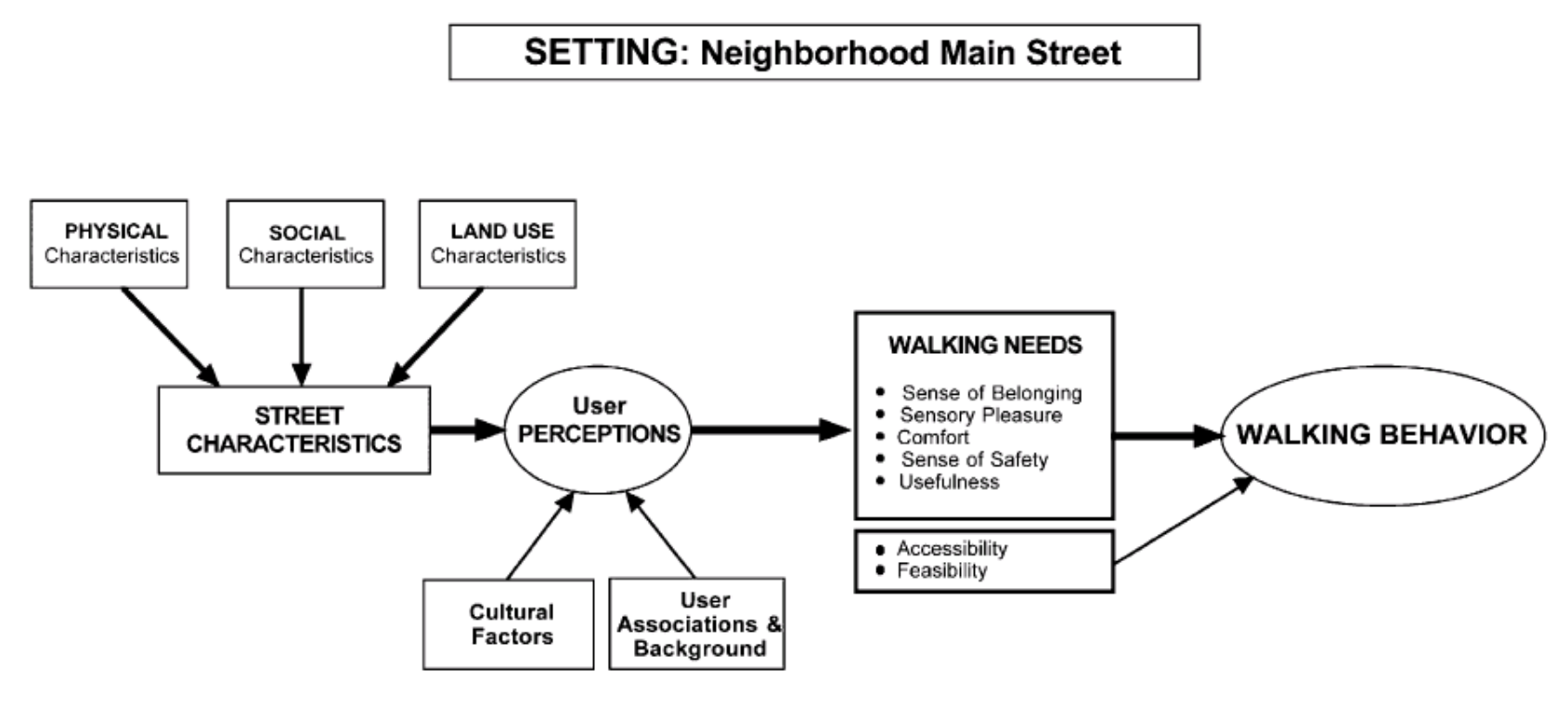
Built environment factors related to walking

Orion Stewart's '7 Ds'

1. Density–jobs and residences per areal unit
2. Diversity–land use mix, jobshousing balance
3. Design–block size, intersection density
4. Destination accessibility–distance to job, store
5. Distance to transit–distance to transit stop
6. Demand management–parking supply, cost
7. Demographics–see individual/HH level of 'Personal factors' above

Built environment factors

Combined environmental and personal characteristics



Metha (2008)

Research on the relationship between built environment and walking

- Results of meta-analysis of home neighborhood built environment characteristics and walking
- "Elasticities" represent % change in probability of walking per 1% change in BE variable

Table 3. Weighted average elasticities of VMT with respect to built-environment variables.

		Total number of studies	Number of studies with controls for self-selection	Weighted average elasticity of VMT(e)
Density	Household/population density	9	1	−0.04
	Job density	6	1	0.00
Diversity	Land use mix (entropy index)	10	0	−0.09
	Jobs-housing balance	4	0	−0.02
Design	Intersection/street density	6	0	−0.12
	% 4-way intersections	3	1	−0.12
Destination accessibility	Job accessibility by auto	5	0	−0.20
	Job accessibility by transit	3	0	−0.05
	Distance to downtown	3	1	−0.22
Distance to transit	Distance to nearest transit stop	6	1	−0.05

Ewing and Cervero (2010)

Research on the relationship between built environment and walking

Review of 13 reviews on BE correlates of walking

TABLE 1. Summary of correlates identified in previous reviews.

Correlates	**Review**
Accessibility or proximity	(29,37,44,49,52)
Mixed land use	(2,33,58)
Density	(2,29,58)
Aesthetics	(18,29,33,37,44,49,52)
Sidewalks	(29,33,49,52)
Street connectivity	(2,58)
Safety	(18,37,44,54)
Neighborhood type	(2,29,58)

Saelens and Handy (2008)

Research on the relationship between built environment and walking

Review of 29 original studies on BE and walking

TABLE 4. Number of study results in considered 2005 to mid 2006 published articles in the expected or null/unexpected direction by environmental factors and by walking type.

	Type of Walking					
	Transportation		Recreation		General	
Environmental Factors	**Expected**	**Null or Unexpected**	**Expected**	**Null or Unexpected**	**Expected**	**Null or unexpected**
Density (population or employment)	6	2	1	3	2	2
Distance to nonresidential destinations	7	2	1	4	2	5
Proximal nonresidential destinations (e.g., land use mix)	8	3	3	4	3	1
Route/network connectivity	3	4	0	4	3	3
Parks and open space	2	3	0	2	2	3
Pedestrian infrastructure	2	6	4	2	2	2
Personal safety	3	4	1	4	2	2
Traffic	2	6	0	6	1	1
Aesthetics	1	4	2	0	1	1
Physical activity facilities (nonpark)	0	4	0	2	1	2
Composite/interaction*	2	0	1	1	3**	1

Note. * Composite/interaction is for findings in which environmental factors were combined or interacted for examining their association with walking behavior; **one of these findings was an interaction of an objective and perceived measurement of different environmental factors.

Saelens and Handy (2008)

Background

Research has shown relationships between characteristics of the built environment (BE) and physical activity (PA).

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- B. E. Saelens and S. L. Handy, "Built environment correlates of walking: a review," Med. Sci. Sports Exerc., vol. 40, no. 7 Suppl, pp. S550-566, Jul. 2008.
- R. R. Ewing and R. Cervero, "Travel and the Built Environment," J. Am. Plan. Assoc., vol. 76, no. 3, pp. 265-294, Jun. 2010.
- J. A. Hirsch, K. A. Moore, P. J. Clarke, D. A. Rodríguez, K. R. Evenson, S. J. Brines, M. A. Zagorski, and A. V Diez-Roux, "Changes in the Built Environment and Changes in the Amount of Walking Over Time: Longitudinal Results From the Multi-Ethnic Study of Atherosclerosis.," Am. J. Epidemiol., vol. 180, no. 16, pp. 799-809, Sep. 2014.

Major limitations of current research

However, most of this research has suffered from two important limitations

- Self-reported physical activity measures.
- "Location" has meant a single residential point.

