

Advances in Measuring Behavior

PHTH 5228
2nd Class

Prof. Stephen Intille
Office: 450 WVH
s.intille@neu.edu

Advances in Measuring Behavior

Fall 2011

Booth article

- Cascade of measurement
- Graphic method of recording data
- Clever thinking about what to measure
 - “Counter pressure which would be necessary to cause the pulsation in an artery to cease”
- Complexity important – simplicity of instrument paramount
- Surgeons – notice things researchers miss
- Value in establishing a normal range

Northeastern University

2

Advances in Measuring Behavior

Fall 2011

Booth article

- As tool gets good enough, start seeing patterns
- Compressed on all sides and width: “small change” leads to big performance gain
- Small observations

Northeastern University

3

Advances in Measuring Behavior

Fall 2011

Stone article

- Reported compliance: 90%
- Actual compliance 11% (20% 90 min)
- Hoarding: 32% of days no openings but reported compliance 92%
- 75% of 40 people had 1+ day of hoarding (“parking lot compliance”)

Northeastern University

4

Advances in Measuring Behavior

Fall 2011

Smyth article

- Behavioral medicine: integrative and wide array of outcome types and models
- Time! Need to understand interactions over time
- Experience sampling vs EMA

Northeastern University

5

Advances in Measuring Behavior

Fall 2011

Smyth article

- Recall of past events
 - Beliefs about behavior or the way the world functions (“effort after meaning”)
 - Outcome of the event (retroactive reconstruction)
 - Current state, particularly mood (congruent mood state)
 - Salient events

Northeastern University

6

Advances in Measuring Behavior	Fall 2011
Smyth article	
<ul style="list-style-type: none"> • External validity/generalizability of findings <ul style="list-style-type: none"> – Lab vs. real world – “White-coat hypertension” – Missing social environment – Surprisingly weak correspondence (e.g. HRV) • Dynamic processes <ul style="list-style-type: none"> – Repeated measures – Suggestive of causal associations 	
Northeastern University	7

Advances in Measuring Behavior	Fall 2011
Smyth article	
<ul style="list-style-type: none"> • External validity/generalizability of findings <ul style="list-style-type: none"> – Lab vs. real world – “White-coat hypertension” – Missing social environment – Surprisingly weak correspondence (e.g. HRV) 	
Northeastern University	8

Advances in Measuring Behavior	Fall 2011
Smyth article	
<ul style="list-style-type: none"> • Dynamic processes <ul style="list-style-type: none"> – Think about your own life! (mood/stress) – Variations in time of day (e.g., diurnal patterns of mood; “obscured at best, and contribute to error or bias at worst”) – Repeated measures – Suggestive of causal associations 	
Northeastern University	9

Advances in Measuring Behavior	Fall 2011
Smyth article	
<ul style="list-style-type: none"> • EMA <ul style="list-style-type: none"> – Multiple times per day – Weeks or months – Reduce period of recall – In the moment (reduce summary) – Natural environment – Natural events – Date/time stamped (+ timing info) – Prompt or “event driven” actions 	
Northeastern University	10

Advances in Measuring Behavior	Fall 2011
Smyth article	
<ul style="list-style-type: none"> • “Recall the most stressful event of the last month” • Coping: much of what was reported in real time was forgotten at recall and that coping efforts that were not reported in real time were reported at recall 	
Northeastern University	11

Advances in Measuring Behavior	Fall 2011
Smyth article	
<ul style="list-style-type: none"> • EMA challenges <ul style="list-style-type: none"> – Questionnaire design – Training of participants – Extra device – Field monitoring – Motivation to follow protocol (e.g., stylus) – Tech glitches – Expensive – Reactivity 	
Northeastern University	12

Advances in Measuring Behavior Fall 2011

Smyth article

- EMA challenges (continued)
 - “Massive” amounts of data
 - Stats challenges
 - Aggregation
 - Multi-level
 - Missing data (unbalanced)

Northeastern University 13

Technological innovations

Circa 2003

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Take away: 4 new opportunities

- Continuous, rich recording from a variety of sensors
- Algorithms to process data to reduce coding time
- *Context-sensitive* data collection to collect data and prompt for self-report at desired times and places
- *Context-sensitive*, personalized interventions

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Your task...

