Methods for Integrating with Ecological Momentary Methods

(or, thinking about the future of behavior measurement)

Stephen Intille
Professor
Khoury College of Computer Sciences and Bouvé College of Health Sciences
Northeastern University, Boston MA

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Take away

- Ecological momentary assessment (EMA) is useful for measurement in research

- New forms of context-sensitive, multi-modal EMA could be used to develop and support future personal AI-driven just-in-time adaptive longitudinal interventions

Caveat: Studies described not with older adults

mHealth and AI promise

Exploit ubiquitous and increasingly powerful consumer mobile devices to measure health-related behavior and states continuously and permit *highly-tailored* real-time interventions:

Detect past/current/likely:

- Physical activity
- Sedentary behavior
- Sleep
- Social interaction
- Affect
- Stress
- And more…

AI *needs* training data

Difficult to obtain!

"Big data"	"Small data"
Points in time	Longitudinal
Population based	Unique to individuals
Data about illness	Data before/after/during illness
Easy to obtain and massive	Difficult to obtain
Fully/somewhat labeled	Difficult to label

Examples:

EHRs

Claims data

All text on Internet

YouTube

Genetic data

Mostly passive

Examples:

Wearable data

Device use data

Communications

Response to information/prompts

Requires interaction

Self-reported info/feelings/labels

“Small data” behavioral measurement

- Computationally detect patterns of behavior from “digital breadcrumbs" using machine learning and AI
- Simultaneously measure across health research silos to obtain a holistic view of behavior
- Find unexpected relationships between behavior and health outcomes
- Develop computational models of behavior change

Reduce measurement noise ⇨ **Advance science**

Better (temporally-dense) small data measures

Better questions

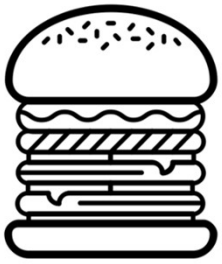
E.g., Are short bouts of physical activity as protective against disease as continuous long bouts?

Better (temporally-dense) small data measures

Real-time interventions

E.g., System responds at actionable/teachable time to what someone *is doing/feeling or likely to do/feel next* with relevant content/action tailored to the person and the situation.

But, *need* some self-report



EATING

RELATIONSHIPS

PAIN

MOOD

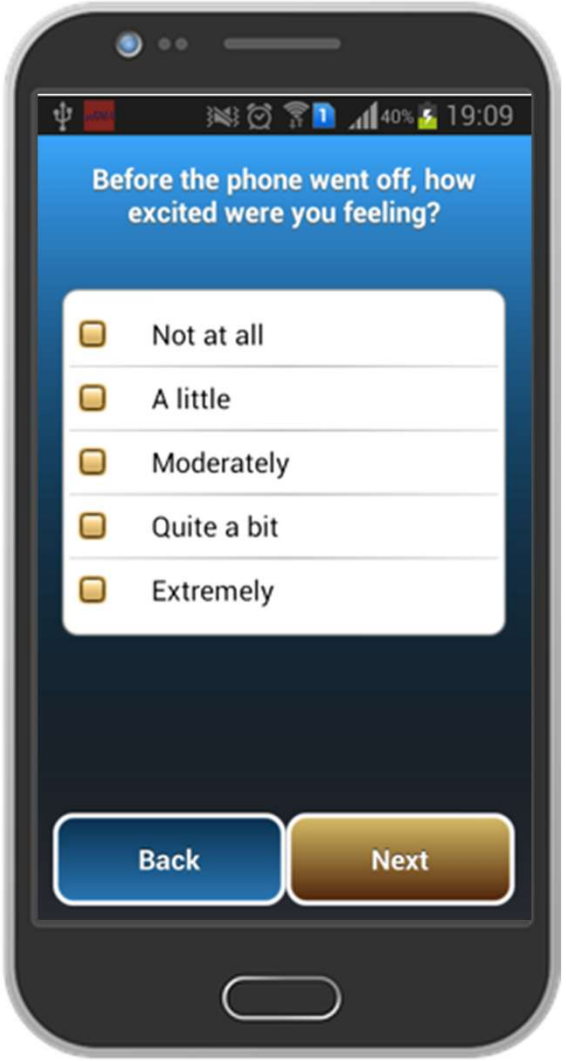
PERCEIVED EXERTION

+ collecting AI training & validation data

What is EMA?

