Advances in Measuring Behavior

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Who am I?

- BSE in CSE from Penn
- Ph.D. from MIT (computer vision)
- "Home of the Future" and architects
- Health and House_n
- 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 for 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?

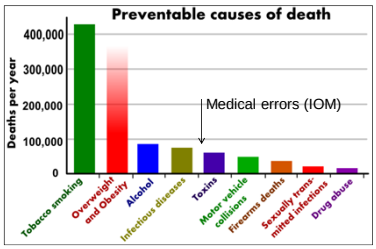
(And why?)

WHO worldwide: caused death

World	Deaths in millions	% of deaths
Ischaemic heart disease	7.25	12.8%
Stroke and other cerebrovascular disease	6.15	10.8%
Lower respiratory infections	3.46	6.1%
Chronic obstructive pulmonary disease	3.28	5.8%
Diarrhoeal diseases	2.46	4.3%
HIV/AIDS	1.78	3.1%
Trachea, bronchus, lung cancers	1.39	2.4%
Tuberculosis	1.34	2.4%
Diabetes mellitus	1.26	2.2%
Road traffic accidents	1.21	2.1%

- New ideas?

US preventable causes of death



Mokdad et al. (March 2004). "Actual causes of death in the United States, 2000". *JAMA* **291** (10): 1238–45

- New ideas?

Highly prevalent conditions

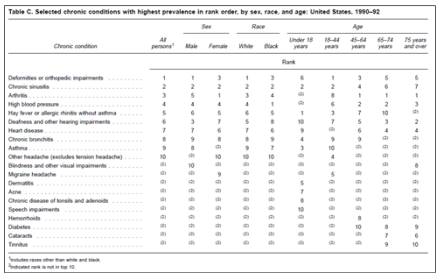


Table C. Selected chronic conditions with highest prevalence in rank order, by sex, race, and age: United States, 1990–92

Chronic condition	All persons[1]	Sex: Male	Sex: Female	Race: White	Race: Black	Age: Under 18 years	Age: 18–44 years	Age: 45–64 years	Age: 65–74 years	Age: 75 years and over
	Rank									
Deformities or orthopedic impairments	1	1	3	1	3	6	1	3	5	5
Chronic sinusitis	2	2	2	2	2	2	2	4	6	7
Arthritis	3	5	1	3	4	(2)	8	1	1	1
High blood pressure	4	4	4	4	1	(2)	6	2	2	3
Hay fever or allergic rhinitis without asthma	5	6	5	6	5	1	3	7	10	(2)
Deafness and other hearing impairments	6	3	7	5	8	10	7	5	3	2
Heart disease	7	7	6	7	6	9	(2)	6	4	4
Chronic bronchitis	8	9	8	8	9	4	9	9	(2)	(2)
Asthma	9	8	(2)	9	7	3	10	(2)	(2)	(2)
Other headache (excludes tension headache)	10	(2)	10	10	10	(2)	4	(2)	(2)	(2)
Blindness and other visual impairments	(2)	10	(2)	(2)	(2)	(2)	(2)	(2)	(2)	8
Migraine headache	(2)	(2)	9	(2)	(2)	(2)	5	(2)	(2)	(2)
Dermatitis	(2)	(2)	(2)	(2)	(2)	5	(2)	(2)	(2)	(2)
Acne	(2)	(2)	(2)	(2)	(2)	7	(2)	(2)	(2)	(2)
Chronic disease of tonsils and adenoids	(2)	(2)	(2)	(2)	(2)	8	(2)	(2)	(2)	(2)
Speech impairments	(2)	(2)	(2)	(2)	(2)	10	(2)	(2)	(2)	(2)
Hemorrhoids	(2)	(2)	(2)	(2)	(2)	(2)	(2)	8	(2)	(2)
Diabetes	(2)	(2)	(2)	(2)	(2)	(2)	(2)	10	8	9
Cataracts	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	7	6
Tinnitus	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	9	10

[1]Includes races other than white and black.
[2]Indicated rank is not in top 10.