Problems with self-reported data

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → ***Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY***

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
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IPAQ Committee (2006)

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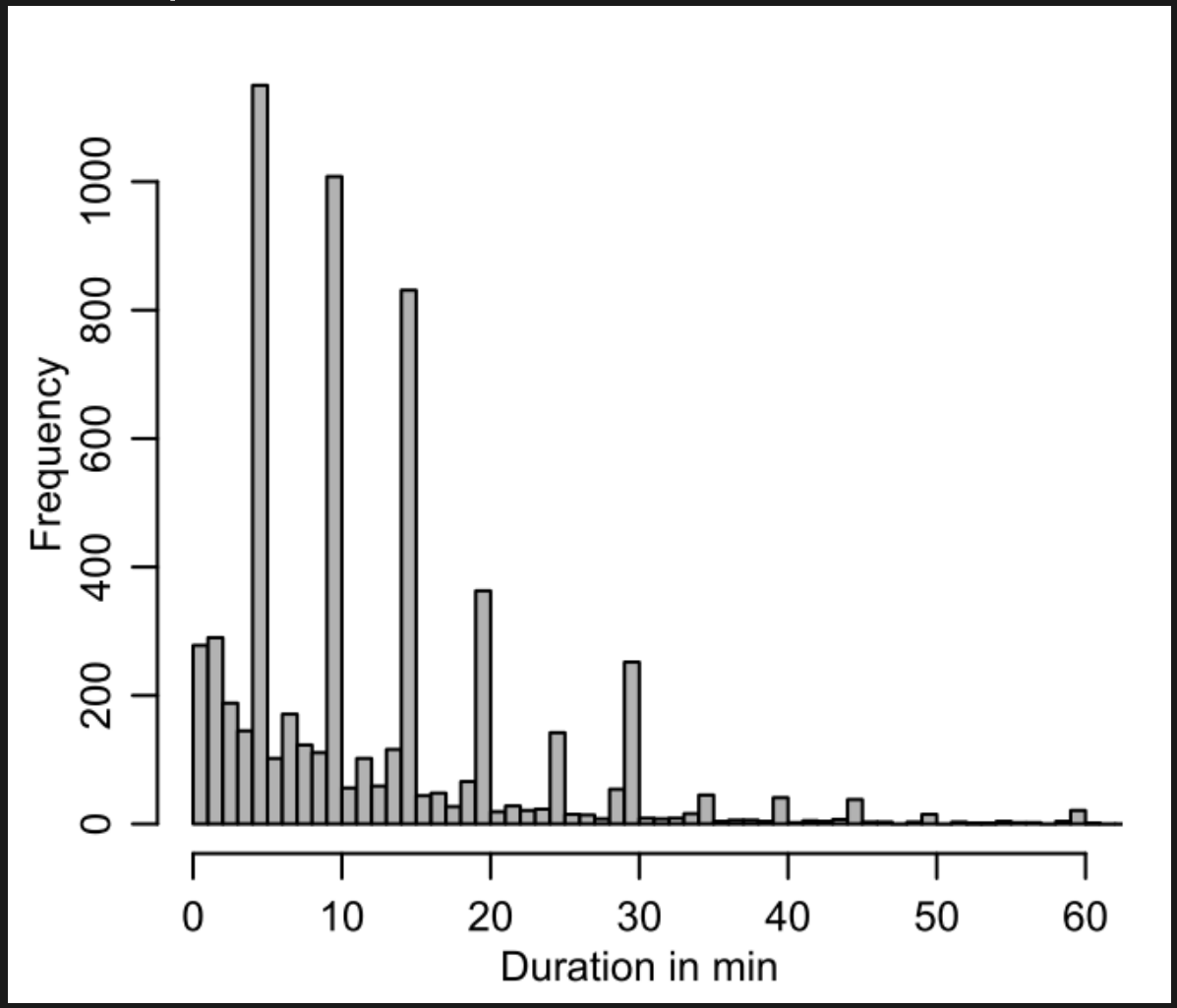
$4d/wk \times 25min/d = 100min/wk$

Bias

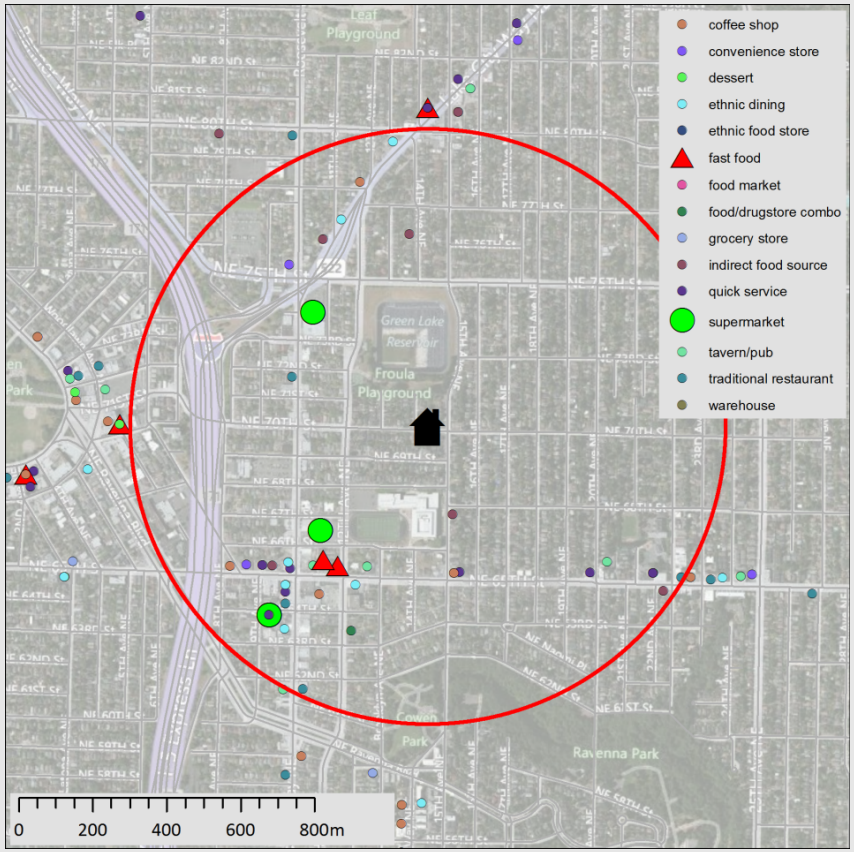
Self-report can induce bias in data



2006 PSRC Household Activity Survey

Exposures to the (built) environment are not limited to the residential location

Where my home is



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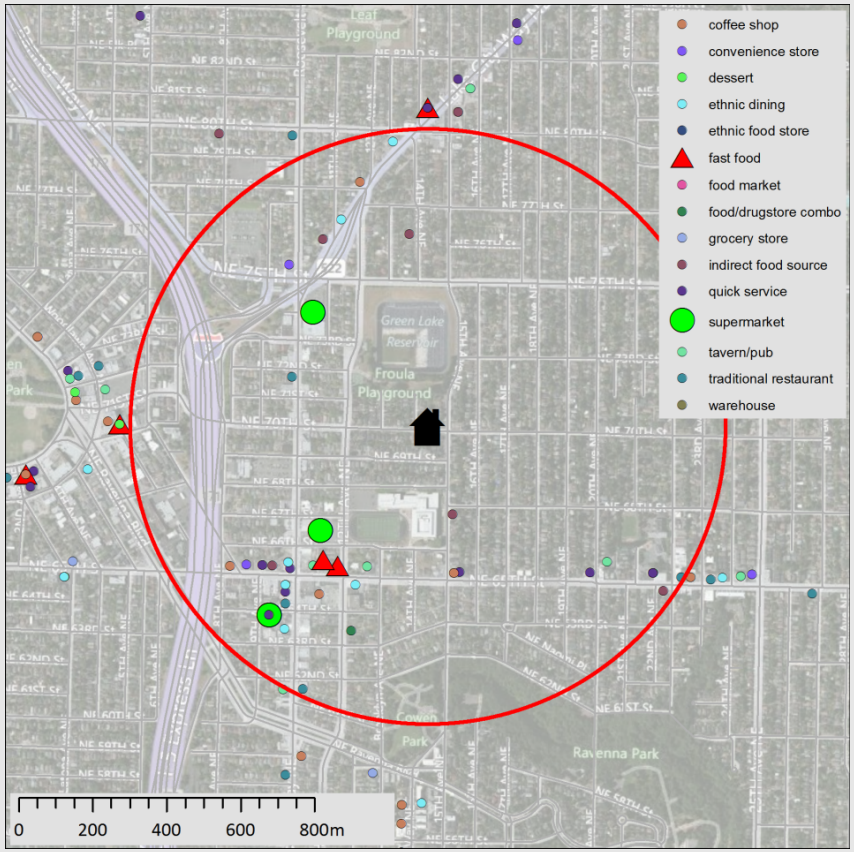
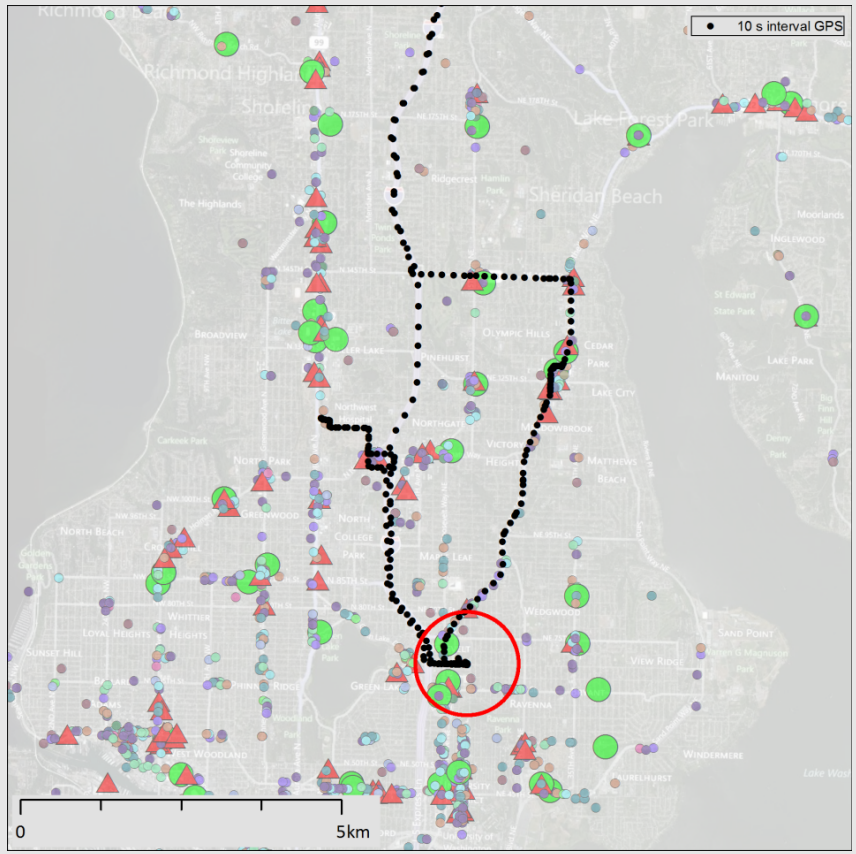