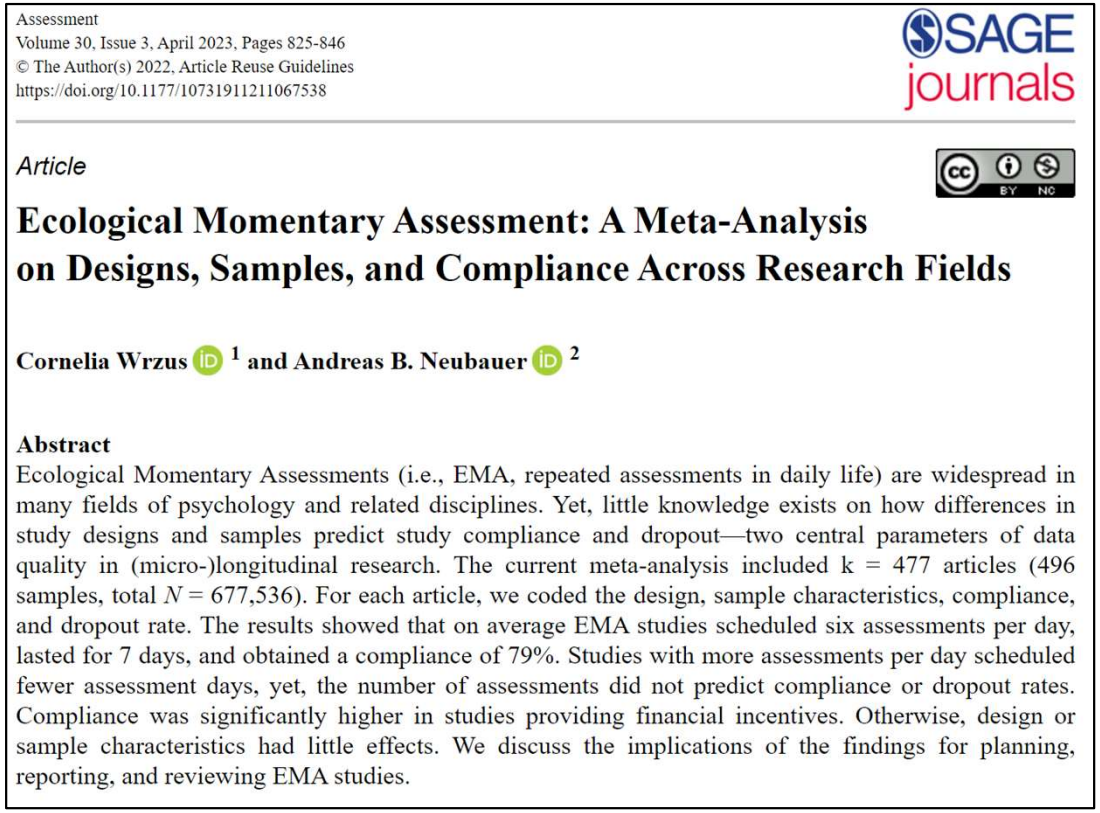
EMA or Ecological momentary assessment is an ***in situ*** **self-report data collection method** to assess behavior

Shiffman & Stone, 1998; *Smyth & Stone, 2013*



Typical EMA studies short

- 6 assessments per day
- 7 days
- 79% compliance



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SAGE journals

Article

Ecological Momentary Assessment: A Meta-Analysis on Designs, Samples, and Compliance Across Research Fields

Cornelia Wrzus [1] **and Andreas B. Neubauer** [2]

Abstract

Ecological Momentary Assessments (i.e., EMA, repeated assessments in daily life) are widespread in many fields of psychology and related disciplines. Yet, little knowledge exists on how differences in study designs and samples predict study compliance and dropout—two central parameters of data quality in (micro-)longitudinal research. The current meta-analysis included k = 477 articles (496 samples, total N = 677,536). For each article, we coded the design, sample characteristics, compliance, and dropout rate. The results showed that on average EMA studies scheduled six assessments per day, lasted for 7 days, and obtained a compliance of 79%. Studies with more assessments per day scheduled fewer assessment days, yet, the number of assessments did not predict compliance or dropout rates. Compliance was significantly higher in studies providing financial incentives. Otherwise, design or sample characteristics had little effects. We discuss the implications of the findings for planning, reporting, and reviewing EMA studies.