CDC

- New ideas?

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)

Why a survey course?

Top secret image of typical NIH grant review meeting on research related to health behavior …

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)

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

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

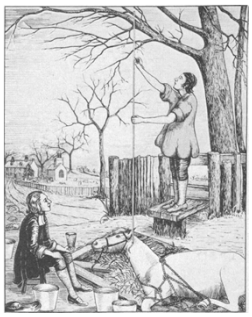
Looking for new "biomarkers"

- 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

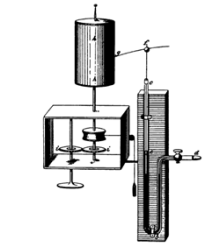
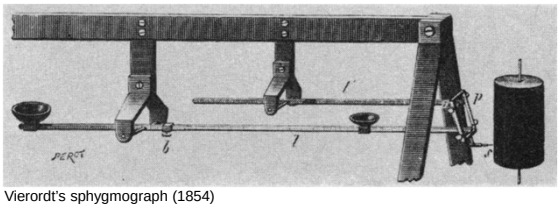


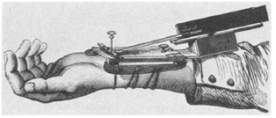
Fig 3 *Ludwig's kymograph, invented 1847. The bent glass tube, abc, contains mercury and connects by d with the artery. The slender upright rod, ef, swims on the surface of the mercury and bears at its free end, f, a brush, g, which registers the movements of the mercury on the revolving cylinder, hh. (Reproduced from Brunton 1908 by courtesy of the Wellcome Trustees)*

Ludwig's kymograph (1847)

Blood pressure

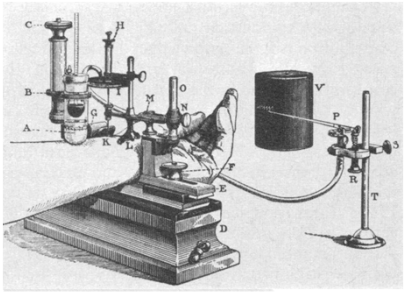


Vierordt's sphygmograph (1854)



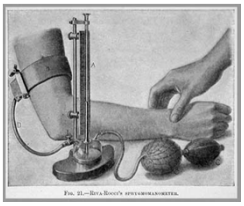
Marey's sphygmograph (1881)

Blood pressure



Von Bash's sphygmograph (1881)

Blood pressure



Riva Rocci 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

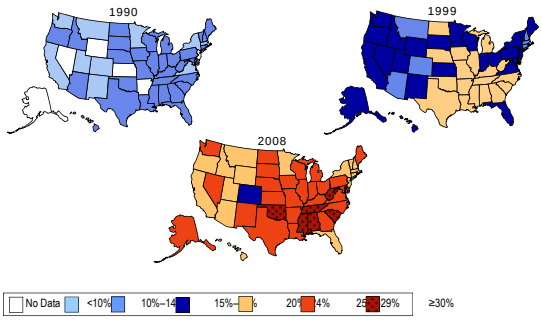
(In the field!)

What's the point?

Why is it important to measure physical activity?

Obesity Trends* Among U.S. Adults
BRFSS, 1990, 1999, 2008

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



Obesity & overweight...

Source: NHLBI, NIH Publication No. 98-4083, 1998

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

Obesity & overweight...

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

Surveys

What might we measure?

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

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
- ?

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

Option: direct observation

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

Option: direct observation

- Pros:
  - Detailed
  - Contextual information recording
- Cons:
  - Tedious
  - Expensive
  - Requires specialized training
  - Requires custom coding
  - Invasive

Option: direct observation

- 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

Option: “simple” recall survey

- 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?

Option: “simple” recall survey

- 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?

