Using GPS and Accelerometers in Neighborhood Research

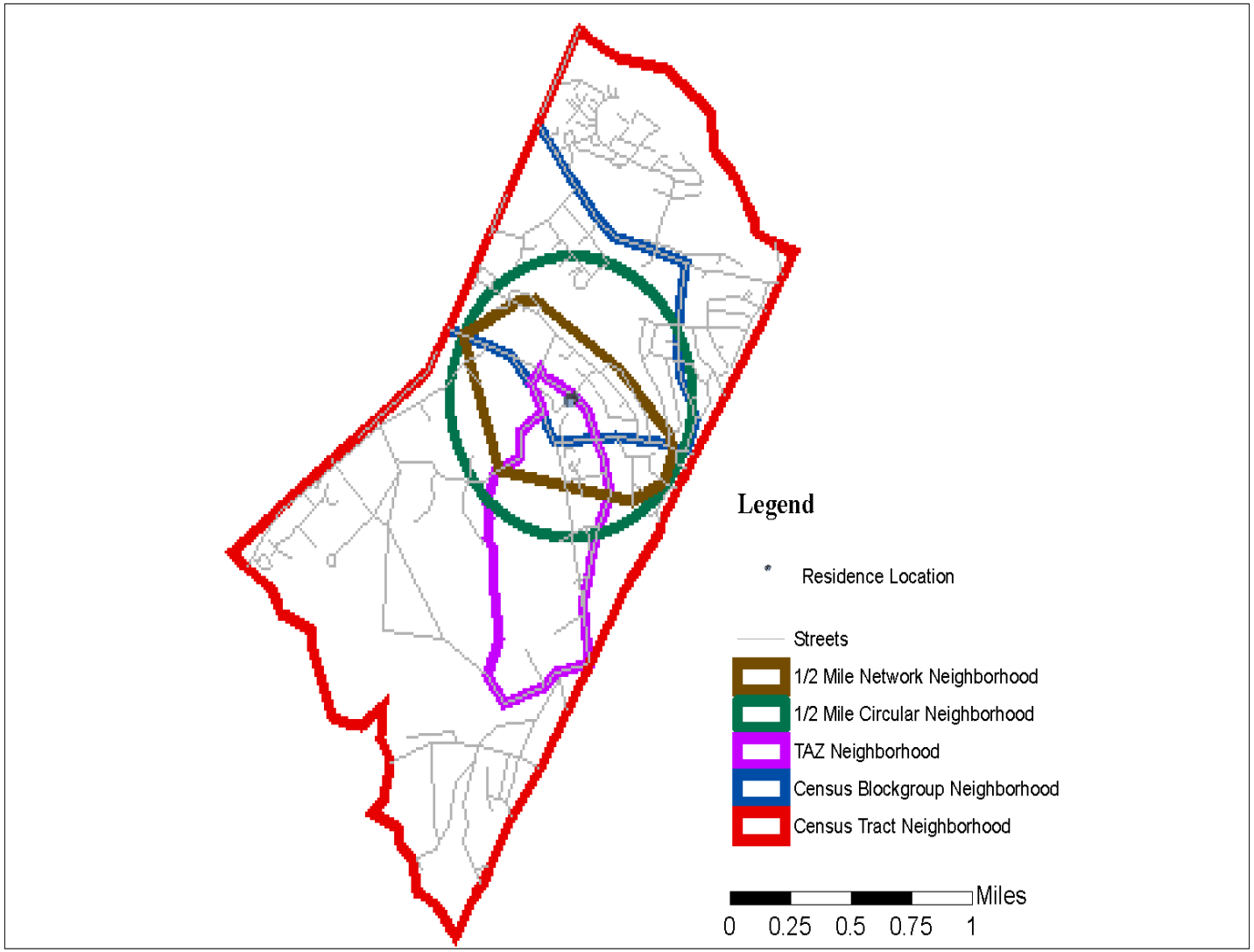
Daniel Rodriguez, Ph.D., MS
Elizabeth Shay, Ph.D.,
University of North Carolina, Chapel Hill

Deborah A. Cohen, M.D., M.P.H.,
RAND Corporation

Conceptual Overview

- Environmental exposures currently poorly measured
- Exposures critical in influencing outcomes (causal model)
- New technology has promise in more precisely defining exposure

Standard Way of Measuring Neighborhood Influences



Need to Go Beyond Drawing Circles to Define Exposures

The Environment

Everything that comprises the context and surroundings of our everyday worlds, created by humans

- Physical structures
- Social structures (policy/organizations)
- Media
- Accessibility of consumer products

Why Is the Environment a Key Factor?

- People react to the environment automatically.
- Motor neurons fire BEFORE neurons that activate our consciousness

(Although we have the illusion that we consciously control our own behaviors)

- People are NOT in complete conscious control of their own behaviors

Mechanisms that Govern Automatic Behavior

- Limited cognitive capacity
- Hardwired survival strategies: conserve energy, find shortcuts, reduce work
- Forage and search for variety, novelty
- Mirror neurons
- Stereotype Activation, Conditioning, Priming (choices are not independent)

We are typically UNAWARE of these mechanisms

People Lack Insight into their Behavior

- Don’t always know why they make various choices
- Are not consciously aware of all cues and primes
- Deny they are influenced by environmental cues, but believe others are so influenced

People Lack Insight Into Physical Activity

- In CDC BRFSS about 50% report exercising at least 30 minutes during 5 days per week.
- NHANES study measuring MVPA using accelerometers on >6,200 showed < 5% of adults meet PA guidelines

Walking and Talking

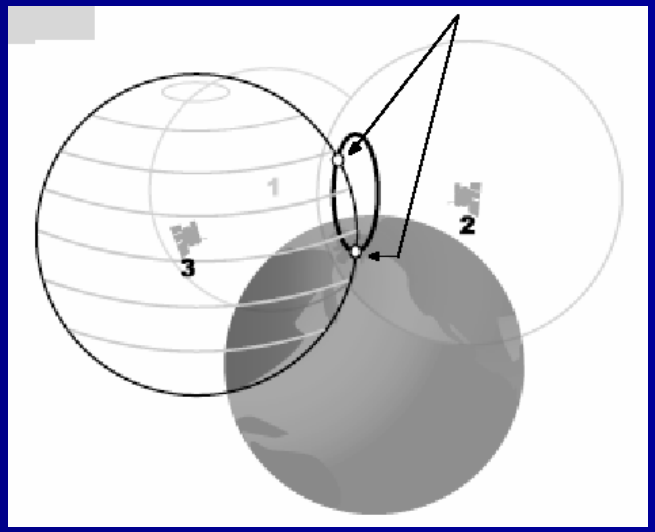
- Can walk and talk at same time, but walking is automatic
- Look around us, and ignore our own bodies
- Physical activity is a means, not an end.