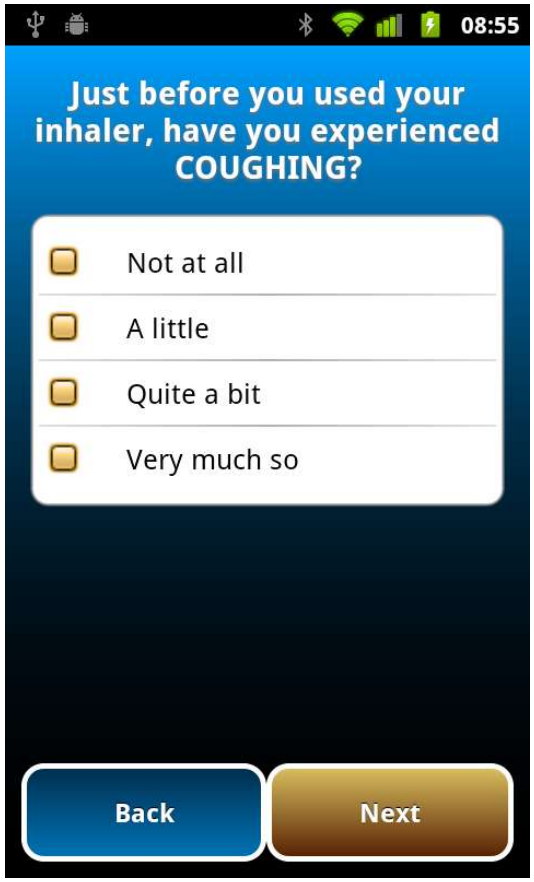
"Compliance was significantly higher in studies providing financial incentives"

Self-report measurement

For science	For interventions
Often short term	Need longitudinal
Can incentivize with $$$	Financial incentives impractical
Boring/intrusive may be ok	Boring/intrusive intolerable
People will change their behavior to accomplish	Must fit into everyday life Compete for attention economy!
Get away with random sampling (and over sampling)	Need to target questions to the moment
Small number of constructs to measure	Wholistic picture of behavior/states desired
Limited temporal density	Behavior changes quickly

Context-sensitive sampling

Teen asthma measurement prompted just after inhaler used:



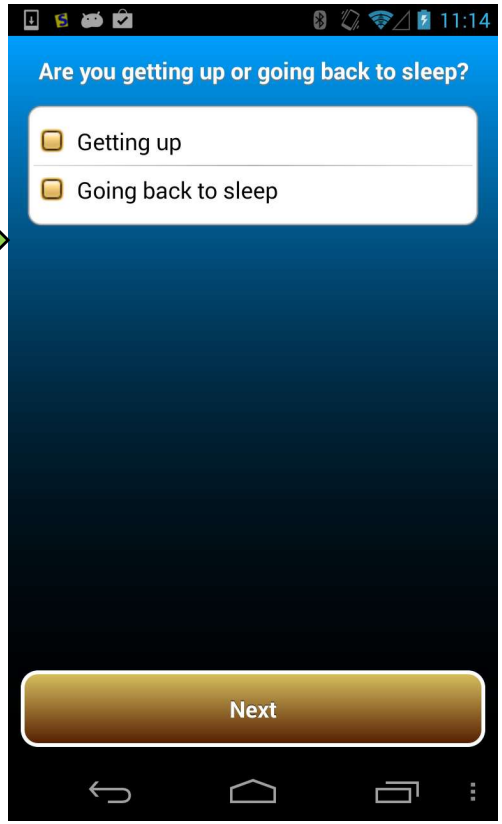
E. Dzubur, M. Li, K. Kawabata, Y. Sun, R. McConnell, S. Intille, and G. F. Dunton, "Design of a smartphone application to monitor stress, asthma symptoms, and asthma inhaler use," Ann Allergy Asthma Immunol, vol. 114, pp. 341-342, 2015.