Option: “simple” recall survey

- 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

Option: assisted recall survey

- 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

Option: assisted recall survey

- 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

Option: physical activity diary

- 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

Option: EMA & electronic diaries

- 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

Option: EMA & electronic diaries

- Example:
  - PA survey from CITY
  - PA "survey" from StepLively

Option: "Objective" measures

- Measure either heart rate or movement of the body using miniature electronic monitors

Option:"Objective" measures:HR

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

Option:"Objective" measures:HR

- 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"

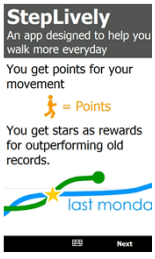
Option: "Obj." measures: motion

- 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

Option: "Obj." measures: motion



Option: "Obj." measures: motion

MyWalk (Video)

(Conducting pilot study looking at engagement in response to positive/negative messages)

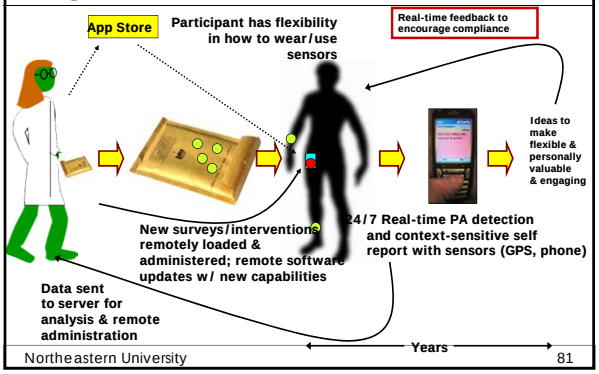
Option: "Obj." measures: type

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

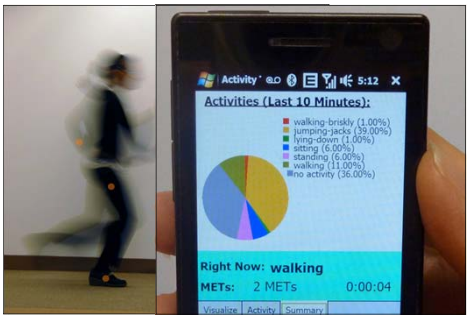
Option: "Obj." measures: type

- 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

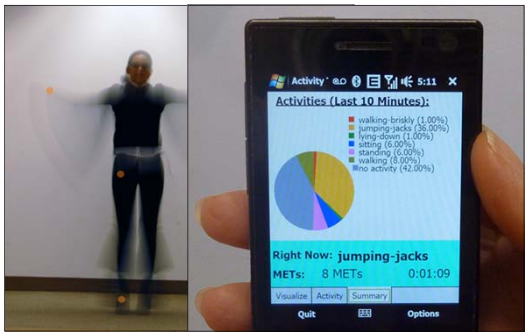
Population-scale PA detection



Real-time activity type

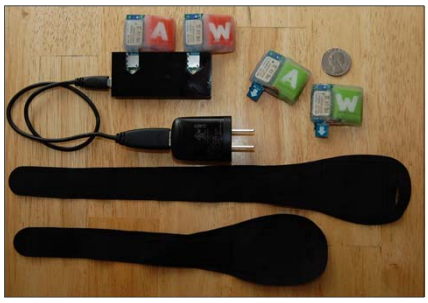


Real-time activity type



Wocket "kit" (+ phone)