What are the possibilities for *your* research?

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Relevance to health research (1)

- Ability to better study how context (people, places, things) impacts behavior
- Examples
 - Measurement of moderate intensity or greater physical activity
 - Dietary decision making
 - Making every interruption count

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Relevance to health research (2)

- Ability to create and measure impact of “just-in-time” interventions
- Example: physical activity
 - Measurement is important, but we already know people don’t get enough physical activity!
 - Just-in-time detection of activity for positive reinforcement

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Overview

- New developments
- Examples
 - Context-sensitive experience sampling
 - Portable kit of “tape on” environmental sensors
 - PlaceLab
- Emerging opportunities
- Challenges

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

New developments

- New developments
- Examples
- Emerging opportunities
- Challenges

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Data collection in the (not-so-distant) future

- Record and save everything from subjects:
 - 24/7 video stream (160x120 resolution, 10fps, MPEG-4) [1.56 GB/day]
 - 24/7 audio stream (24kHz mp3) [.57 GB/day]
 - 24/7 1 photo per minute or other data [.57 GB/day]
 - 16/7 One 3MB data file per hour [72MB/day]
- A year of data: **990MB**
- 2007: Terabyte of data <\$300

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Sensors in the (not-so-distant) future

- Example:
 - Video/photos from miniature pocket/cap camera
 - Continuous audio recording, keyword detection
 - Real-time HR data
 - Real-time motion data all limbs, hip
 - Real-time indoor/outdoor position
 - Real-time position relative to other people
 - Real-time data from home: objects touched/used
 - Data on use of communication devices
 - No encumbering or nerdy-looking devices
 - Context-sensitive self report

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Data analysis in the (not-so-distant) future

- Computers pre-process data:
 - Translate noisy sensor data into meaningful labels
E.G. Cooking, socializing, running, smoking, ...
- Computer helps researcher search data:
 - “find all the moments when the subject might have been cooking”
 - “query the subject whenever the subject is near another subject”
 - “show me video clips of moments when the subject was with other people”
 - “indicate where the subject spent the most time”

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Personalized mobile computing device



Take your pick...

Powerful, inexpensive, sensor-enabled mobile computing device *carried nearly everywhere*

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

The mobile computing device...

- ❑ Color touch screen
- ❑ Light, comfortable to carry everywhere
- ❑ 1GB+ disk space
- ❑ Sound player (MP3 and other)
- ❑ Sound recorder
- ❑ Camera
- ❑ Fingerprint recognizer
- ❑ 400+ MHz processor
- ❑ Always on wireless connection
- ❑ **Battery life**
- ❑ **Cost (not for long)**
- ❑ Barcode scanner
- ❑ Handwritten input
- ❑ Speech input
- ❑ Video game player
- ❑ GPS / location detection
- ❑ Accelerometers
- ❑ Biomonitors

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

New developments in pattern recognition

- ❑ Innovation:
 - Real-time recognition of activities (e.g. walking, running, posture, cooking ...)
 - Recognition of affect (e.g. frustration, stress, anger)
 - Speech recognition
 - Recognition of socialization activity
- ❑ Remaining challenges:
 - Real-time recognition of many activities
 - Unencumbering recognition of many emotional states

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Technologist's interest

- ❑ Want to design technology for real-world environments and to test technology in context, but...
- ❑ Vast majority of homes and workplaces do not look anything like our labs and prototype environments!



Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Motivation for sensing/measurement tools

- ❑ Behavior is "situated", i.e. influenced by environment
- ❑ Simulating natural setting in lab difficult (impossible?)
- ❑ Real environments are terribly complex
- ❑ Need sensors to measure *reaction to interventions* in context of everyday life


Examples

- New developments
- **Examples**
- Emerging opportunities
- Challenges

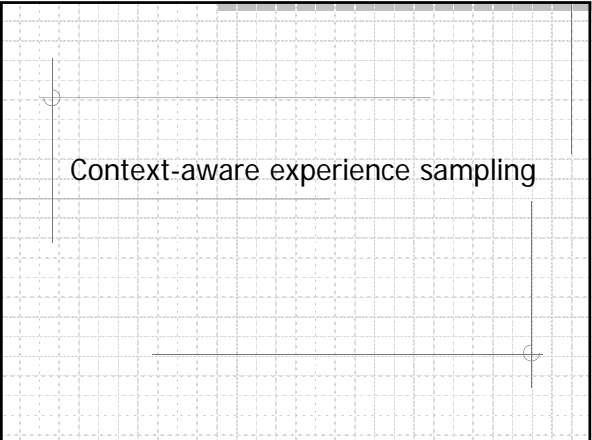
Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

House_n: tools to study natural settings

Portable data collection and intervention toolkit PlaceLab residential research facility




Context-aware experience sampling




Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Electronic experience sampling




Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

MIT version: new data collection capabilities



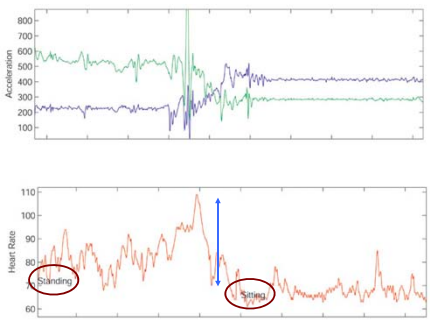
Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

E.g.: trigger sample based on position



Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

E.g.: trigger sample based on HR



Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Context-aware experience sampling

- Scheduling options
 - Fixed
 - Random within intervals
 - User-initiated
 - *Triggered by context*
- PDA plug-in sensors and sampling devices
 - GPS
 - Heart rate
 - Bar code scanner
 - Camera
 - Accelerometers
- Future: Bluetooth

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Context-aware experience sampling tool

- Uses at MIT:
 - Machine learning algorithm development
 - Physical activity interventions
 - Studying interruptions (using biometric data)
 - Planned: workplace studies
- Available to researchers
<http://caes.sourceforge.net>

What were you doing at the beep?

Preparing lunch

Watching TV

Getting ready for work

Sleeping

Answers 1-4 of 12

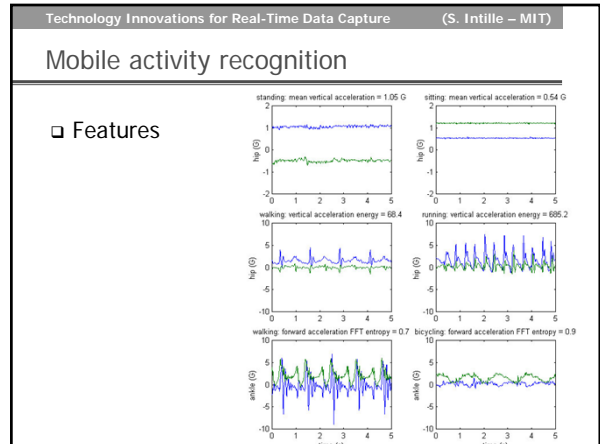
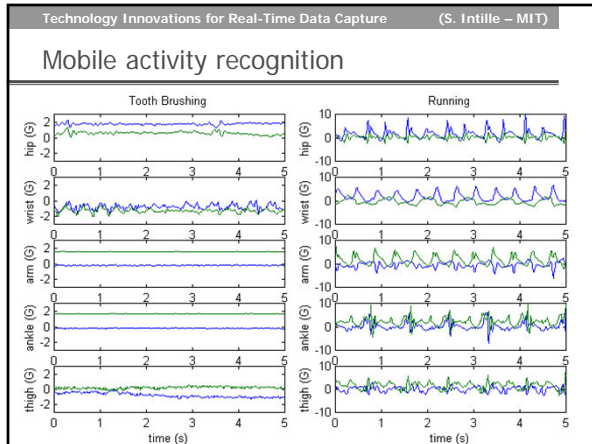
Mobile activity recognition

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Multiple, wire-free accelerometers

- Placement
5 points
- Collect data up to 24 hours
- 2 axis, 85Hz sampling
- No wires
- Next version (Fall):
watch size, comfortable,
real-time wireless



Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Mobile activity recognition

- Aggregate confusion matrix for fast C4.5 classifier based on leave-one-subject out validation for 20 subjects using laboratory and obstacle course data.