Where I went on one particular day



More recent research using objective methods

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- Place names
- Place arrival and departure times
- Travel mode
- Activity type

GPS measurement for location

QStarz BG Q-1000XT

- 7 $\times$ 4.5 $\times$ 2 cm, 65 g
- $>$ 24 h battery life
- ˜400,000 logged locations (fewer if more variables, e.g., precision, number of satellites captured)
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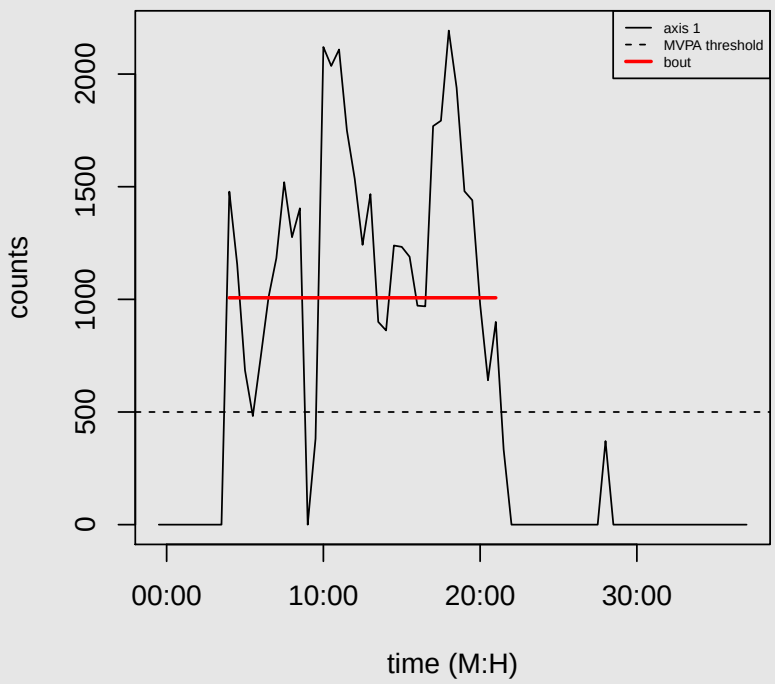
- Don't forget to budget $1,495 for the software to configure, download, and process data!

Physical activity bouts: sustained activity allowing for periodic dips

At least 5 minutes above 500 counts / minute, allowing for $\leq$ 2 minutes below 500 counts / minute



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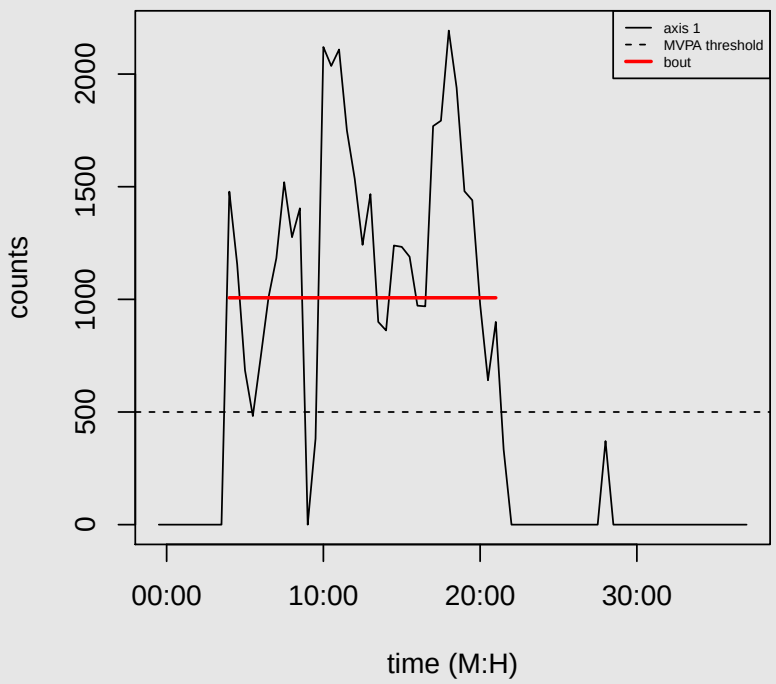

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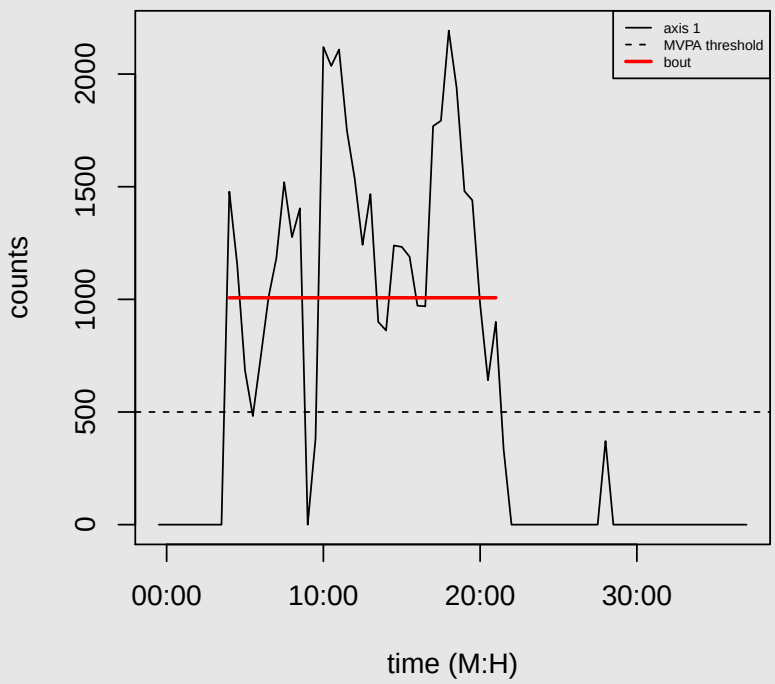

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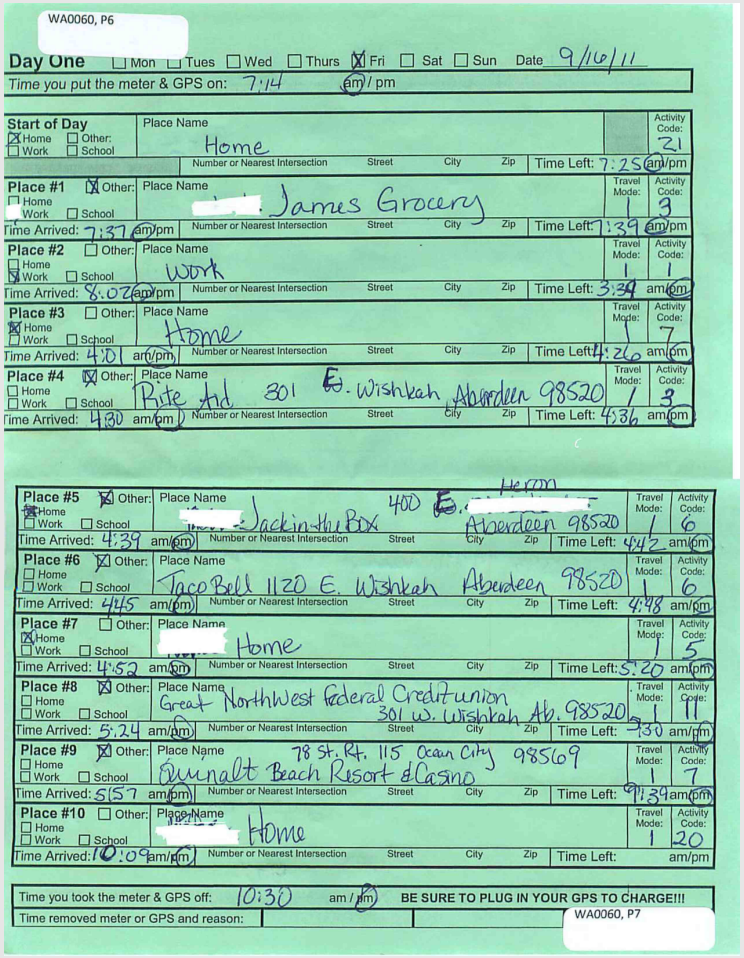
Travel diary for qualitative behavior