Challenge and Goal

- Need more objective measures to identify what environmental factors facilitate and constrain physical activity (and other behaviors)
- Once identified, we can potentially alter those factors to help people engage in PA automatically
- Enter GPS

GPS

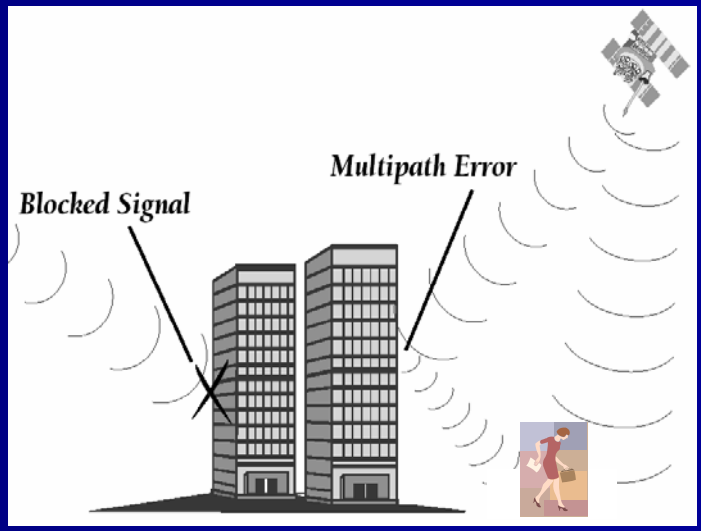
- Use of satellites (and land towers) to determine location on earth
- Units determine
  - Lat, long, altitude, accuracy
- Various sizes & features
  - Accuracy
  - Data recording
  - Battery life
  - Portability



(Source: Garmin, Ltd. 2004)

GPS Challenges

- Satellite-specific
  - Each satellite's reported location
  - Locations relative to other satellites
  - Atmospheric delays of signal
  - Unit clocks
- Earth-specific
  - Multiple signals
  - Satellite visibility



(Adapted from Garmin, Ltd. 2004)

GPS Units Available

- Three generation of units –from Stopher et al in press

GPS Units Available: 1st gen

- Geostats' (unit of Nustats) data logger
  - Size: 35mm. camera, weight: 1. 6lb
  - Pros
    - Large memory capacity; battery life
    - Most used
      - Trail study (Troped et al)
      - Transportation studies (SMARTRAQ, London Dept. of Transport Trial)
    - Units can be rented
  - Cons
    - Size for PA studies, Cost
    - Geostats data processing is proprietary

GPS Units Available: 1st gen

- Enertech's GPS-PAL
  - Similar pros and cons of data logger
  - Used in children and EMF exposure
  - Requires vest

GPS Units Available: 2nd gen

- Smaller, more portable
- Shorter battery life
- Increased accuracy

GPS Units Available: 2nd gen

- Garmin Foretrex/Forerunner (78 g)
- Pros
  - Size; Cost
  - Market-tested
  - Memory for 15k points
- Cons
  - Short battery life
  - User feedback

GPS Units Available: 2nd gen

- Neve Steplogger (100g), Globalsat datalogger
- Pros
  - Size; Cost
  - Memory (150k records)
- Cons
  - Size
  - Short battery life (~8)
  - Easy to turn on inadvertently

GPS Units Available: 3rd gen

- Neve Steplogger (50g)
- Pros
  - Size; Cost
  - Memory (800k records)
  - Accelerometer to determine power use
- Cons
  - Battery life?
  - Voice communication
  - Light feedback

Accuracy of GPS Units

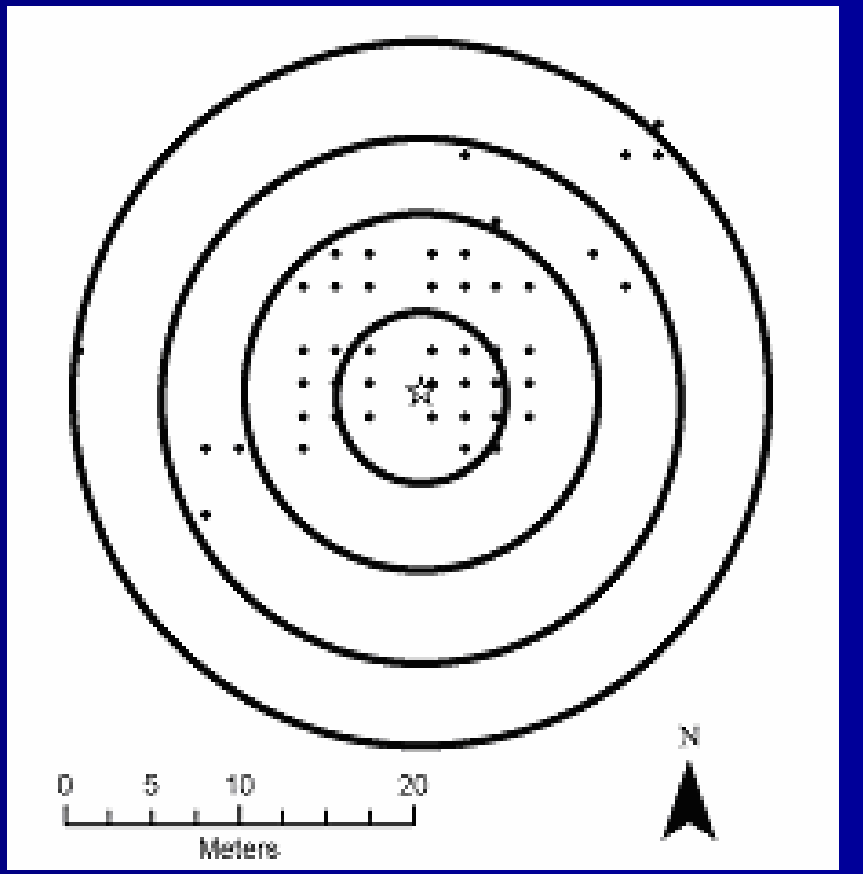
- Commercial units RMSE = 5-10 m
  - Some down to RMSE = 3 m
- Increasing with technology
  - dGPS, WAAS

Accuracy of GPS Units

- Six Garmin Foretrex 201 GPS units
- Units record position every 30 s
- Units placed on a geodetic point for 1 h.
- Static validity
  - Visual comparison of recorded coordinates with true coordinates of geodetic point
- Data cleaned using custom C program

Accuracy of GPS Units

- Each unit recorded 121 observations (N=726)
- Average distance from geodetic point: 3.02 m (SD 2.51)
- 81% within 5 m
- 99.4% within 15 m