Charge 2



Wear 2 for 24h

Upper + lower body motion

Thin for continuous wearability

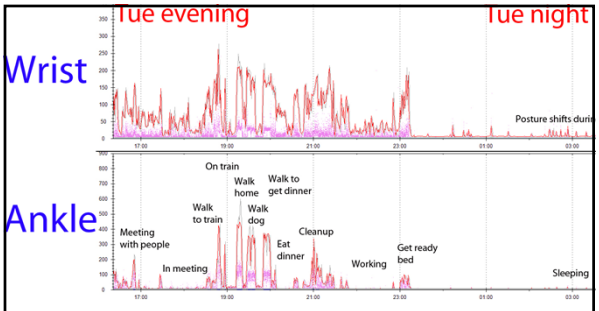
Usability critical

WRIST AND ANKLE BAND DESIGN

POCKET BAD DESIGN

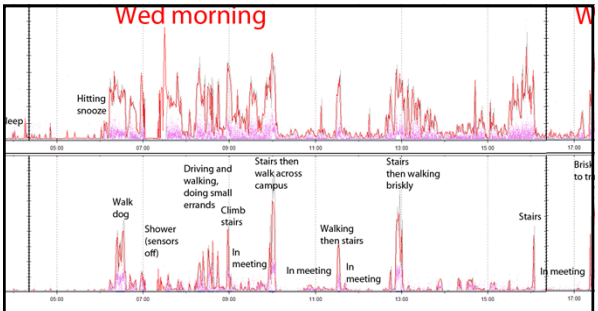
Continuous data collection

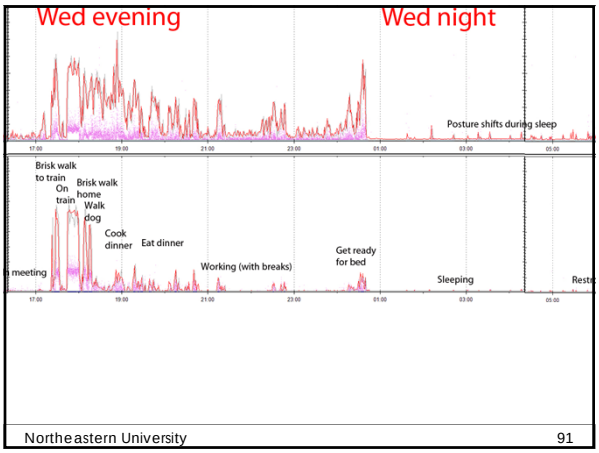
- 2 sensors wearing, 2 charging
- Summary data sent hourly to server
- Plug phone nightly (uploads raw data)
- Wockets last 42+ hours, phone waking day
- Phone detects data quality & missingness in real time and provides feedback to encourage study compliance

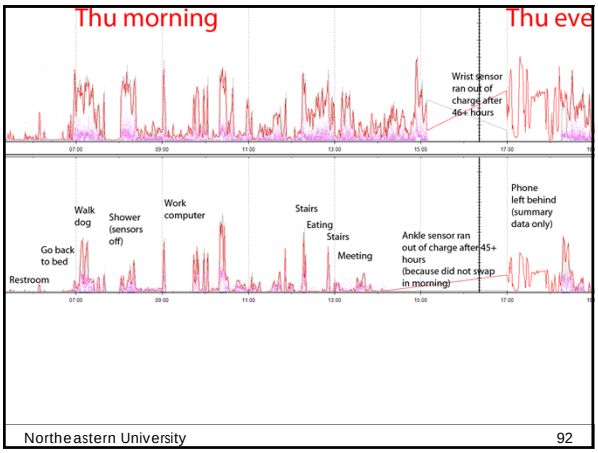


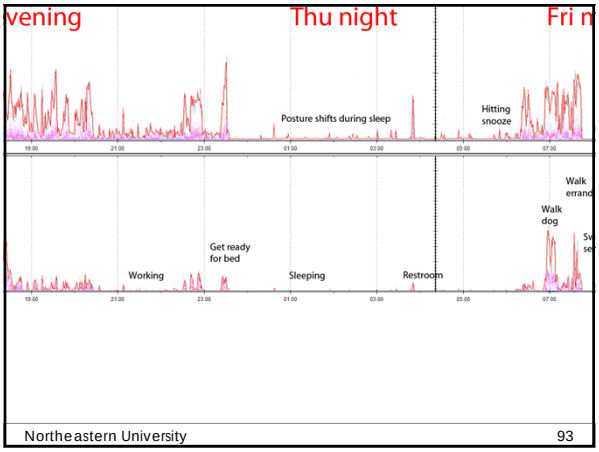
Note: Activities manually labeled ...