Diaries are scanned for easier review during data processing



WA0060, P6

Day One ☐ Mon ☐ Tues ☐ Wed ☐ Thurs ☒ Fri ☐ Sat ☐ Sun Date 9/16/11

Time you put the meter & GPS on: 7:14 am / pm

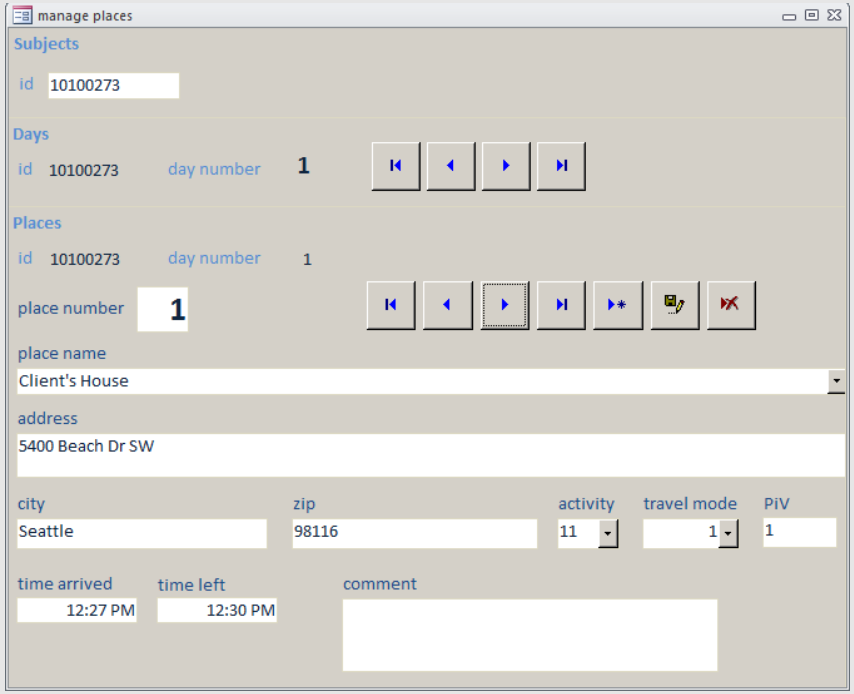
	Place Name	Number or Nearest Intersection	Street	City	Zip	Time Left	Travel Mode	Activity Code
Start of Day ☒ Home ☐ Other: ☐ Work ☐ School	Home					7:25 am/pm		21
Place #1 ☒ Other: ☐ Home ☐ Work ☐ School	James Grocery					7:39 am/pm	1	3
Place #2 ☐ Other: ☐ Home ☒ Work ☐ School	Work					3:34 am/pm	1	1
Place #3 ☐ Other: ☒ Home ☐ Work ☐ School	Home					4:26 am/pm	1	7
Place #4 ☒ Other: ☐ Home ☐ Work ☐ School	Rite Aid	301 E. Wishkah	Aberdeen		98520	4:36 am/pm	1	3
Place #5 ☒ Other: ☐ Home ☐ Work ☒ School	Jack in the Box	400 E. Heron	Aberdeen		98520	4:42 am/pm	1	6
Place #6 ☒ Other: ☐ Home ☐ Work ☐ School	Taco Bell	1120 E. Wishkah	Aberdeen		98520	4:48 am/pm	1	6
Place #7 ☐ Other: ☒ Home ☐ Work ☐ School	Home					5:20 am/pm	1	5
Place #8 ☒ Other: ☐ Home ☐ Work ☐ School	Great Northwest Federal Credit Union	301 W. Wishkah	Ab.		98520	5:30 am/pm	1	11
Place #9 ☒ Other: ☐ Home ☐ Work ☐ School	Quinault Beach Resort & Casino	78 St. Rt. 115	Ocean City		98569	9:34 am/pm	1	7
Place #10 ☐ Other: ☐ Home ☐ Work ☐ School	Home					am/pm	1	20

Time you took the meter & GPS off: 10:30 am / pm BE SURE TO PLUG IN YOUR GPS TO CHARGE!!!

Time removed meter or GPS and reason:

WA0060, P7

Data are transcribed using VBA-enhanced forms in MS Access



Data collection/preparation sequence

"Wrapper" is a set of R scripts

- Relatively easy programming language
- Handy IDE (RStudio): runs on Linux server for centralized data access & persistent connections (WWW)
- `RPostgreSQL` library for connecting to `PostgreSQL` database running on server
- Integrated versioning with `git`

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Sequence:

- Data downloaded from devices
- Travel diary transcribed using MS Access forms
- Data collected as tables in `PostgreSQL` database
- GPS data stored in `PostGIS` (spatial extension for `PostgreSQL`)
- Data merged by common time stamp into new tables

“Spatializing” the data

PostGIS is used to add binary-format geometric objects
Add the geometry column:

```
dbGetQuery(trac_p2, ‘‘SELECT
AddGeometryColumn(‘gps_001’,‘the_geom_4326’,4326,‘POINT’,4)
```

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```

Populate the geometry column as XYZ data (where Z is the recorded GPS timestamp):

```
dbGetQuery(trac_p2, ‘‘UPDATE gps_001 SET the_geom_4326
= ST_PointFromText(‘POINT(‘ || longitude || ’ ‘ ||
latitude || ’ ‘ || time_gps)’, 4326);’’)
```

"Validity"

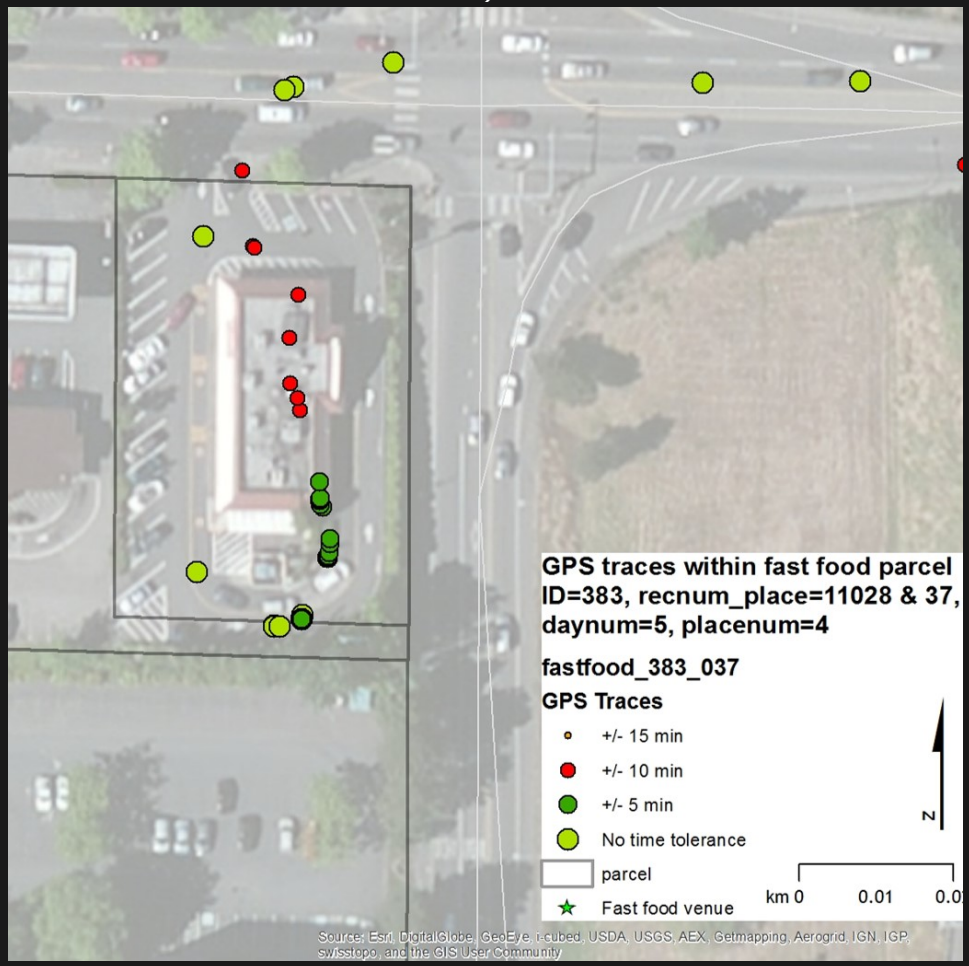
Determining what data to keep and what to toss out

- Accelerometer 'wearing' time: for measurement of 'active' time we need to distinguish between wearing and nonwearing.
- GPS 'wearing' time is not as straightforward–data from a typical home sojourn will be similar for device being carried or sitting on a table (due to inherent imprecision or "drift").
- Travel log: we have no practical choice but to naïvely assume entries are accurate.