Accuracy of GPS Units

- Wore units along route in three built environment scenarios
  - Open space, clustered development and urban
  - Route within each scenario had 25 locations
  - Each scenario was tested three times
- Inter-unit reliability
  - Comparison of the distance between each unit's recorded location and average location recorded by the other 5 units

Accuracy of GPS Units

Scenario	Average distance (m)	SD	N
Open space	10.7	11.9	450
Clustered development	20.1	21.8	450
Urban	18.5	18.4	450

Accuracy of GPS Units

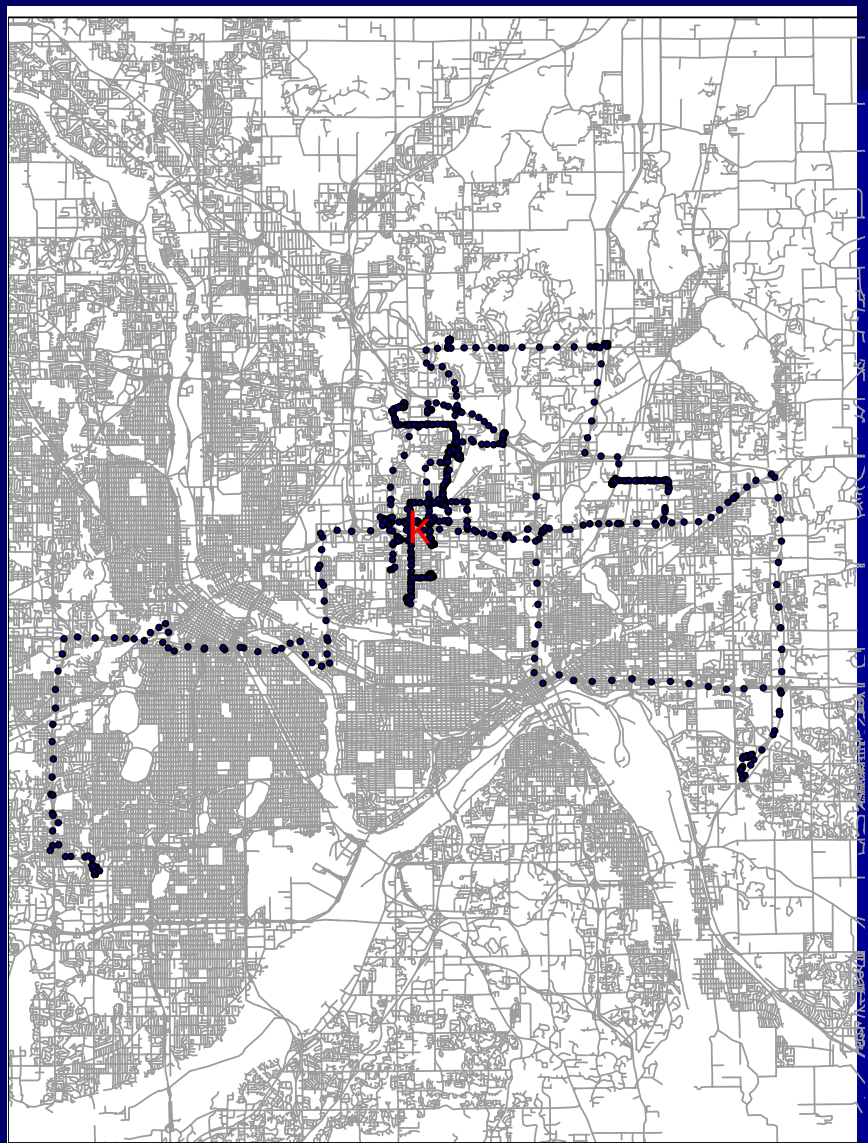
	Wrist	Belt	Ankle	N
Open space	100.0%	100.0% ($P = 0.16$)	98.4% ($P < 0.05$)	25
Clustered development	86.8%	92.3% ($P < 0.05$)	65.8% ($P < 0.01$)	25

- Average battery life: 15.97 hrs (SD 1.01) (N=14)
- Average recharge time: 2.66 hrs (SD 0.1) (N=7)

Uses of GPS

- Determine travel routes taken
  (Stopher, FitzGerald, and Xu 2007; Duncan and Mummery 2007)
- Identify environmental exposures (e.g., walking)
  (Rodriguez et al 2005; Greaves et al 2008; Elgethun et al. 2007)

GPS and Spatial Exposures



Uses of GPS

- Determine travel routes taken
  (Stopher, FitzGerald, and Xu 2007; Duncan and Mummery 2007)
- Identify environmental exposures (e.g., walking)
  (Rodriguez et al 2005; Greaves et al 2008; Elgethun et al. 2007)
- With diaries
  - Agreement regarding visit durations
    (Elgethun et al. 2007)
  - Agreement regarding # of trips
    (Stopher et al 2007b)