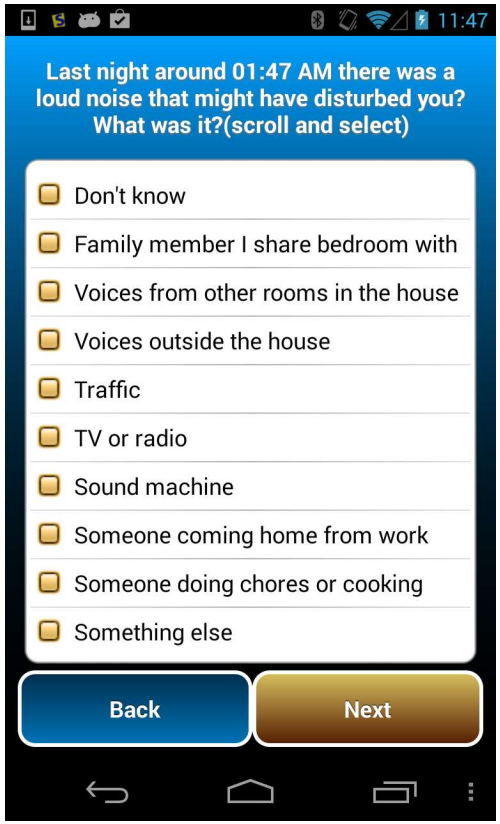
Context-sensitive sampling

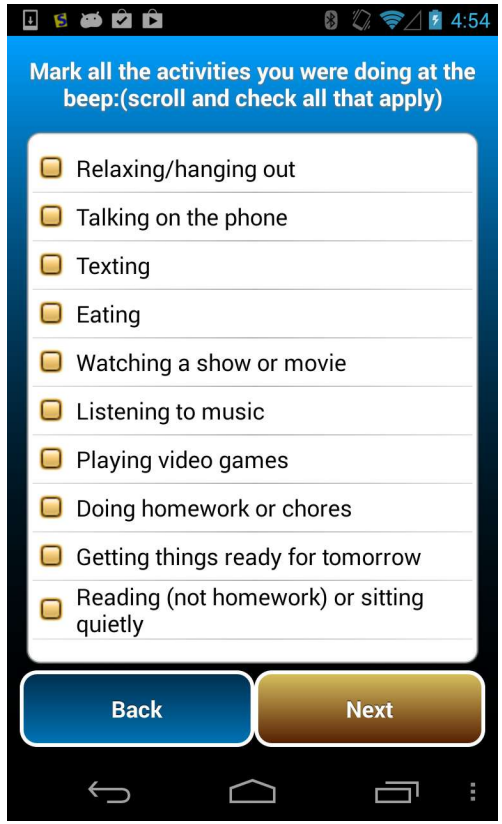
Prompted after 60 min of phone motion or no motion:

Context-sensitive sampling

Detect sleep to wake in real-time from watch:







J. C. Spilsbury, S. R. Patel, N. Morris, A. Ehyaei, and S. S. Intille, "Household chaos and sleep-disturbing behavior of family members: Results of a pilot study of African American early adolescents," Sleep Health, vol. 3, pp. 84-89, 2017.

EMA limitation

Interruption burden

- Long question sets
- Frequent questioning
- Obtaining device access
- Prompt disruptiveness