Legend for confusion matrix:

- classified as
- a = walking while carrying the
- b = walking and relaxing
- c = sitting and relaxing
- d = working on computer
- e = standing still
- f = eating or drinking
- g = watching TV
- h = reading
- i = running
- j = stop typing
- k = stretching
- l = strength training
- m = reading
- n = vacuuming
- o = rotating laundry
- p = lying down and relaxing
- q = brushing teeth
- r = climbing stairs
- s = riding elevator
- t = riding escalator

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Current work

- Development of comfortable, 24 hour wireless, 2-3 axis mobile accelerometers
 - Smaller than CSA actigraph
 - Real-time data streaming
 - High sampling rate
- Real-time mobile activity recognition for context-sensitive data collection

Tape-on environmental sensors

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Environmental sensor kit

- Data collection board with swappable sensor
- Small, robust
- Relatively inexpensive (\$27 each at qty of 150)
- Collect state change data 4+ weeks
- +/- 2 second timestamp synchronization
- Tape-on install
- Non stigmatizing
- Relatively non-invasive

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Environmental sensor kit


Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

One subject's home

- 3 hours with small team
- Install: tape-on
- Approx. 85-100 sensors in small 1 bedroom
- On | Off
- Open | Closed
- Position | Identity

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

Studying behavior in context



Technology Innovations for Real-Time Data Capture (S. Intille – MIT)




Technology Innovations for Real-Time Data Capture (S. Intille – MIT)




Technology Innovations for Real-Time Data Capture (S. Intille – MIT)

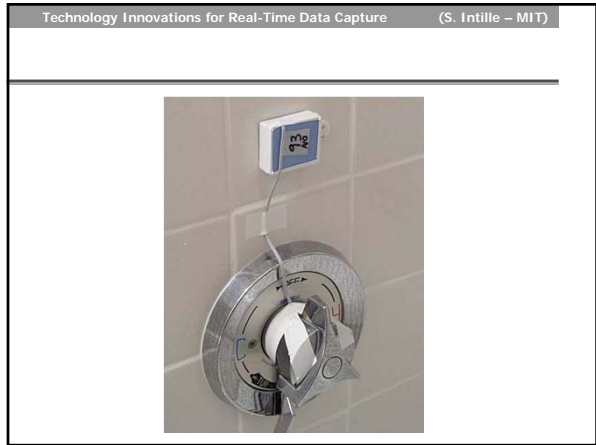
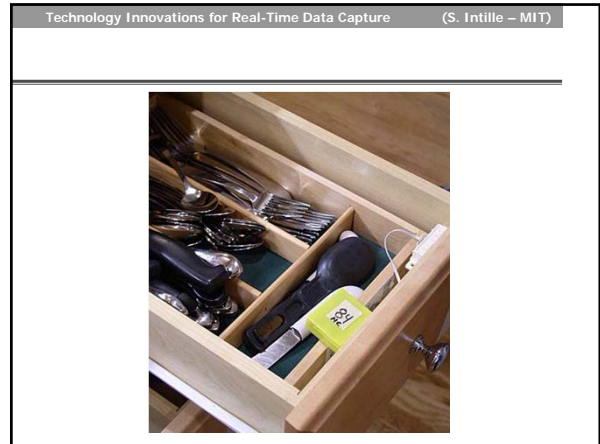