Uses of GPS + Accelerometers

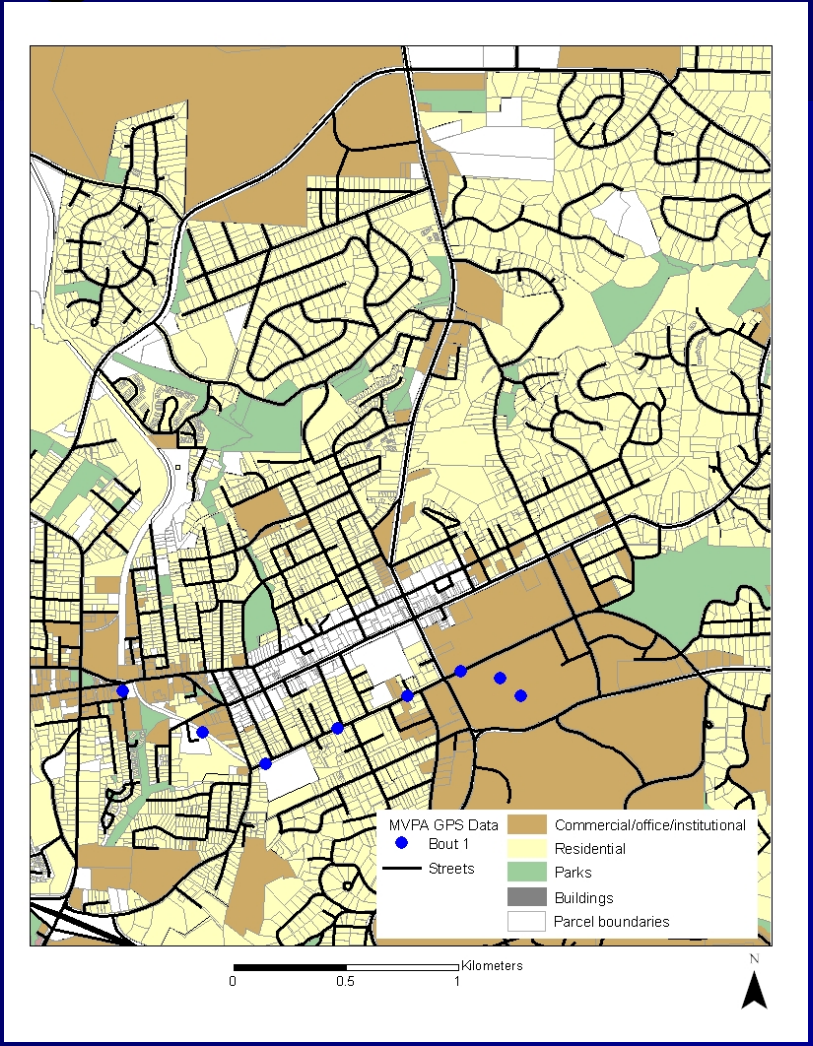
- Identify walking activity

  (Ermes et al. 2008; Troped et al. In Press; Duncan, Mummery, and Dascombe 2007; Pober et al. 2006)

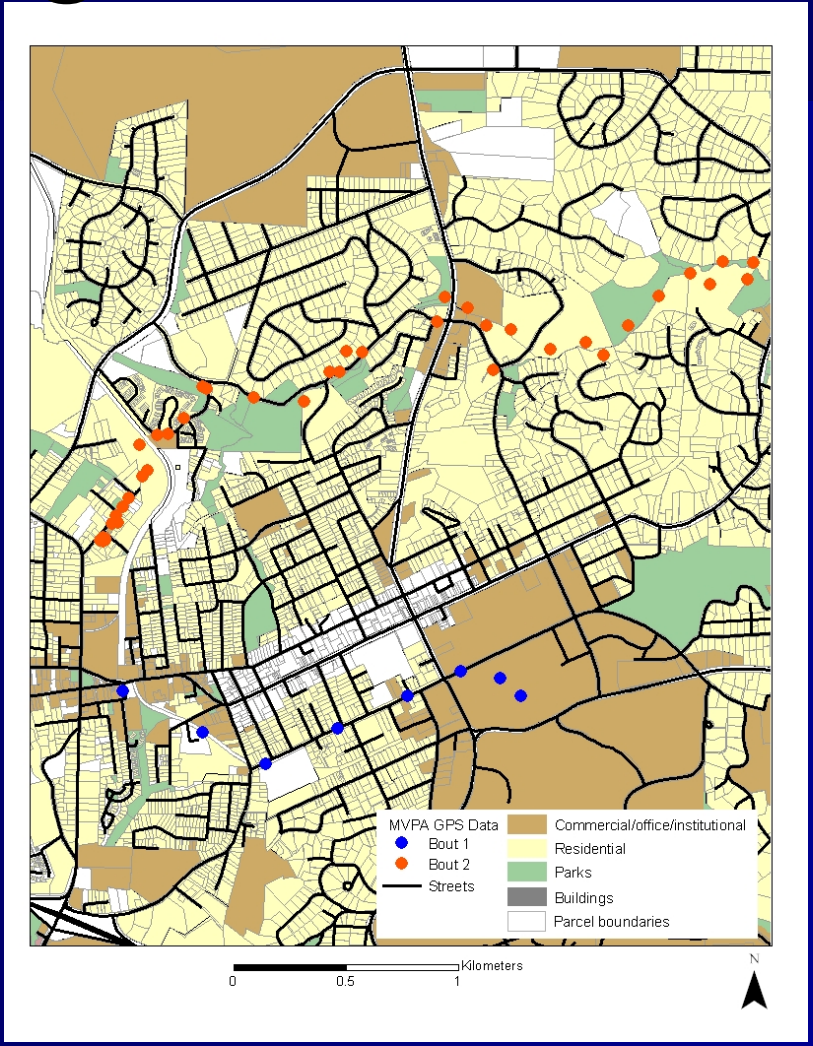
- Identify where walking activity occurs

  (Rodriguez et al 2005; Duncan and Mummery 2007)

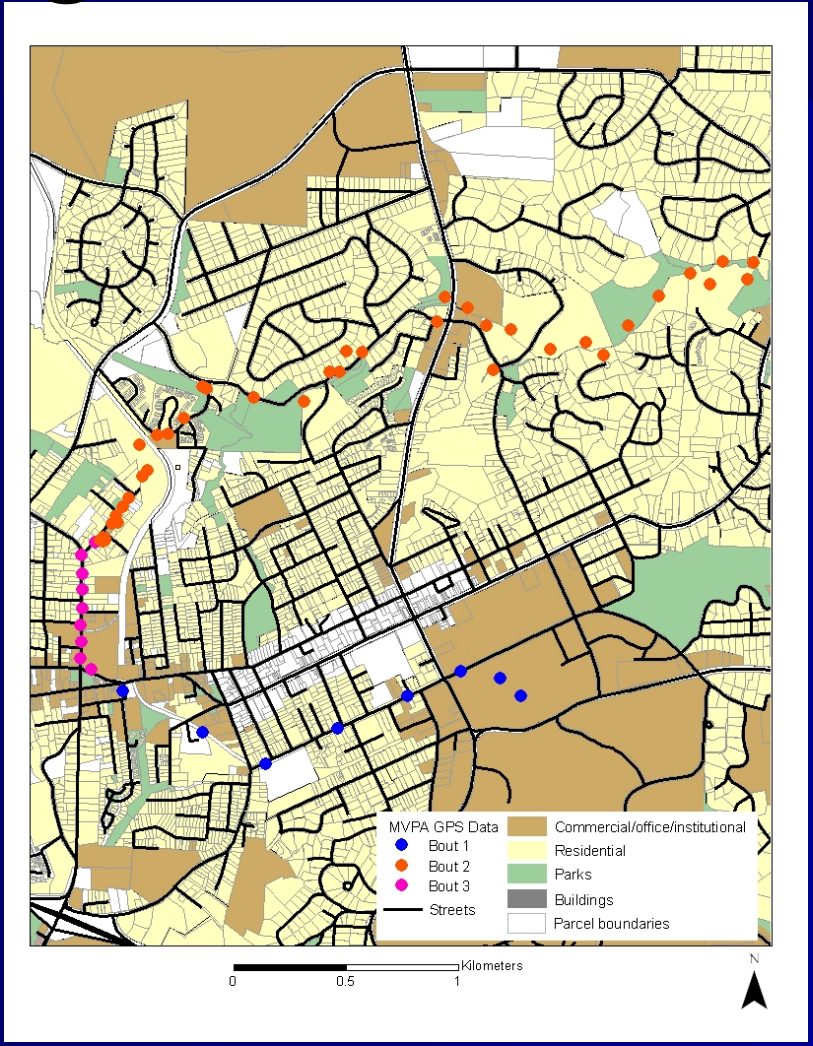
Combining with Accelerometer



Combining with Accelerometer



Combining with Accelerometer



Logistics: Hand-held technology

Participants carry three types of technology

- Geographic positioning system (GPS) units provide longitude/latitude within a few meters
- Accelerometers record vertical movement to represent physical activity
- Personal digital assistants (PDAs) allow participants to enter data on travel, food consumption, activities