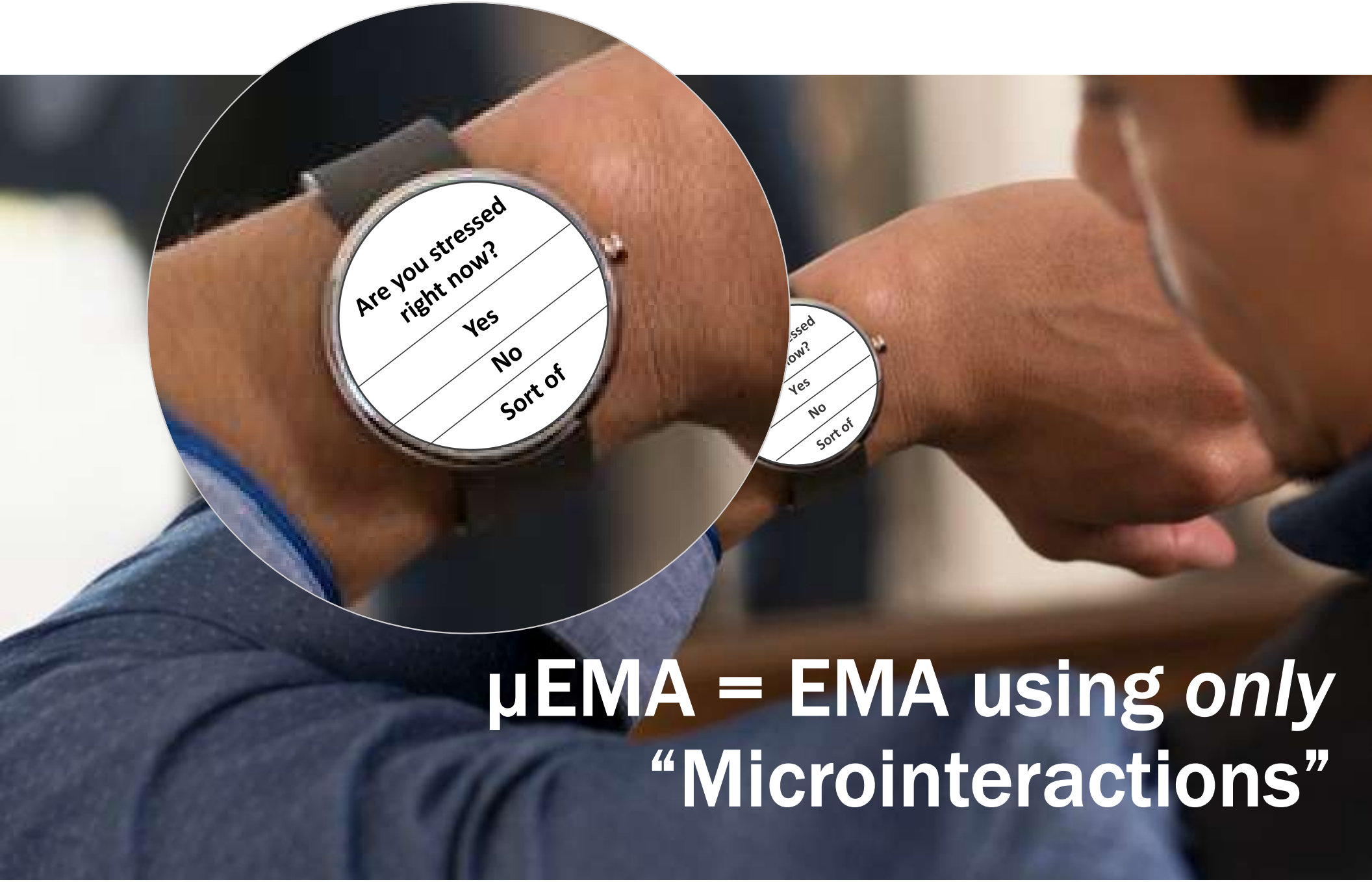
!

Resulting in high perceived burden and lower long-term study compliance

EMA challenge

How might we reduce interruption burden, but still achieve high temporal density in EMA?

“At a glance” microinteractions



Microinteraction EMA (or μEMA[1])

EMA using only microinteractions

