Who am I?

- B.S. in CSE from Penn
- Ph.D. from MIT (computer vision)
- "Home of the Future" and architects
- Health and House
- Northeastern (Sep 2011)
  - New Ph.D. Personal Health Informatics
  - Interests: measuring and motivating behavior change using technology, person-facing health and wellness systems, disruptive health

Who are you?

Your behavior...

Today, how many minutes have you spent sitting?

How confident are you?

Your behavior...

In the last week, how many sodas have you drank?

How confident are you?

Your behavior...

In the last week, how many minutes have you been in the car? On the T?
Your behavior...
In the last year, on average, how many cups of tomato sauce have you eaten each week?

Your behavior...
In the last week, list all the events that caused you stress.

Your behavior...
In the last year, roughly how many stairs have you climbed per week?

Your behavior...
In the last month, how often were you caught in a traffic jam?

Your behavior...
In the last month, how often were you potentially late because of the T?

Your behavior...
In the last ten years, how often have you won the lottery?
Your behavior...
How many times were you woken from sleep in the middle of the night each night in the last week?

Your behavior...
Approximately many calories did you consume yesterday?

Your behavior...
On a scale from 1 (very happy) to 7 (very unhappy), how happy were you yesterday?

Your behavior...
On a scale from 1 (very happy) to 7 (very unhappy), how happy are you right now?

Your behavior...
In the last 30 days, how many times have you taken a daily vitamin?

Your behavior...
On average on weekdays in the last month, for how many hours are you exposed to strong sun?
How about weekend days?
Your behavior...
Yesterday, approximately how many minutes did you spend communicating with friends or family via (1) email, (2) messaging, (3) phone, and (4) face-to-face?

Your behavior...
How many times did you sneeze in the last week?

Your behavior...
How many times did you sneeze in the last hour?

What's easy? What's hard?
• Recent vs. long ago?
• Mundane vs. extraordinary?
• Binary vs. fuzzy distinction?
• Constant vs. context-dependent?
• Marked temporal boundaries?
• Gut response vs. cognitive challenge?
• ?

What might we measure?  
(And why?)

WHO worldwide: caused death

<table>
<thead>
<tr>
<th>Disease</th>
<th>Deaths (millions)</th>
<th>% of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infectious heart disease</td>
<td>1.3</td>
<td>10.5%</td>
</tr>
<tr>
<td>Stroke and other cerebrovascular disease</td>
<td>6.3</td>
<td>18.0%</td>
</tr>
<tr>
<td>Lower respiratory disease</td>
<td>1.4</td>
<td>4.6%</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>3.2</td>
<td>5.0%</td>
</tr>
<tr>
<td>Diabetic diseases</td>
<td>2.4</td>
<td>4.5%</td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>1.7</td>
<td>3.1%</td>
</tr>
<tr>
<td>Tuberculosis, lung cancer</td>
<td>1.1</td>
<td>2.4%</td>
</tr>
<tr>
<td>Tuberculosis, lung cancer, other</td>
<td>1.3</td>
<td>2.4%</td>
</tr>
<tr>
<td>Diabetic nephropathy</td>
<td>1.2</td>
<td>2.2%</td>
</tr>
<tr>
<td>Road traffic accidents</td>
<td>1.2</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

New ideas?
**US preventable causes of death**

- New ideas?

Northeastern University

---

**Highly prevalent conditions**

- New ideas?

CDC

---

**Measuring behavior is complex**

- Each of the behaviors we cover could be the subject of one or more courses on their own

- Researchers within each field have strong opinions about the best instruments to use in their subspecialty

  (on other areas they are usually more open, but approach new tools cautiously)

Northeastern University

---

**Why a survey course?**

- Most behaviors are interrelated, but today often studied in a vacuum (e.g., dietary decision making)

- While understanding correlation is interesting, causality is really what we want to design solutions (e.g., screen time)

Northeastern University

---

**Why a survey course?**

- Sometimes measuring multiple behaviors together may simplify measuring particular behaviors of interest (e.g., location and PA, sitting and driving)

- Technologies, especially mobile and sensing, create new opportunities to transform quality of measurement

Northeastern University
Our goals are to be able to...

- Describe why behavior measurement is important for public health and public health research
- Explain why it is difficult to measure behavior

Our goals are to be able to...

- Compare and contrast how a variety of behaviors are measured today and the pros/cons of the most popular instruments used in research
- Critique papers describing new instruments

Our goals are to be able to...

- Describe how emerging technologies may change behavior measurement
- Describe some of the new systems/software available today that could be used to measure behavior

Our goals are to be able to...

- Use low-fidelity prototyping to construct ideas for new instruments that may use emerging technologies
- Evaluate a prototype implementation of a new instrument created by us and analyze the results of small-scale feasibility testing

Think creatively w/ open mind!