ActiGraph™ ...the Technology of Health

GPS Preparation & Operation

Using GPS units in field research

- Initializing/preparing units at study sites by staff
- Distributing units and tracking documents
- Training participants to
  wear / charge / protect units
- Collecting units and documents
- Downloading data

GPS Preparation & Operation

Initializing/preparing units at sites

- Fully charge battery
- Initialize: settings for recording tracks, time interval, silent mode, battery-saving features (backlight, WAAS)
- Set recording to “on”
- Cover screen
- Note GPS & computer times (to match accelerometer and GP

GPS Preparation & Operation

TAAG 2

To be completed by TAAG 2 staff:

Student ID: _____

Form Code: **MEQ** Version: **A** Timepoint: __ ___ Seq. #: ___

Equipment Tracking Form

1. Today's Date (data collection start date): ___ ___ / ___ ___ / 20 ___ ___ (m m d d y y) 2. Initials: ___ ___ ___

3. GPS Time: ___ ___ : ___ ___ : ___ ___ 4. Computer Time: ___ ___ : ___ ___ : ___ ___

5. Equipment:

	#	Checked out (✓)	Date Checked in	Staff Initials
Pouch #				
Activity Monitor Serial #				
GPS Unit #				
GPS Belt or Wrist				
GPS Charging Cradle				
GPS Charger Power Cord				
PDA Unit #				
PDA Stylus				
NPL Booklet				

3. Last Day of Data Collection: ___ ___ / ___ ___ / 20 ___ ___ (m m d d y y)

Distributing units and tracking documents

- Pack units with charger, cradle, pouch, belt
- Record GPS identifier on tracking sheet
- Instructions on wearing / handling, practice basic use
- Reference sheet
- Start recording on distribution day

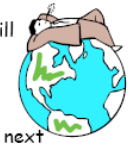
GPS Preparation & Operation

Training participants to wear / charge / protect units

- How to charge
- How to turn on/off
- How to wear
- Do's-and-don'ts

What You Need To Know About Carrying the GPS Unit

GPS stands for Global Positioning System. This unit will continuously record your position on the face of the earth as you move about during the day. We are asking you to carry this unit so that we can learn more about what environments people are physically active in. The unit is waterproof, so don't worry about getting it a little wet if you go out in the rain. Here is a list of things that will help you remember what to do:



DO:

- **Do** remember to carry the unit with you everywhere you go for the next seven days (except when swimming or bathing).
- **Do** remove the unit just before you go to bed to recharge it. Turn the unit off, snap it into the charger cradle and plug the cradle into an outlet.
- **Do** remember to turn the unit on first thing in the morning when you unplug it.
- **Do** call us if you think there may be something wrong with the unit.

DON'T:

- **Don't** drop the unit or knock it against hard objects.
- **Don't** press any of the buttons on the unit at any time, or remove the protective cover from the screen.
- **Don't** keep it in your pocket, purse or bag.
- **Don't** forget to take the unit with you everywhere you go!

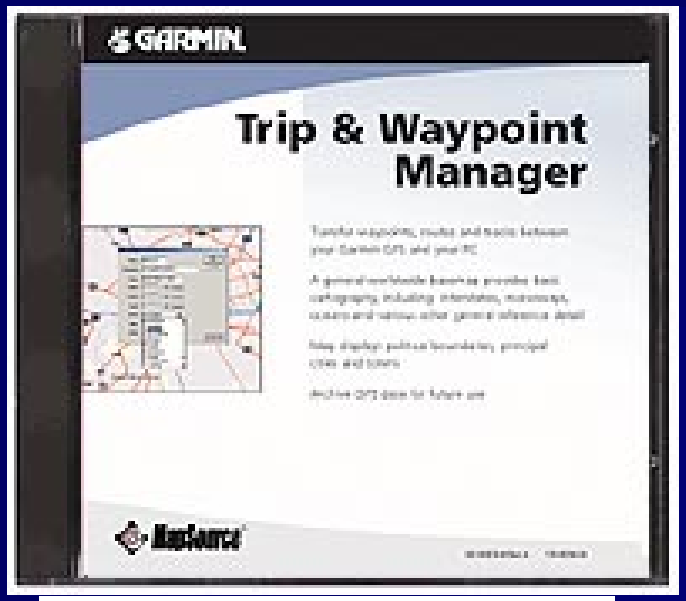
AVOID exposure of unit to:

- **Excessive heat** (such as in the trunk of a car)
- **Cleaners** or other **chemicals**
- **Complete submersion** in water

What to do if you have questions:

Call or email [SDSU or UMN contact info here] if you have any concerns. Please leave a message if you reach the voice mail, and someone will return your call.

GPS Preparation & Operation



Collecting units, downloading data

- Collect units
- Set recording to “off”
- Download data
- Label files with naming convention
- Upload files
- Clean memory from unit, prepare for next participant

Merging and Managing Data

Data management

- Field sites upload data to commercial storage
- UNC staff download data to secure computer
- UNC staff merge spatial (GPS) and activity (accelerometer) data; clean and analyze data for quality / compliance

Trouble-shooting GPS units

Problems encountered in field and lab

- Defective units (~5%): frozen screens, missing tracks, weak batteries, loose belt pins
  - Batteries: loose charge connections, power drains (lighting, recording interval, cold, WAAS)
  - Satellites: frozen screens, corrupted data
- Human behavior: stray button-punching, curiosity/peeking, forgotten starts
- Daylight saving time: requires reset

Analyzing GPS + Accelerometer Data

- Clean GPS data
- Summarize accelerometer data (see Kerr et al., next session)
- Determine compliance
- Merge data based on timestamps