Overall valid day: $\geq$ 8 hours of accelerometer wearing, "some" GPS time, $\geq$ 1 travel log entry

How well does GPS match travel diary?

Big light green dots indicate when subject reported being at McDonald's (a particularly bad example)



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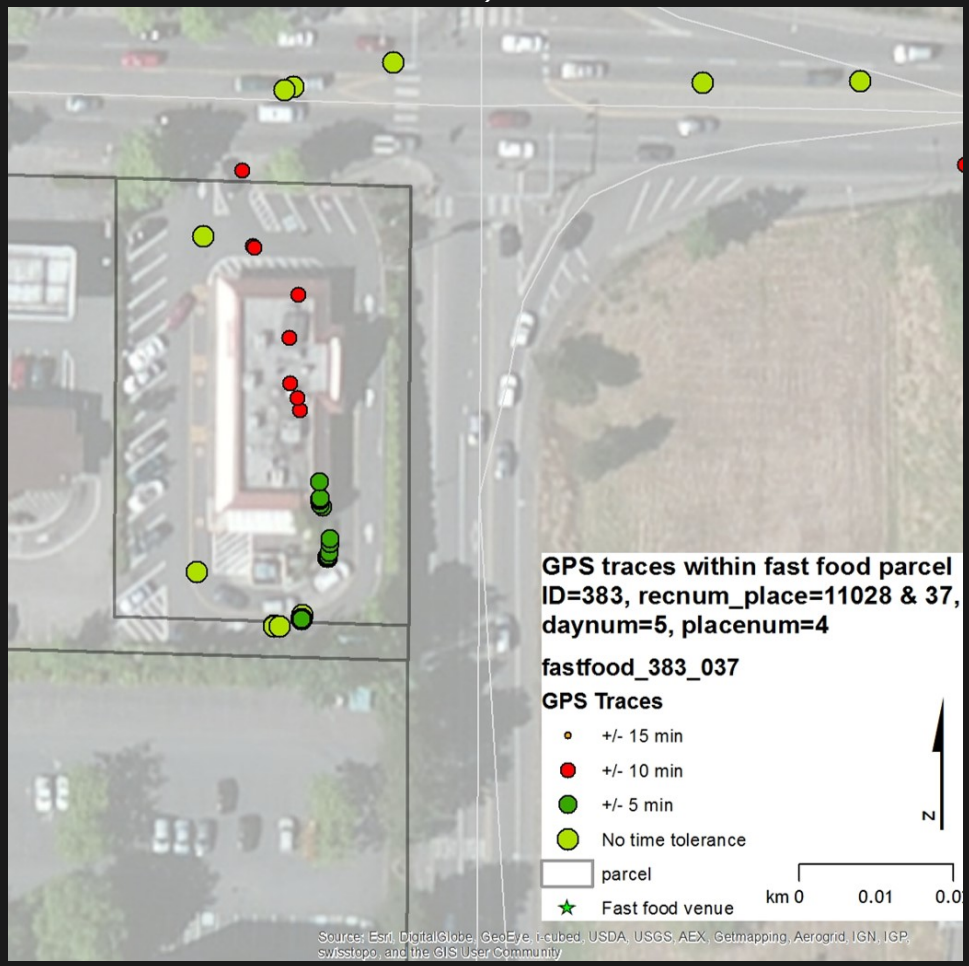
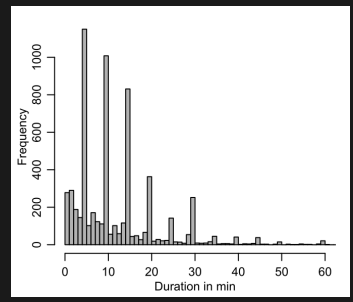
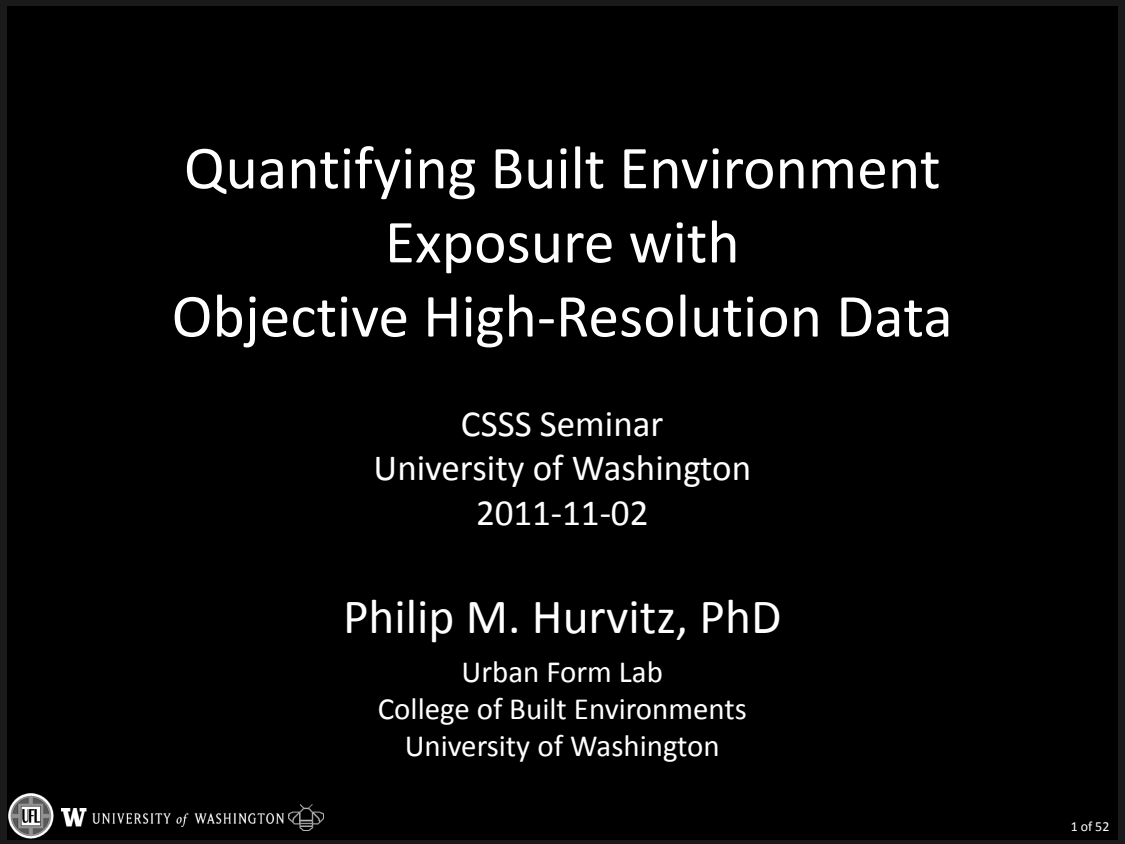




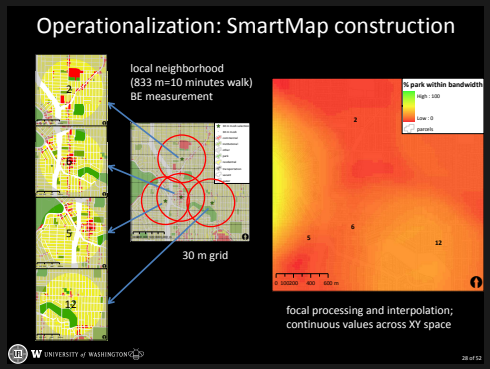
Credit: Jason Scully

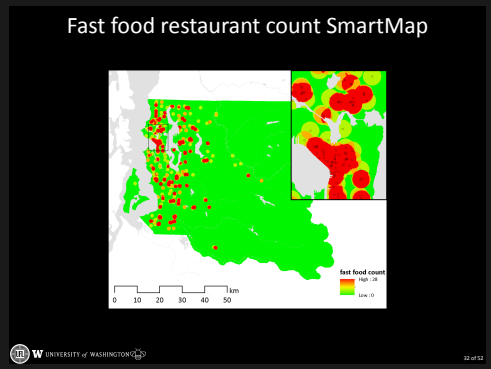
Use of 'SmartMaps' for assigning BE characteristics



CSSS Presentation, 2011-11-02: *Home vs. non-home neighborhood: Measuring differences in exposure to the built environment*