Source: microinteractions.org

Microinteractions

~2 seconds to perform [2]

One interaction per task

No distraction from current activity

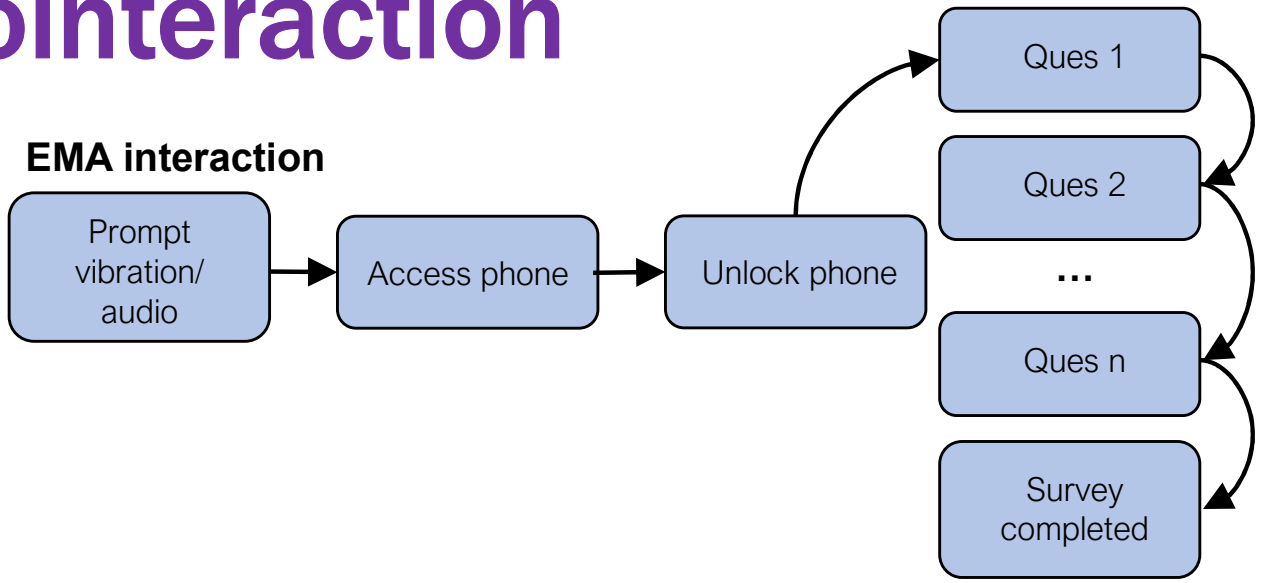
[1] Intille, Hayens, Maniar, Ponnada, Manjourides. uEMA: Microinteraction-based Ecological Momentary Assessments Using a Smartwatch. *UbiComp'16*