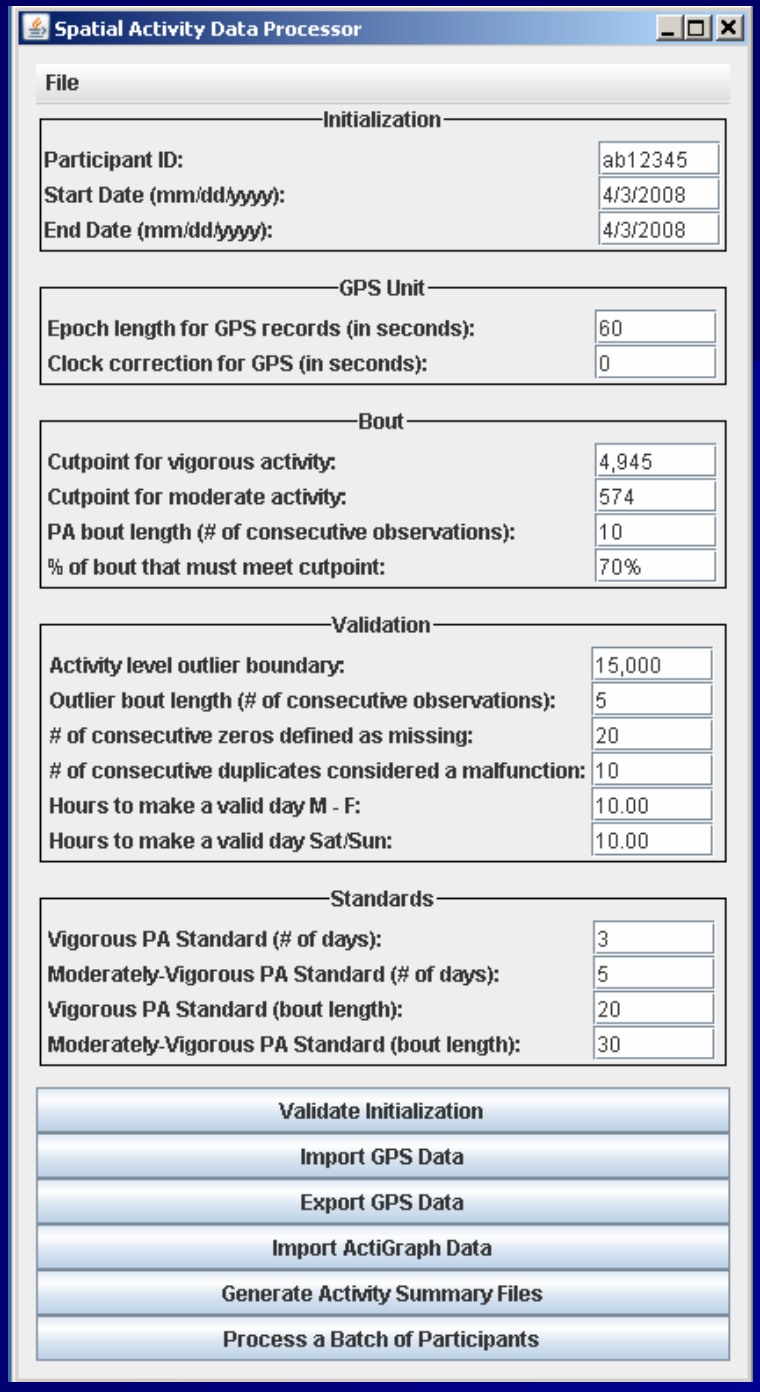
Analyzing GPS + Accelerometer Data

- Clean GPS data

LAT	LON	ALT	DATE	TIME
35.92676617	-79.07169694	-1493.74671915	07/01/2003	08:06:08 AM
35.92595547	-79.06991813	94.95734908	07/01/2003	08:06:33 AM
35.92673114	-79.07151983	94.95734908	07/01/2003	08:06:58 AM
35.92873114	-79.07252524	95.03280840	07/01/2003	08:07:23 AM
35.93036477	-79.07045541	95.03280840	07/01/2003	08:07:48 AM
35.93013285	-79.06836857	94.81955381	07/01/2003	08:08:13 AM
35.92830710	-79.06788326	94.76049869	07/01/2003	08:08:38 AM
35.92453675	-79.07008887	94.81299213	07/01/2003	08:09:03 AM
35.92221036	-79.07213104	94.89173228	07/01/2003	08:09:28 AM

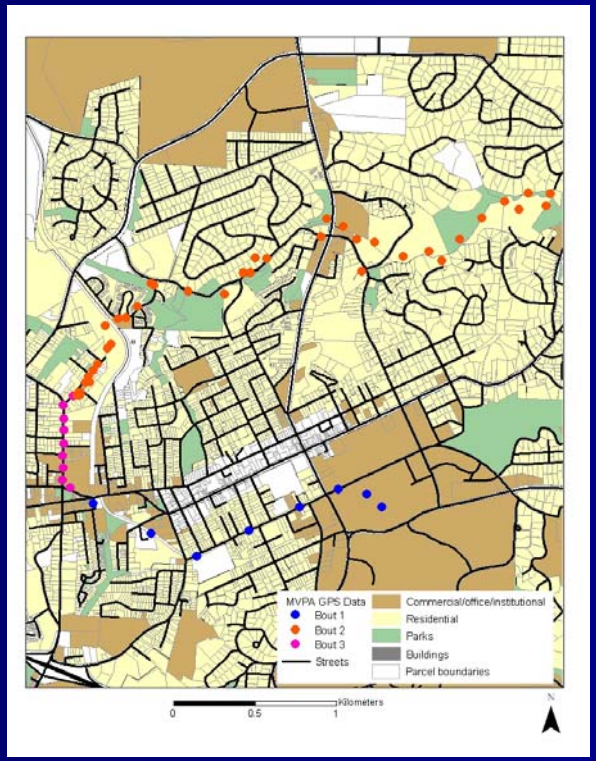
Analyzing GPS + Accelerometer Data

- GPS+Accelerometer data cleaner
  - Open source
  - JAVA
  - Cleans + merges GPS data with accelerometer
    - What is a bout (cutoff, duration, % under cutoff)?
    - Reports wearing time and compliance
    - Identifies outliers
    - Weekend/weekday average values by MVPA and MVPA in bouts


Spatial Activity Data Processor
File
Initialization
Participant ID:
ab12345
Start Date (mm/dd/yyyy):
4/3/2008
End Date (mm/dd/yyyy):
4/3/2008
GPS Unit
Epoch length for GPS records (in seconds):
60
Clock correction for GPS (in seconds):
0
Bout
Cutpoint for vigorous activity:
4,945
Cutpoint for moderate activity:
574
PA bout length (# of consecutive observations):
10
% of bout that must meet cutpoint:
70%
Validation
Activity level outlier boundary:
15,000
Outlier bout length (# of consecutive observations):
5
# of consecutive zeros defined as missing:
20
# of consecutive duplicates considered a malfunction:
10
Hours to make a valid day M - F:
10.00
Hours to make a valid day Sat/Sun:
10.00
Standards
Vigorous PA Standard (# of days):
3
Moderately-Vigorous PA Standard (# of days):
5
Vigorous PA Standard (bout length):
20
Moderately-Vigorous PA Standard (bout length):
30
Validate Initialization
Import GPS Data
Export GPS Data
Import ActiGraph Data
Generate Activity Summary Files
Process a Batch of Participants