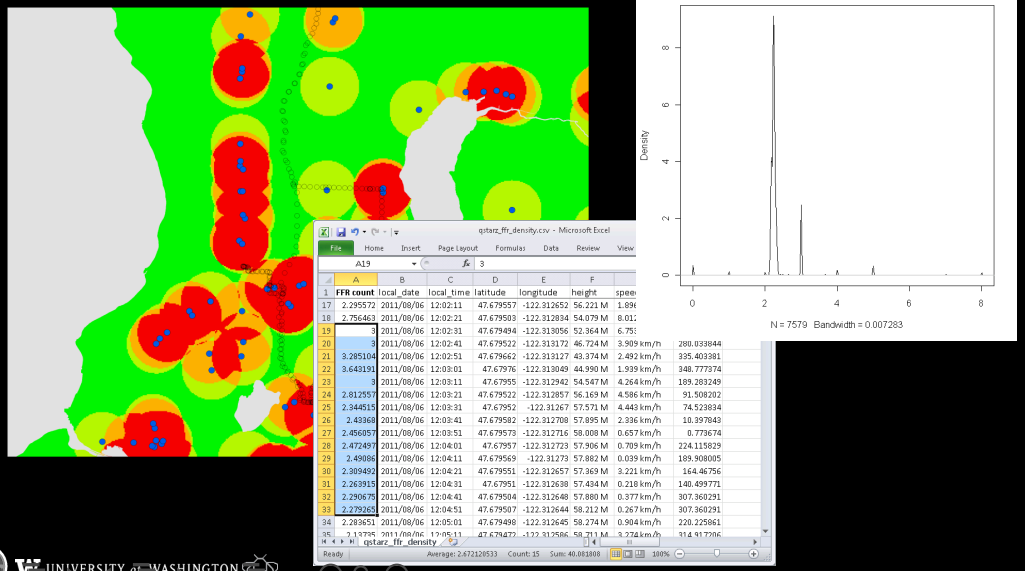
Assigning contextual information on large numbers of GPS points





FFR SmartMap with GPS trace

- Each GPS point is marked with its local FFR density



Some of our research

- Light rail and walking (a natural experiment): ~700 persons $\times$ 1 week $\times$ 3 measurement waves (GPS, accelerometry, travel diary); PI B. Saelens
- Built environment, food accessibility, and diet quality: ~500 persons $\times$ 1 week (GPS and travel/food diary); PI A. Drewnowski
- Twins residing apart: are different environments associated with different energy balance behaviors? ~200 persons $\times$ 2 weeks (GPS, accelerometry, 2 different smartphone-based diary instruments); PI G. Duncan

Identifying walking bouts

Deterministic classifier for walking bouts

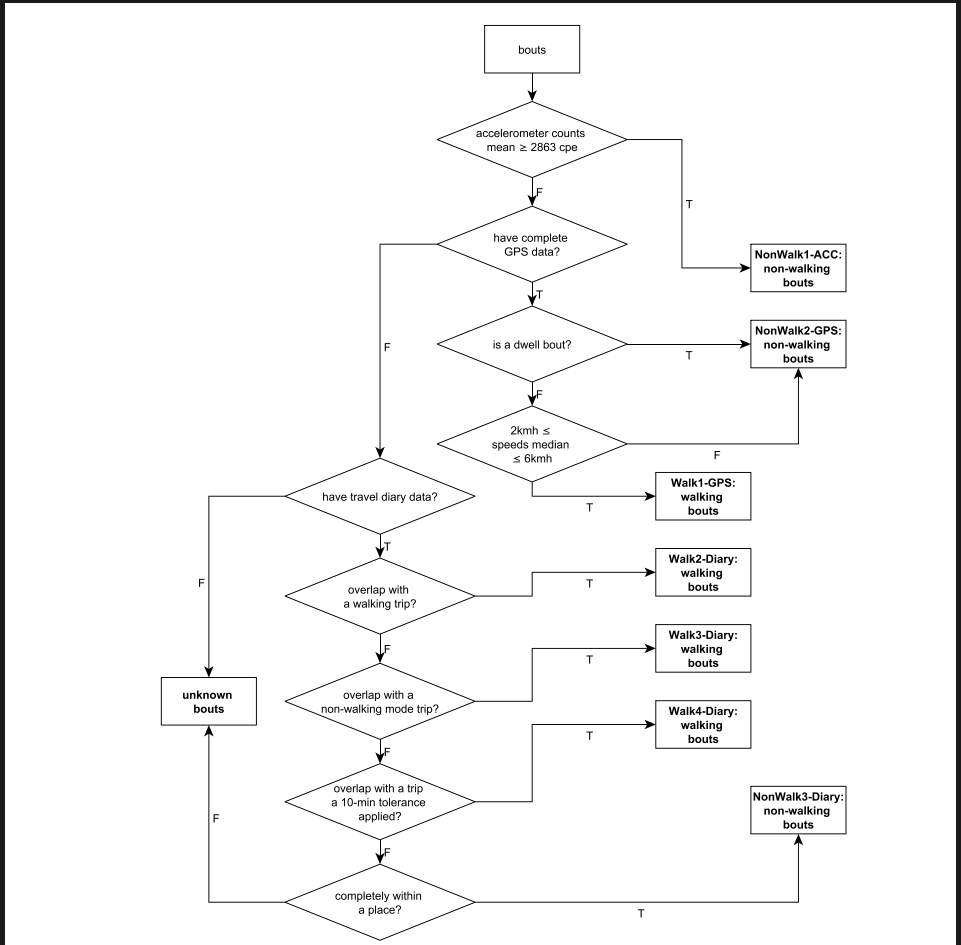
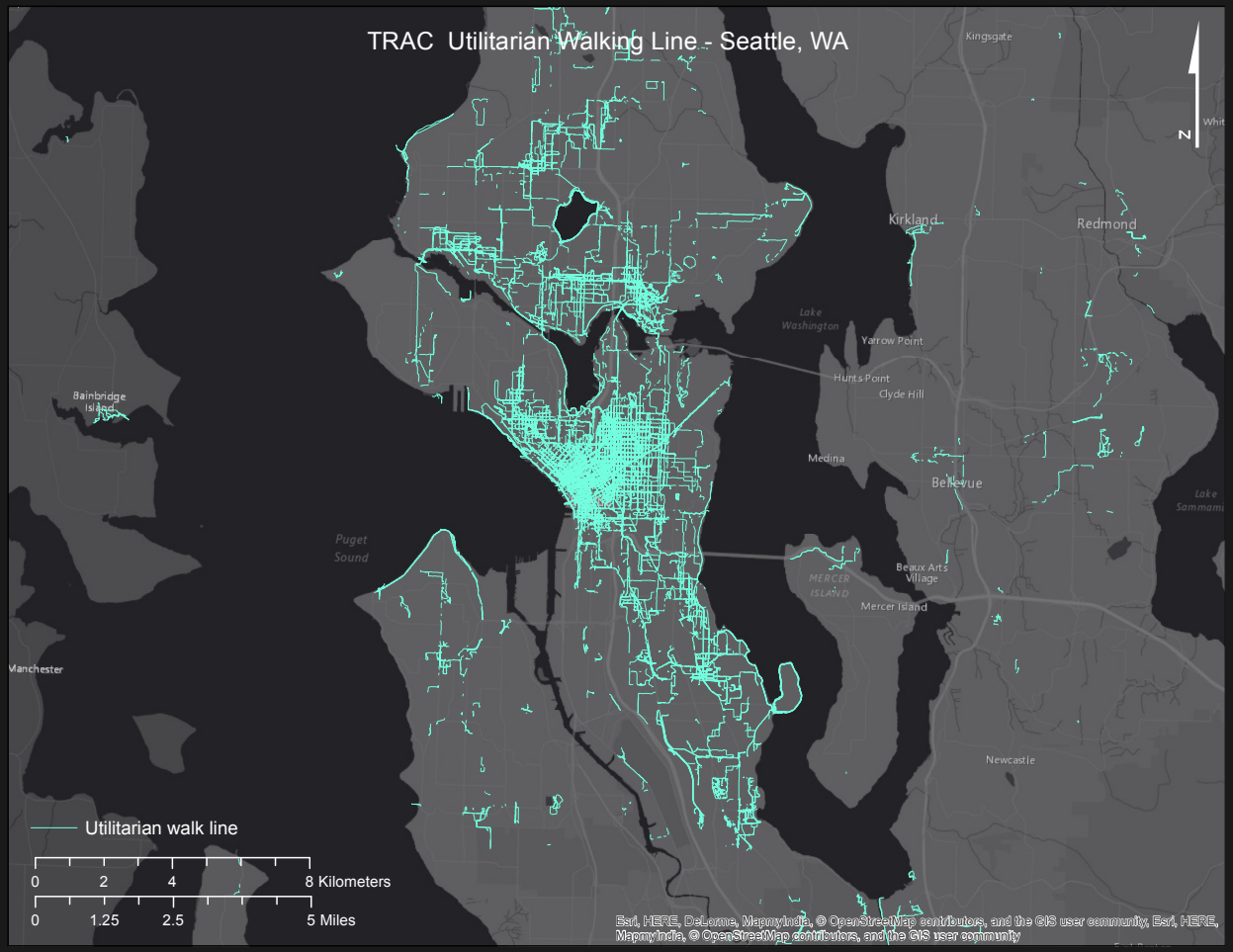


FIGURE 2—The decision-tree algorithm shows sequential application of the seven scenarios to classify PA bouts as walking or nonwalking.