[2] Ashbrook, D. L. (2010). Enabling mobile microinteractions. *Georgia Institute of Technology.*

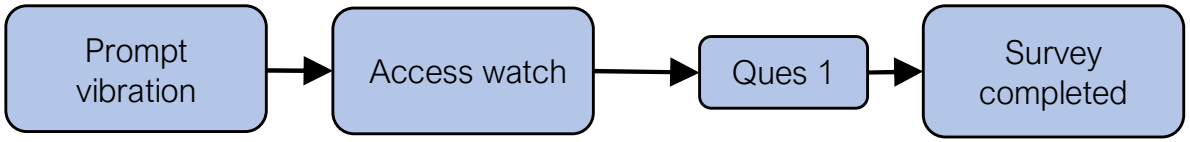
µEMA and microinteraction

Microinteraction =
{watch access + cognitive simplicity + fewer answers}

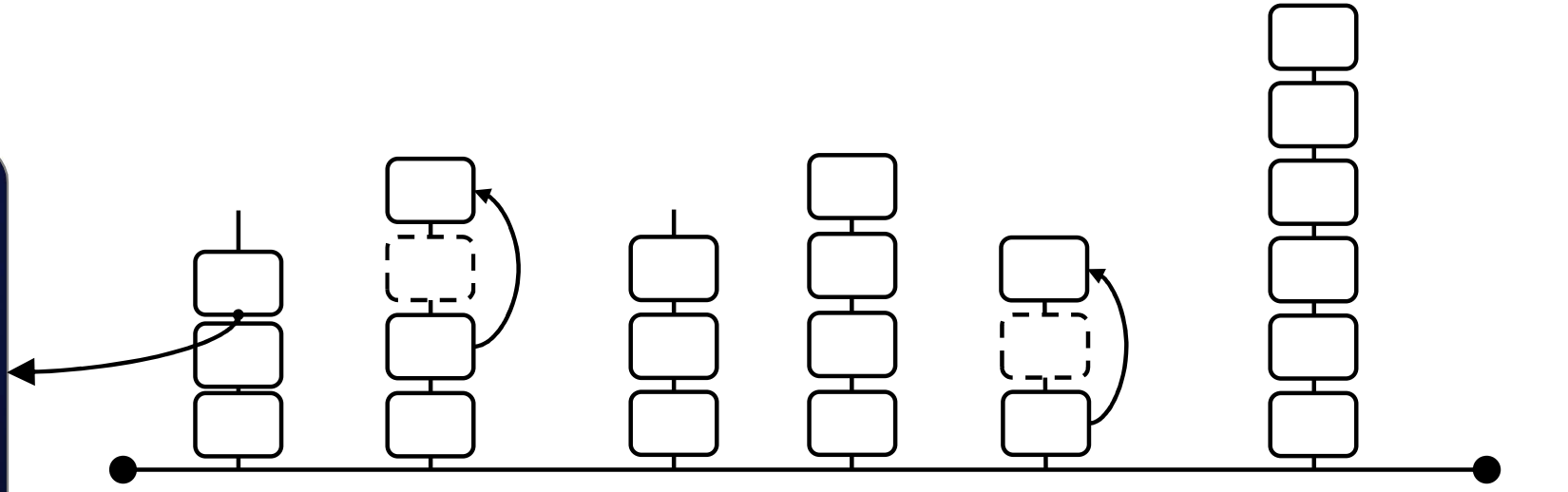
EMA interaction

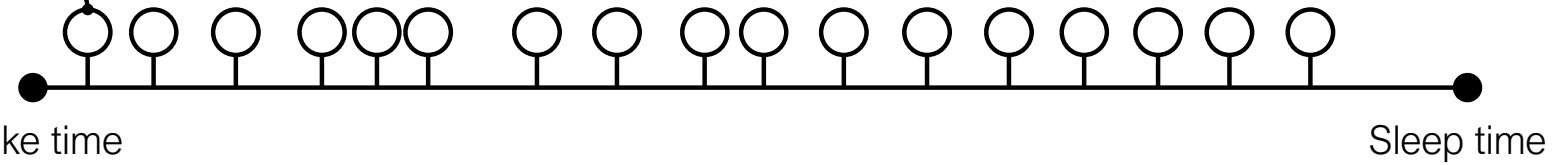


µEMA's microinteraction



µEMA prompting frequency

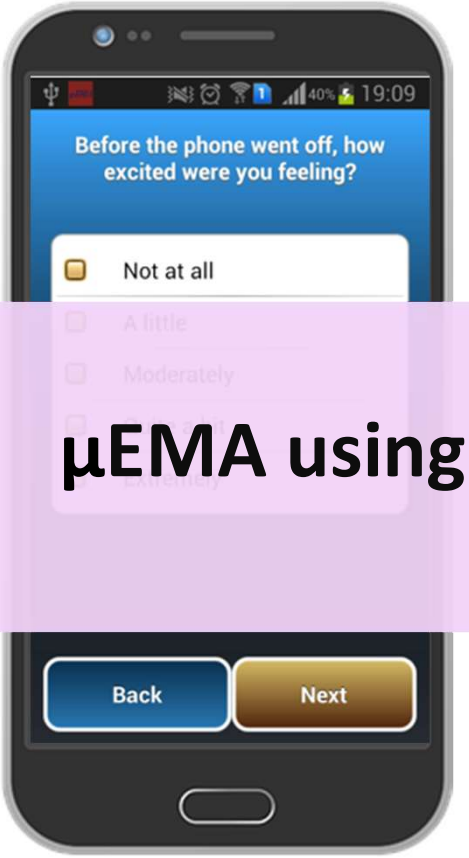




µEMA's frequency >> EMA frequency

Use microinteractions

mobile-EMA



Watch-µEMA

µEMA using a smartwatch → Watch-µEMA

Interrupt less, ask more

Interrupt more, ask less

Initial pilot results

- **Despite ~8 times more interruption**, watch-µEMA had **higher response rates and study compliance** than mobile-EMA

- Despite **interruption rates as high as 8 per hour**, watch-µEMA was **perceived as more tolerable** than mobile-EMA

?

Motivated many questions (e.g., Is the effect due to microinteractions or the watch? How does context impact response rates? Could people answer 4 per hour for a year?

µEMA: Microinteractions or watch?

The novelty of a smartwatch and its easy access alone are **not sufficient to drastically improve EMA compliance** and reduce burden

Microinteractions appear to be necessary

Intille et al., "µEMA: Microinteraction-based ecological momentary assessment (EMA) using a smartwatch," in Proc. of the 2016 ACM Int'l Joint Conf. Pervasive and Ubiquitous Computing: ACM, 2016, pp. 1124-1128.