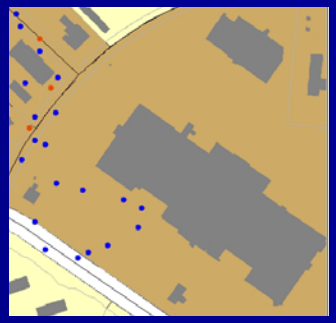
Analyzing GPS + Accelerometer Data

- GPS+Accelerometer data cleaner
  - For each MVPA bout, tie in GPS data



Example

- Bout locations categorized using GIS software
  - Indoors versus outdoors
    - 33 % rule within footprint



  - Inside neighborhood versus outside neighborhood
    - 33 % rule within 1-mile buffer around home

Sample Study Pilot

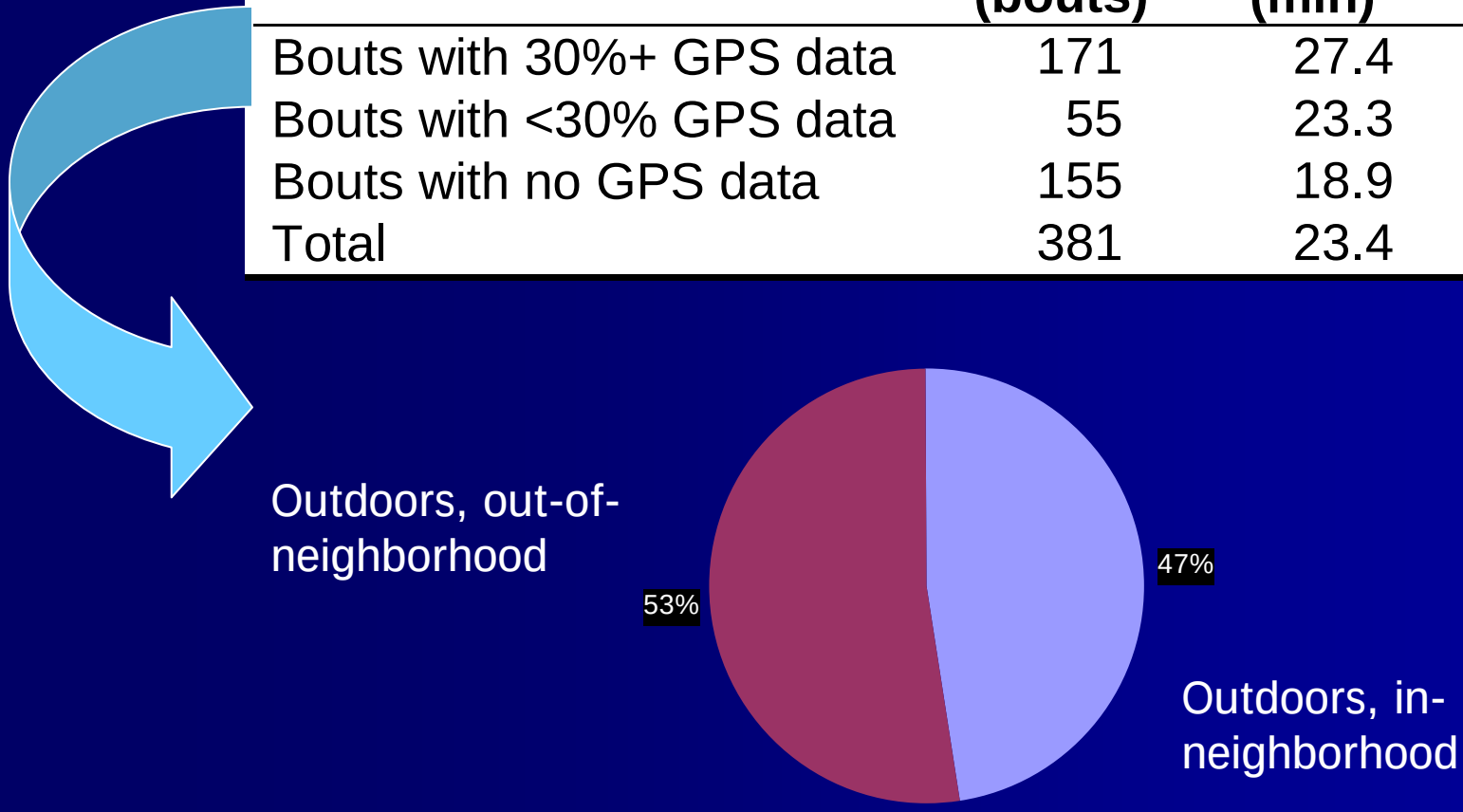
- 35 volunteers (60% F, Age = 31.8)
  - GPS unit set to record locational data every 60 seconds
  - Actigraph model 7164 recording at a 60-second epoch
  - Units time-synchronized
- Participants carried units for 3 days
- Data were downloaded, processed, and merged together

Sample Study: Bouts and GPS

	N (bouts)	Time per bout (min)	% of total MVPA time
Bouts with 30%+ GPS data	171	27.4	53.0
Bouts with <30% GPS data	55	23.3	14.0
Bouts with no GPS data	155	18.9	33.0
Total	381	23.4	100.0

Sample Study: Bouts and GPS

	N (bouts)	Time per bout (min)	% of total MVPA time
Bouts with 30%+ GPS data	171	27.4	53.0
Bouts with <30% GPS data	55	23.3	14.0
Bouts with no GPS data	155	18.9	33.0
Total	381	23.4	100.0



Discussion

- High number of Actigraph-GPS data matches
  - 60% of bouts and 66% of time with GPS data
- Potential bias
  - Missing bouts are shorter in duration
    - Indoor bouts?
    - Non-compliance wearing GPS units?
    - Bouts when battery ran out?
- Missing Actigraph data
  - Over 1hr per day with GPS data, w/out Actigraph data

Sample study: TAAG2

- 51 adolescent girls
  - Convenience sample
  - GPS unit set to record every 60 s
  - Actigraph model 7164 recording at 30 s epoch
  - Units time-synchronized
  - Diary filled out
- Participants carried units for 7 days