Kang et al. (2013)

Where do people walk?

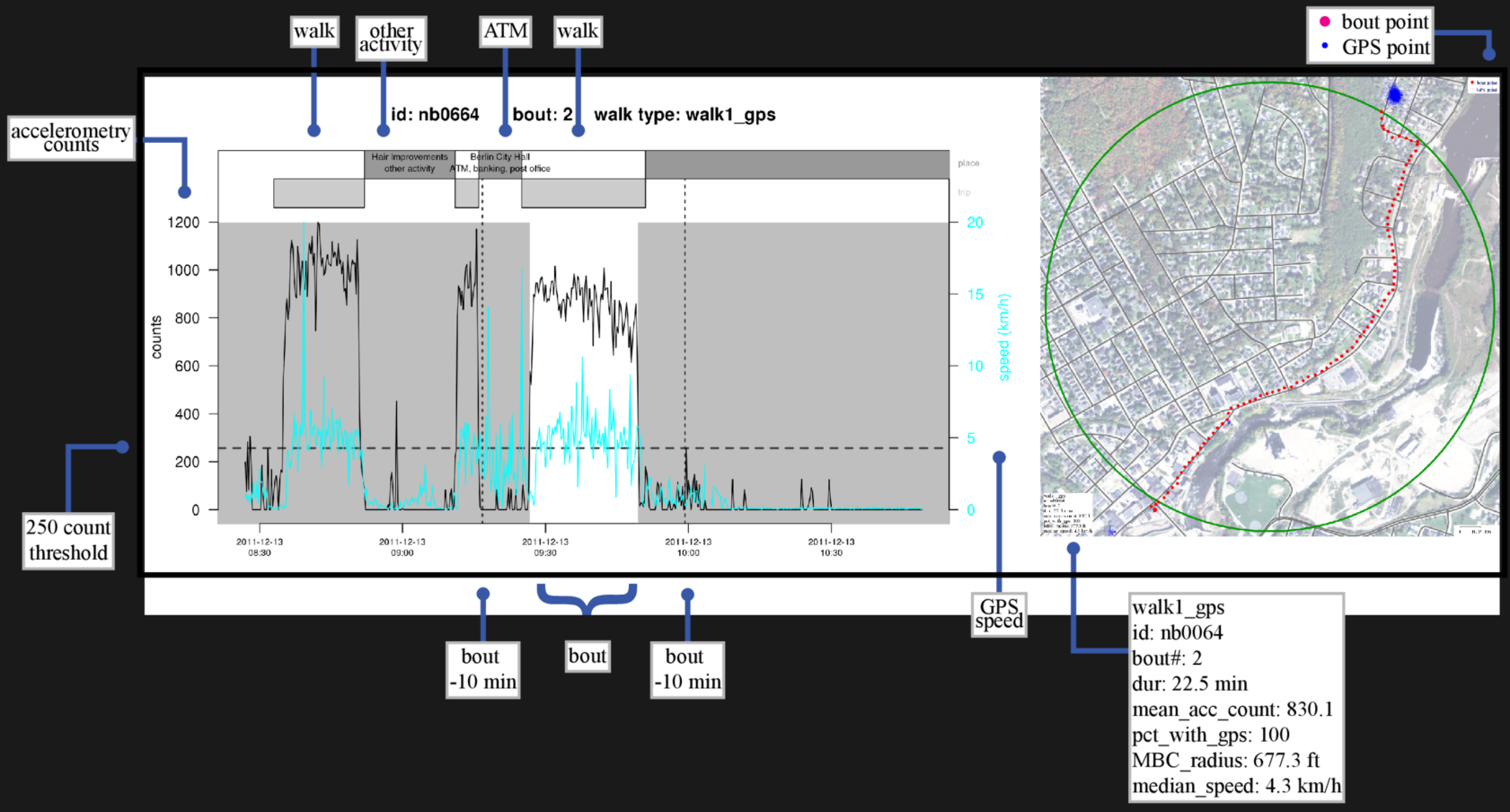
Utilitarian walking from ~700 subjects over 1 week



Credit: Eric Howard

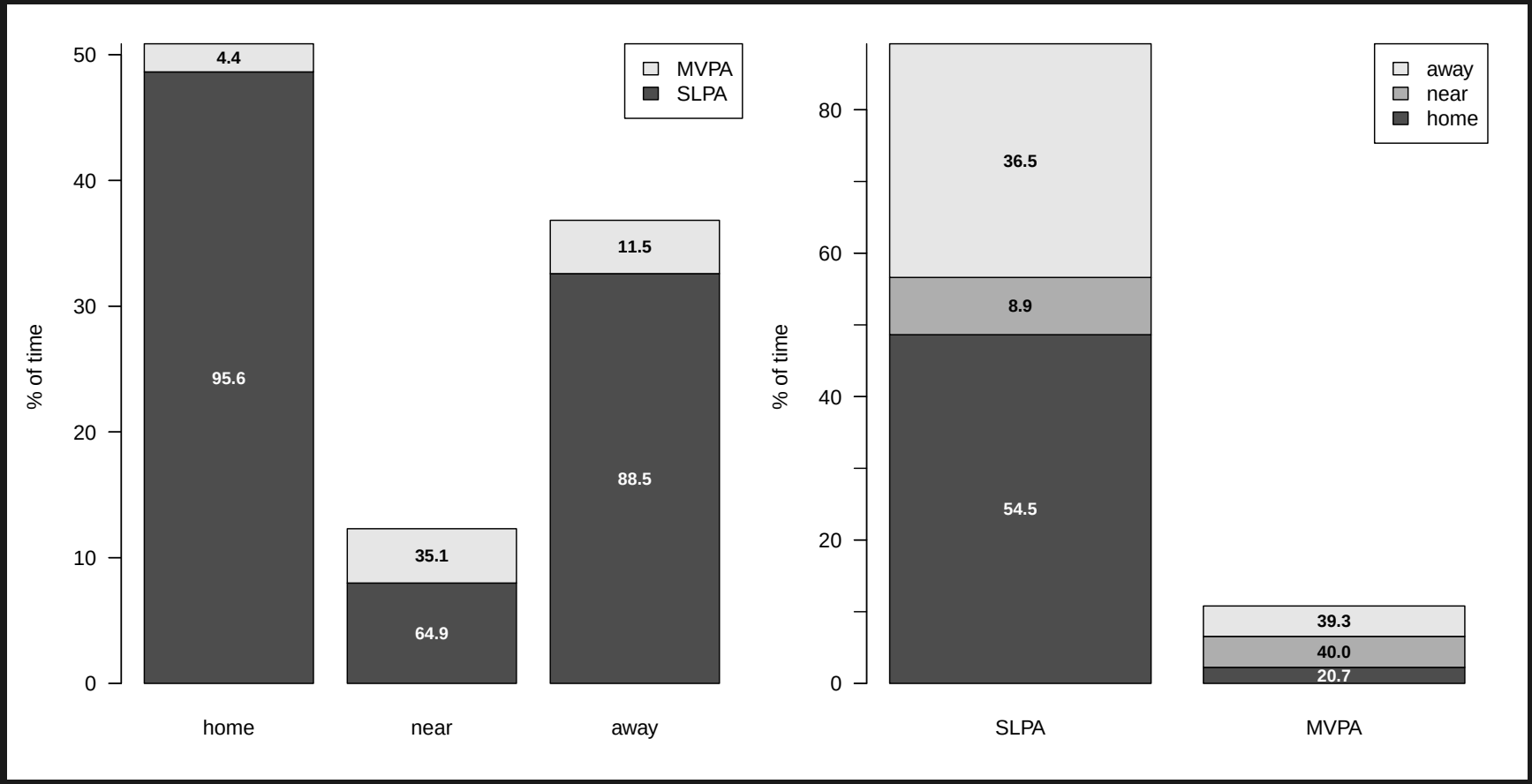
“LifeLog view”