- Google Flu Trends  
  - http://www.google.org/flutrends/about/how.html
- "Intelligent toilet"  http://bit.ly/o74oMi

Looking for new “biomarkers”

- Better measurement can transform medicine and advance scientific discovery
- In some cases, benefits of measurement might not be fully apparent
Keep an open mind

• British Medical Journal on a new measurement technology when first introduced:
  - By using it, “we pauperize our senses and weaken clinical acuity”

Blood pressure

Hale determining blood pressure of a horse (1733)

Blood pressure

Ludwig's kymograph (1847)

Blood pressure

Vierordt's sphygmograph (1854)

Blood pressure

Von Bash's sphygmograph (1881)

Blood pressure

Riva Roccì method (1896)

- Benefits: ease of application, fast, precise, harmless to patient
- Method on which present-day method is based
Blood pressure

- Two measurement techniques combine to form a better one

Korotkoff method (1905) 207 word long paper!

Cascading effect

Popularity of BP monitoring led to change in stethoscope

Modern example: measuring physical activity

(In the field!)

What's the point?

Why is it important to measure physical activity?

Obesity Trends among U.S. Adults


(*BMI ≥ 30, or about 30 lbs. overweight for 5'4" person)

Obesity & overweight...

- Coronary heart disease
- Hypertension
- Type 2 diabetes
- Stroke
- Dyslipidemia
- Gallbladder disease
- Osteoarthritis
- Sleep apnea

Source: NHLBI, NIH Publication No. 98-4683, 1998
Advances in Measuring Behavior Fall 2011

Obesity & overweight...

- Respiratory problems
- Several cancers (e.g., breast, colon, endometrial)
- Depression
- Urinary incontinence
- Social isolation
- Gastroesophageal reflux
- Pregnancy risks
- Joint and back problems

Northeastern University

Surveys

What might we measure?

- Activity intensity/energy expenditure
- Activity type
- Muscle strength
- Relative fitness
- Recovery time
- Environmental context (e.g., proximity to parks)

Northeastern University

What should be considered

- Validity
- Reliability
- Discriminatory power (measure change over time)
- For binary test (activity type)
  - Sensitivity: proportion of positives identified
  - Specificity: proportion of negatives identified
- Usability
- Practicality (e.g., complexity, time)
- Cost
- ?

Northeastern University

Physical activity assessment

- Definitions
  - Exercise
  - Physical activity
  - Sedentary behavior (lack of physical activity /= sedentary behavior)
  - Moderate intensity (MOD)
  - Vigorous intensity
  - Moderate or vigorous activity (MOD+)
  - Fitness (age dependent)
  - Resting heart rate
  - Maximal heart rate
  - Energy expenditure

Northeastern University

Option: direct observation

- Researchers(s) (painstakingly) observe people in lab or field settings and code activity

Northeastern University
Option: direct observation

- **Pros:**
  - Detailed
  - Contextual information recording

- **Cons:**
  - Tedious
  - Expensive
  - Requires specialized training
  - Requires custom coding
  - Invasive

Example: SOFIT
- Schools
- 18 page manual
- Paper based

Variation
- Observers use phones/tablets with software optimized for the data entry task

Option: “simple” recall survey

- Participant fills out survey about physical activity behavior

- **Pros:**
  - Inexpensive
  - Widely used (although many variants)

- **Cons:**
  - Serious concerns about validity for long periods of time
  - How to ask about time/intensity in a way people understand?
  - Do the surveys show subtle changes?

Examples:
- PAR-Q
- Champs
- Paffenbarger
- CARDIA sedentary
- Stanford Brief Activity Survey
What’d you think?

• What type of information was easy to enter?
• What felt most difficult?
• What timeframe felt most manageable?

Option: assisted recall survey

• Trained researcher guides subject through a series of questions, probing where necessary

Pros:
- Detailed, few gaps
- Timing of mundane behavior is very difficult to recall
- Intensity is difficult to estimate

Cons:
- Expensive
- Time consuming
- Requires specialized training
- Requires custom coding

Example:
- Global Physical Activity Survey (GPAQ)

Option: physical activity diary

Subject incrementally records their physical activity in a diary at various times throughout the day for some number of days

Pros:
- May be detailed with few gaps

Cons:
- Studies suggest that diaries are problematic (backdating/predating)
- In practice diaries will be missing large amounts of time
- Burdensome, especially when activity quickly changing
Option: EMA & electronic diaries

- Electronic ecological momentary assessment (EMA)
- Mobile device (PDA/phone) prompts for information about a window of time

Pros:
- May be detailed with few gaps
- Fast for subject; no data coding required
- Automatic timestamping (prevents backdating)
- Automatic branching / skip series

Cons:
- Interruption burden
- Cost of technology

Example:
- PA survey from CITY
- PA “survey” from StepLively

Option: “Objective” measures: HR

- Measure heart rate using an ambulatory monitor; chunk activity by time/intensity level