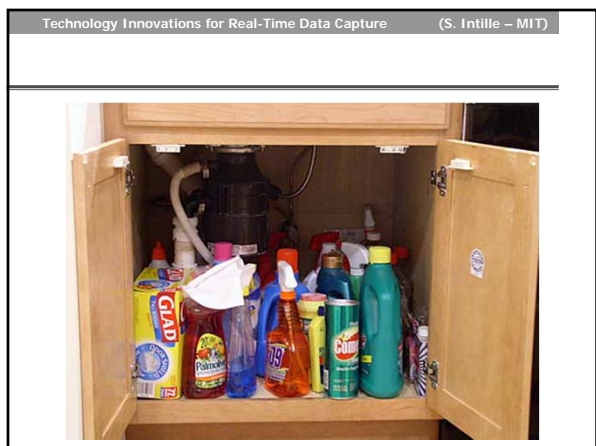
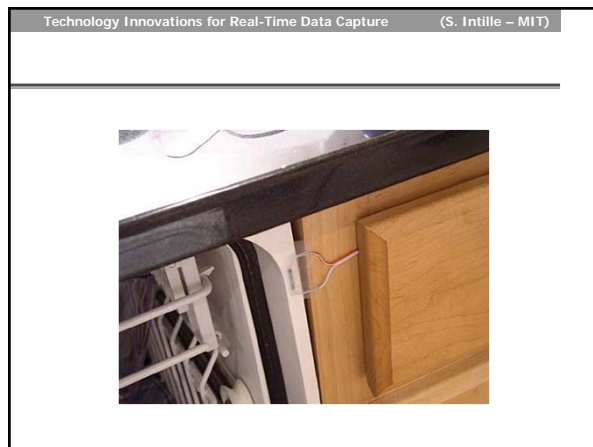
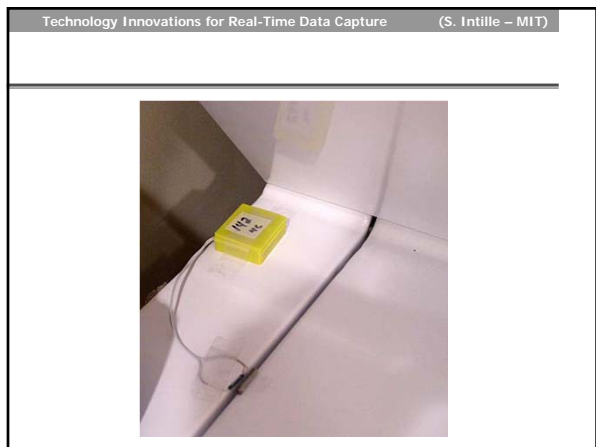
Technology Innovations for Real-Time Data Capture (S. Intille – MIT)



Technology Innovations for Real-Time Data Capture (S. Intille – MIT)







Technology Innovations for Real-Time Data Capture (S. Intille – MIT)
<h3>Volume of data / ethical collection</h3> <ul style="list-style-type: none"> □ Terrabytes possible □ Annotation can be time consuming, costly, and challenging □ Ethical issues may be raised by data collection

Technology Innovations for Real-Time Data Capture (S. Intille – MIT)
<h3>Data analysis techniques</h3> <ul style="list-style-type: none"> □ New types of multi-modal data □ Sensor algorithms noisy/probabilistic □ Desired contextual cues can be ill-defined: <ul style="list-style-type: none"> ■ E.g. "Cooking" ■ E.g. "Jittery" ■ E.g. "Getting dressed" ■ E.g. "Busy"

Advances in Measuring Behavior Fall 2011
<h3>Rappaport article</h3> <ul style="list-style-type: none"> • 70-90% of disease risks probably due to differences in environment • Need better environmental tools for GWAS • "Slicing of the disease pie along parochial lines" • Environmental exposure: body's internal chemical environment • Missing: going beyond correlation: need to know more to change exposure!
Northeastern University 75

Advances in Measuring Behavior Fall 2011
<h3>Kix article</h3> <ul style="list-style-type: none"> • Creative thinking. Yes! • Initial resistance ... common (Kuhn) • Many positives <ul style="list-style-type: none"> – Small number of measurement sites – Easy to instrument – Could measure by the hour – Privacy preserved
Northeastern University 76

Advances in Measuring Behavior Fall 2011
<h3>Kix article</h3> <ul style="list-style-type: none"> • Nothing perfect <ul style="list-style-type: none"> – Septic tanks in rural areas – Accuracy and precision – Legal issues? – Some of the same challenges as EMA • Think creatively! Look for a different point of measurement (e.g. eating)
Northeastern University 77