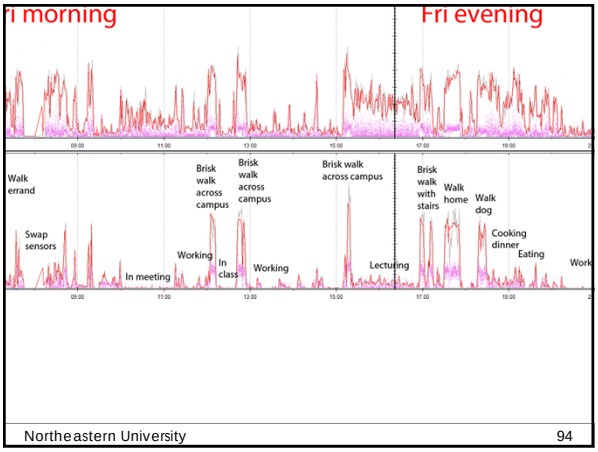
Working on real-time detection of some activity types and context (posture, ambulation, structure exercise, etc.)

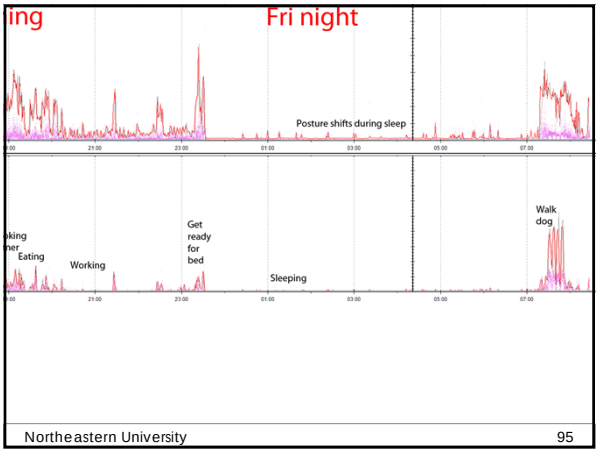












How will the course work?

- 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

Class	Subjects	Readings Due (Beginning of class)	Assignments Due (Beginning of class)
Mon 9/12/11	Introduction to the course, Why measure behavior?	None	
	Designing surveys/instruments and issues to consider		
Mon 9/19/11	Emerging technologies (Electronic EMA, sensors, CS-EMA, CAT)	TBD	Responses to survey email
	Introduction to item response theory	TBD	Compare/contrast assignment #1 due
Mon 9/26/11	Introduction to paper prototyping	TBD	
	Experience sampling on phones: nuts and bolts for projects	TBD	
Mon 10/3/11	In-class paper prototyping practice	TBD	Compare/contrast assignment #2 due
	Measuring everyday behaviors (activities of daily living (ADLs), sleep/wake patterns, etc.)	TBD	
Mon 10/10/11	Columbus Day - No class		
Mon 10/17/11	Measuring diet	TBD	Project idea due
	Measuring eating behaviors and decision making	TBD	
Mon 10/24/11	Measuring physical activity/exercise	TBD	
	Measuring sedentary behavior/posture	TBD	
Mon 10/31/11	Measuring screen time (TV, computer, video games)	TBD	Paper critiquing a measurement technology due
	Measuring activity in the community (i.e. use transportation, context)	TBD	
Mon 11/7/11	War stories from field deployments	TBD	
	Measuring risky behaviors (i.e., driving, home safety)	TBD	
Mon 11/14/11	Measuring social-connectedness/social-interaction/isolation	TBD	Literature review section of final paper due
	Measuring stress, stressful events, and stress management	TBD	
Mon 11/21/11	Measuring affective state	TBD	
	Measuring medication adherence	TBD	
Mon 11/28/11	Measuring use of alcohol and addictive substances	TBD	
	Measuring physiological state (HR, blood pressure, GSR, sleep states)	TBD	
Mon 12/5/11	Project presentations	None	Final presentation and paper due
	(Note: depending on the number of people in the course, it may be necessary to slightly extend the length of the final class).		

Structure

- Readings balanced between existing methods (recommended by experts) and emerging or future methods (identified by us)
- Syllabus (evolving with your input) online:
  - http://bit.ly/nu-behavior
  - 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