Pros:
- HR maps well onto energy expenditure most of the time

Cons:
- All current options are uncomfortable to wear for extended periods of time (i.e. multiple days); require skin contact with moistener
- Psychological influence on HR
- Noisy in field settings
- HR requires calibration to the individual’s fitness level
- Provides only intensity information
Option: “Objective” measures: HR

- Example: Polar chest band, Zephyr band
- Future: embedding in clothing:

Option: “Obj.” measures: motion

- Measure limb/body motion using accelerometers (which sense change in velocity) and summarize into “activity counts”

Option: “Obj.” measures: motion

- Pros:
  - Increasingly a “gold standard” of measurement
  - Experts tend to trust more than recall surveys
- Cons
  - Discrepancies in how proprietary devices compute “counts”
  - Miss or over-count some activities
  - Costly relative to paper
  - Subject error complicates statistical analysis

Option: “Obj.” measures: motion

- Example: Actigraph monitor

MyWalk (Video)

(Conducting pilot study looking at engagement in response to positive/negative messages)
Option: “Obj.” measures: type

- Measure activity type & intensity using advance sensors and signal processing

Pros:
- Detail about activity type (required for intervention?)
- Knowledge of type may improve intensity (EE) estimate

Cons:
- Actively subject of research ... Need more validation
- Multiple sensors lead to best performance
- Cost
- Wearability

Population-scale PA detection

24/7 Real-time PA detection and context-sensitive self report with sensors (GPS, phone)

Data sent to server for analysis & remote administration

Years

Real-time activity type

New survey, interventions, remotely loaded & administered; remote software updates w/ new capabilities

Idea to make flexible & personally valuable & engaging

Real-time feedback to encourage compliance

Participant has flexibility in how to wear/use sensors

Real-time activity type

Wocket “kit” (+ phone)

Charge 2

Wear 2 for 24h

Upper + lower body motion
Advances in Measuring Behavior Fall 2011
Northeastern University

Thin for continuous wearability
Actigraph  Wocket

Usability critical
WRIST AND ANKLE BAND DESIGN
POCKET BAG DESIGN

Production & sizing
WRIST AND ANKLE BAND DESIGN

POCKET BAG DESIGN

Thin for continuous wearability

Usability critical

Continuous data collection
- 2 sensors wearing, 2 charging
- Summary data sent hourly to server
- Plug phone nightly (uploads raw data)
- Wockets last 42+ hours, phone waking day
- Phone detects data quality & missingness in real time and provides feedback to encourage study compliance

Robustness
Note: Activities manually labeled ...
Working on real-time detection of some activity types and context (podium, ambulation, structure exercise, etc.)
How will the course work?

- Tour of behavior measurement
- Focus on understanding how behavior is measured today and how it might be measured in the future
- Get some experiencing deploying a survey on mobile technology
Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Reading/Assignment</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 10:</td>
<td>Introduction to Measuring Behavior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct 18:</td>
<td>Measuring body composition and fatality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct 25:</td>
<td>Measuring heart rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov 1:</td>
<td>Measuring glucose level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov 8:</td>
<td>Measuring stress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov 15:</td>
<td>Measuring smoking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov 22:</td>
<td>Measuring oral health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov 29:</td>
<td>Review and discussion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Structure

- Readings balanced between existing methods (recommended by experts) and emerging or future methods (identified by us)
- Syllabus (evolving with your input) online:
  - Slides posted 1 day after class

Writing assignments

- Compare and contrast 1
- Compare and contrast 2
- Critique of a measurement technology
- Paper on measuring a behavior of interest using self-report on the phone (with thorough literature review and review of emerging technology for that particular behavior)

Project

- Use an open source tool (Open Data Kit) to collect data using mobile phones
- We’ll learn about it together and test with each other
- Project can be made more complex if you like and have a technical background

Presentations

- Everyone presents several times
  - Review most interesting points of reading
  - Pecha kucha format (20 slides, 20s each)
    - Requires practice
    - Requires distilling out important points
  - For articles that use obtainable surveys/systems, do a show and tell
  - Lead discussion on paper, emphasizing connections with other readings

Behavior areas listed on board

- Calories (used/expended)
- Nutritional intake
- Intense (and non-intense) physical activity
- Glucose level
- Stress
- Water quality
- Smoking
- Hygiene
Behavior areas listed on board

- Pain
- Exposure to different temperatures
- Drinking
- TV
- Guns
- Abnormal everyday activity
- Speeding
- Sexual behavior

Behavior areas listed on board

- Contact with other people
- Exposure to pollution
- Respiration
- Exposure to particles
- Exposure to sun
- BP
- HR

Behavior areas listed on board

- Socialization – Doing things, talking with people
- Medication adherence
- Sleep (time, cycles)
- Traffic
- Vaccinations
- Texting while driving
- Seatbelt wearing

Behavior areas listed on board

- Skin conductance
- Cholesterol
- Medication adherence
- Beverage consumption
- Drug use
- Gun use/exposure