Placing walking bouts in a spatial context



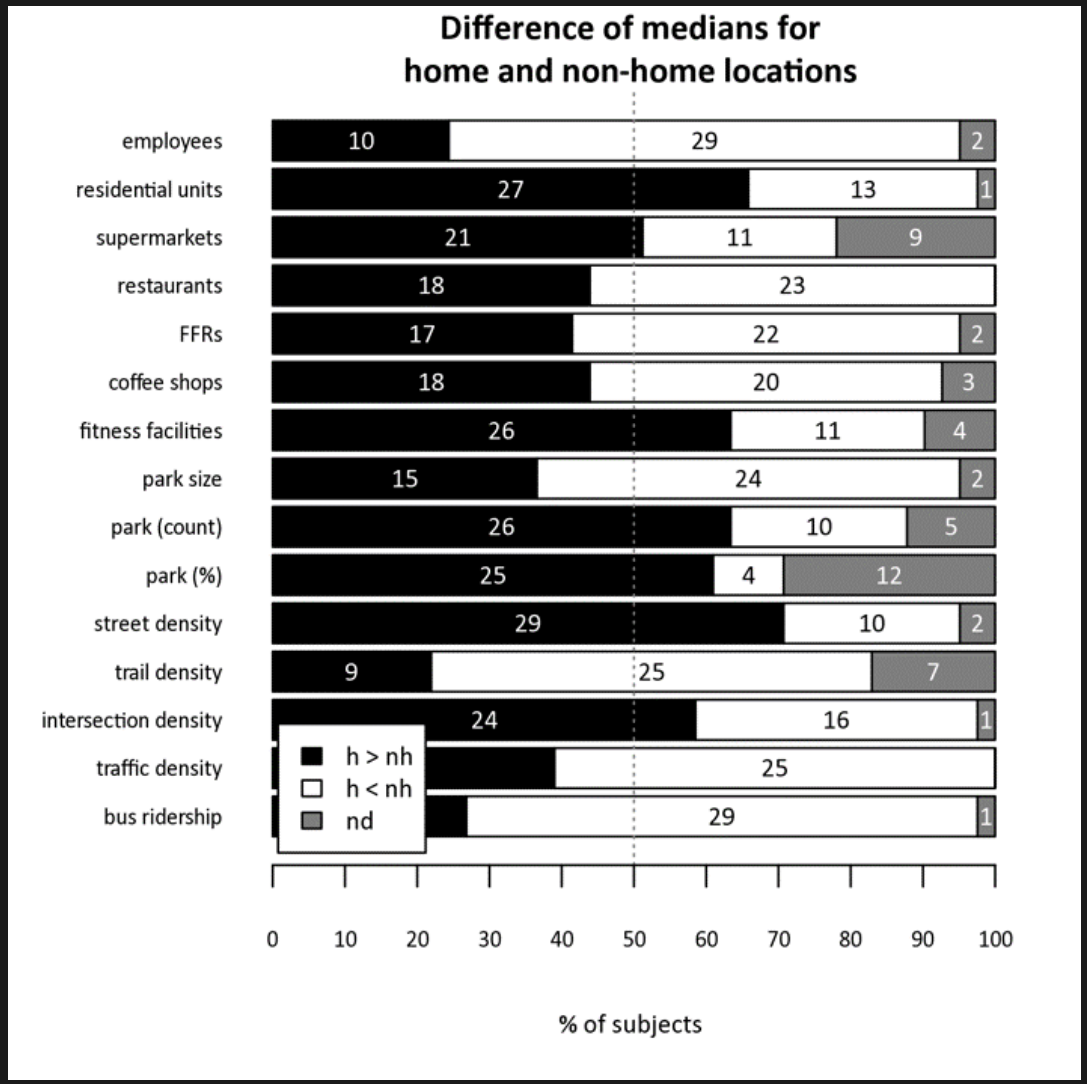
Hurvitz et al. (2014)

Most at home time is sedentary-to-low; More moderate-to-vigorous activity "near" home (within 20 minute walk)



Hurvitz et al. (2014)

How do built environment characteristics vary between home and other locations?



Hurvitz and Moudon (2012)

What effect does transit use have on walking physical activity?

Transit users got more physical activity and specifically more walking

TABLE 2—Overall Daily Physical Activity and Walking and Nonwalking by Nontransit Users and Tertiles of Transit Users' Proportion of Assessment Days That Were Transit Days in the Baseline Travel Assessment and Community Study Sample: King County, WA, 2008–2009

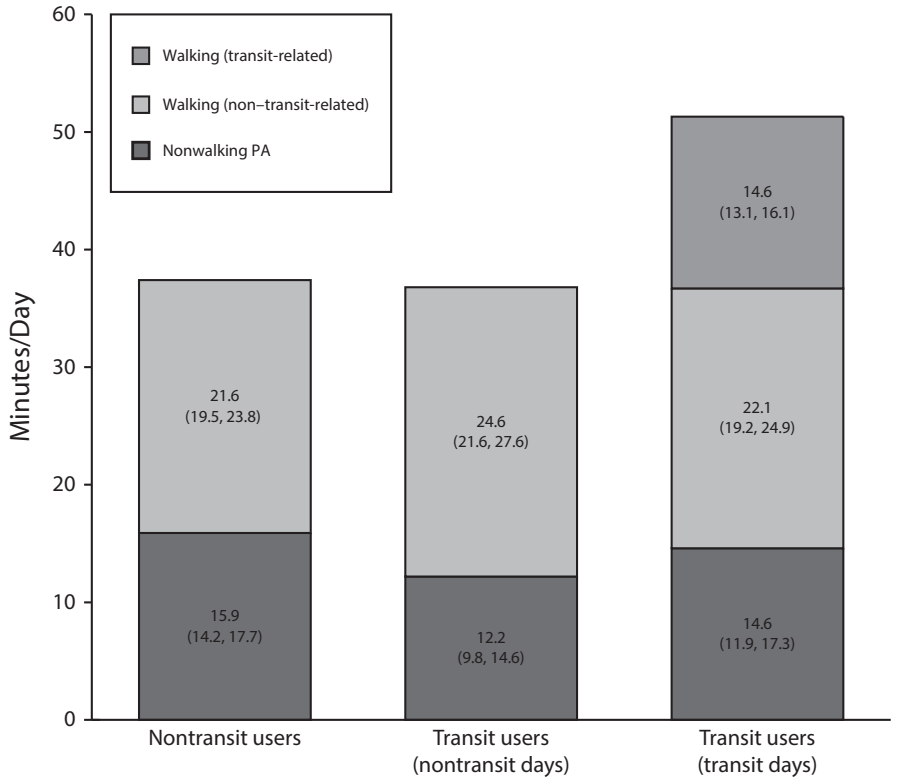
Variable	Nontransit Users (n = 394), Mean (95% CI)	Transit Use ≤ 30% of Days (n = 99), Mean (95% CI)	Transit Use 31%–59% of Days (n = 73), Mean (95% CI)	Transit Use ≥ 60% of Days (n = 83), Mean (95% CI)	Overall *P*
Overall physical activity, min/d	37.7 (34.6, 40.8)[a]	39.3 (33.1, 45.5)[a,b]	46.3 (39.1, 53.5)[a,b]	51.7 (44.8, 58.5)[b]	.001
Walking, min/d					
Total	21.8 (19.5, 24.0)[a]	25.8 (21.3, 30.4)[a,b]	34.4 (29.1, 39.7)[b,c]	36.5 (31.5, 41.5)[c]	< .001
Transit-related	0[a]	2.3 (1.3, 3.3)[b]	6.5 (5.4, 7.6)[c]	14.8 (13.7, 15.9)[d]	< .001
Non–transit-related	21.7 (19.6, 23.9)	23.5 (19.2, 27.9)	27.8 (22.8, 32.9)	21.7 (16.9, 26.5)	.17
Nonwalking physical activity, min/d	16.0 (14.2, 17.7)	13.5 (9.9, 17.0)	11.9 (7.8, 16.0)	15.2 (11.3, 19.1)	.24

Note. CI = confidence interval. Means (95% CI) adjusted for number of assessment days; analysis includes covariates of gender, income, education, and race/ethnicity; where superscripted, not sharing a superscript denotes significant differences between groups within the same row ($P < .05$).

Saelens et al. (2014)

What effect does transit use have on walking physical activity?

The difference was specifically on transit use days



Note. PA = physical activity. All values are means (95% confidence intervals).

FIGURE 1—Walking and nonwalking physical activity among nontransit users (n = 419) and among transit users (n = 274) on transit days (n = 815) and nontransit days (n = 3617) in the baseline Travel Assessment and Community Study sample: King County, WA, 2008–2009.

Saelens et al. (2014)

Conclusion

These data represent a tremendous effort, and we think they also have tremendous potential for additional research.

We hope this presentation has piqued interest among some of you!

We are looking for collaboration, funding opportunities, etc.

Acknowledgments

- US Taxpayers and project PIs
  - R01 DK076608, 2007-2015, PI: Adam Drewnowski
  - R01 HL091881, 2008-2013, PI: Brian Saelens
  - R01 HL103478, 2010-2013, PI: Mark Doescher
  - R01 AG042176, 2011-2015, PI: Glen Duncan

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  - R01 AG042176, 2011-2015, PI: Glen Duncan
- Urban Form Lab Director Anne Moudon
- Urban Form Lab students (current: Jason Scully, Eric Howard, Mingyu Kang) and staff (Orion Stewart, Amir Sheikh)

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Discussion
Q & A

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Slow/Fast Seattle