TAAG2 Pilot GPS + Accl

	Days with GPS data	Hours/day with GPS data
Minn (n=24, 7 days)		
Mean	5.9	3.5
SD	1.6	3.4
San Diego (n=22, 6 days)		
Mean	5.4	5.3
SD	0.9	4.9
Overall (n=46)		
Mean	5.7	4.3
SD	1.3	4.2

TAAG2 Pilot GPS + Accl

	Minn (n=24, 7 days)		San Diego (n=22, 6 days)		Overall
	Mean	SD	Mean	SD	Mean
# of MVPA bouts having any GPS information	0.5	1.2	1.5	2.0	1.0
% of MVPA bouts having any GPS information	50.0	-	94.1	-	75.4
# of MVPA bouts (more than 30% of GPS)	0.3	0.8	1.4	1.9	0.8
% of MVPA bouts (more than 30% of GPS)	33.3	-	85.3	-	63.2

Bringing in context

- Home and school neighborhoods
  - 1-mile circle from location
  - If GPS > 30% of bout → GPS
    - Otherwise use diary; if no diary, back to GPS

Bringing in context

- 24 MVPA bouts (Minn)
- 35 MVPA bouts (SD)

	Location specific					Travel		Other
	In school	In home	In home neighborhood	In school neighborhood	Elsewhere	To/from home, to /from school	From home nhood/elsewhere nhood to elsewhere/home nhood	Unable to identify locations
% of all bouts (SD)	5.7	8.6	14.3	17.1	2.9	31.4	17.1	2.9
% of all bouts (Minn)	16.7	8.3	0.0	12.5	20.8	4.2	29.2	8.3

Next Steps- Putting it all together

- Identify which exposures facilitate PA
- Identify which exposures interfere with healthy eating
- Future: Test by changing the environment

Limitations

- Lack of qualitative information about the type of PA
- Impossible to determine adherence to GPS protocol
  - Data no different when units are off than when they are on but unable to determine their position

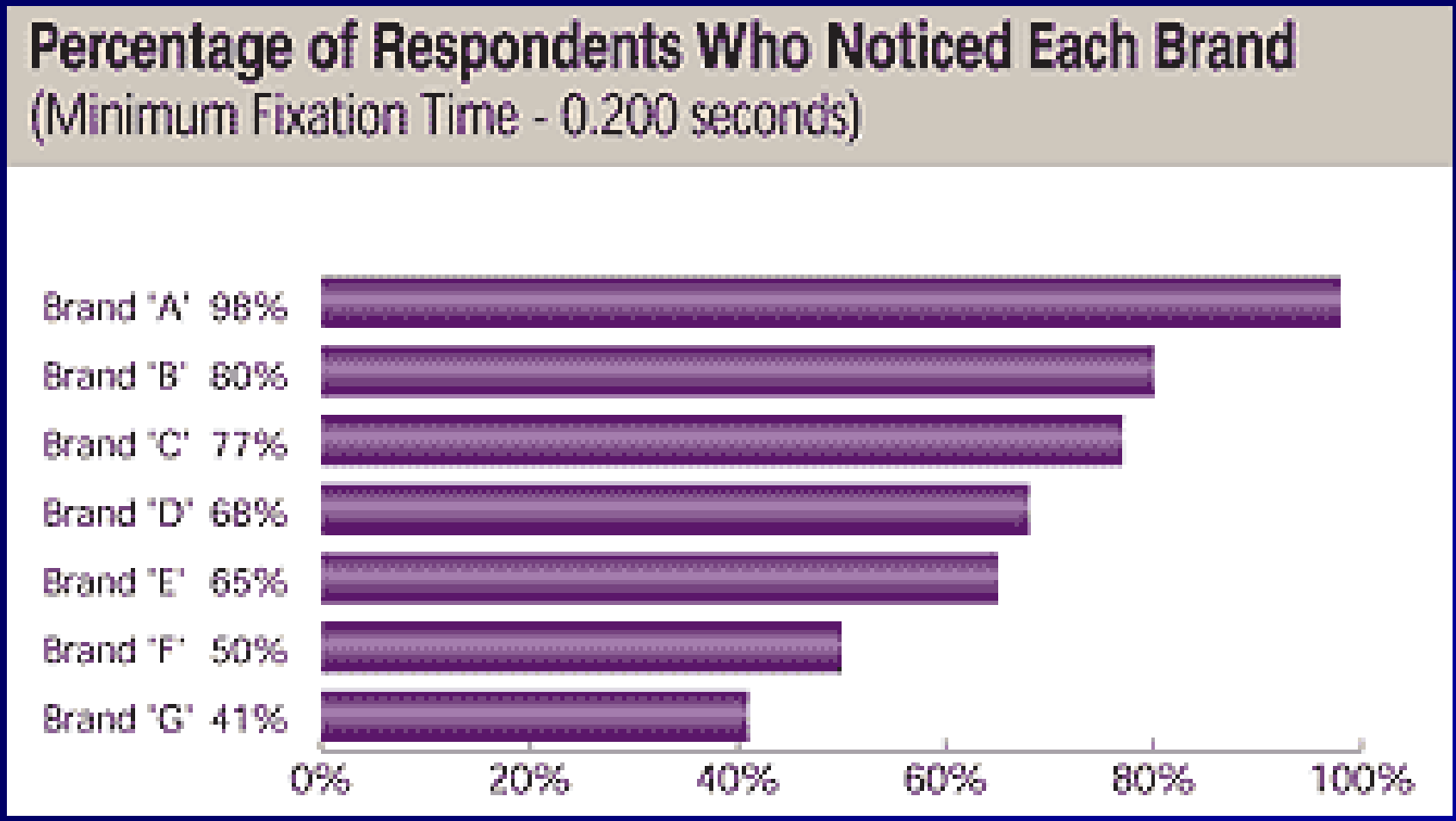
Limitations

- Even though we will be able to identify where people go and what is on their routes, we won’t know precisely what they see or how long they attend to any specific stimulus

Eye-Tracking Technology

- More attention given to a product, more likely to buy it
- What subjects look at, in what sequence, and for how long
- How many times eyes fixated on any given element


3
14 sec
4
20 sec
1
02 sec
5
22 sec
2
04 sec
7
20 sec
6
25 sec
9
17 sec
8
21 sec
10
4.5 sec



Unseen is unsold! Some brands are seen by less than 10% of respondents while nearly all respondents see other brands. We'll tell you which ones and why.

Comments

- Cautious optimism regarding use of GPS to contextualize physical activity
- GPS data provides
  - Advantage of spatial PA information
  - Ability to compare preferred and non-preferred environments for physical activity

Acknowledgements

- NIH R01HL71244
- Pilot funds from UNC-CH
- Sites and their staff
  - Gihyoug Cho, Sara Mortenson, Julie Pickrell