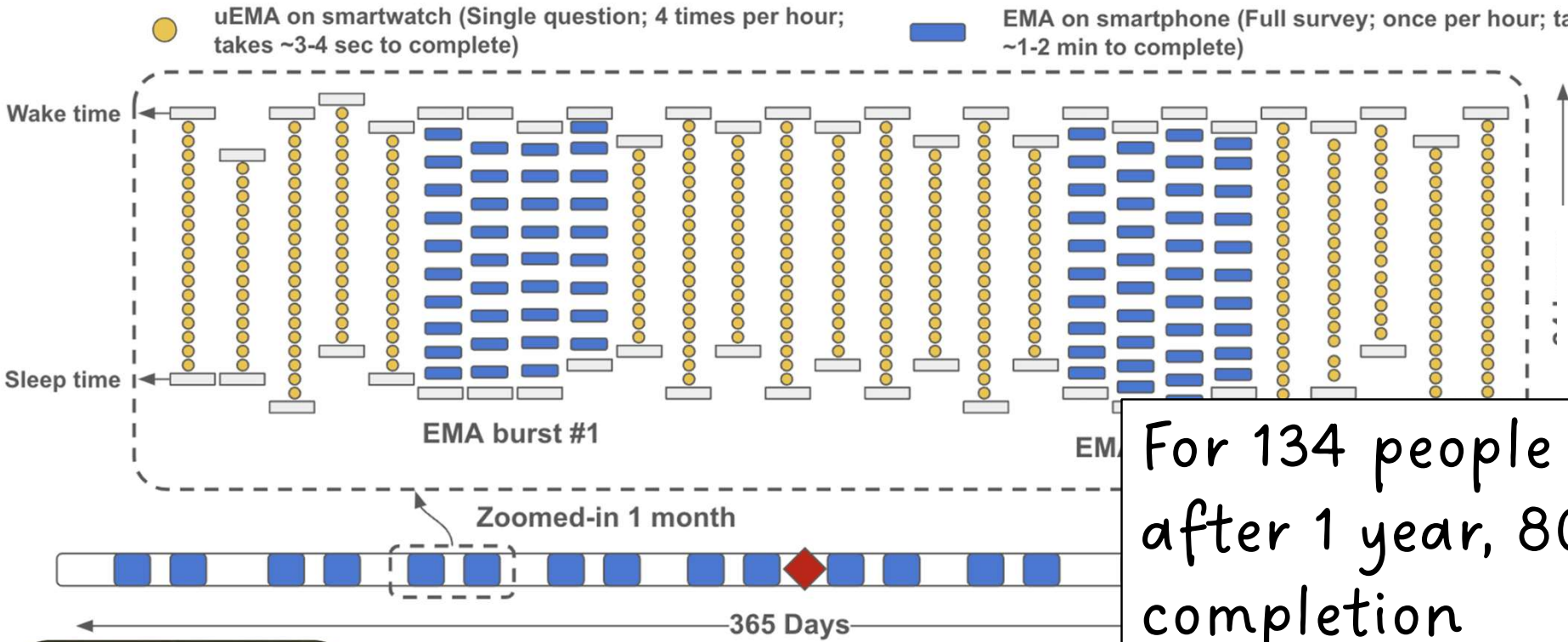
Ponnada et al., "Microinteraction ecological momentary assessment response rates: Effect of microinteractions or the smartwatch?," Proc. ACM J. Interactive, Mobile, Wearable, and Ubiquitous Technology, vol. 1, 2017.

µEMA: Validity? Utility?

- Despite a high interruption, µEMA **yielded accurate self-report** at high-frequency[3]
- Has been used to measure **stress, hyperarousal, and perceived comfort** in real-world settings

[3]Ponnada et. al. Measuring Criterion Validity of Micro-EMA: An Exploratory Pilot Study with Physical Activity Measurement. *JMIR mHealth uHealth'21*

µEMA: Sustainable longitudinally?



For 134 people after 1 year, 80% completion

After 6 months, micro-EMA completion rate was 79% (SD 22.2%) for 81 people.

Ponnada et al. Intensive longitudinal data collection using microinteraction ecological momentary assessment: Pilot and preliminary results. JMIR Form Res. 2022;6(2):e32772.

µEMA: Impact of context on response?

Explored how µEMA response/non-response (from ~1.2 million prompts) is impacted by **context** → temporal, mobility, and device use context

More µEMA non-response:

- Near wake times of day
- On weekends vs. weekdays
- At lower wrist motions → including non-wear and device charging times
- At locations other than home

Ponnada, A. et al., *Contextual biases in microinteraction ecological momentary assessment (µEMA) non-response. IMWUT, 2022. 6(1): p. 1–24 (Article 26).*

Exploring audio-based micro-EMA

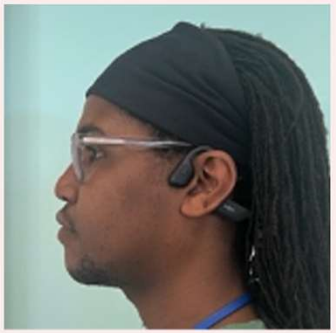
Audio micro-EMA (pilot)

Auditory/ Haptic cue → Speak to the device

Once per 5 min, 7day+,

67.7% response rate

modality options



open-ear earbuds

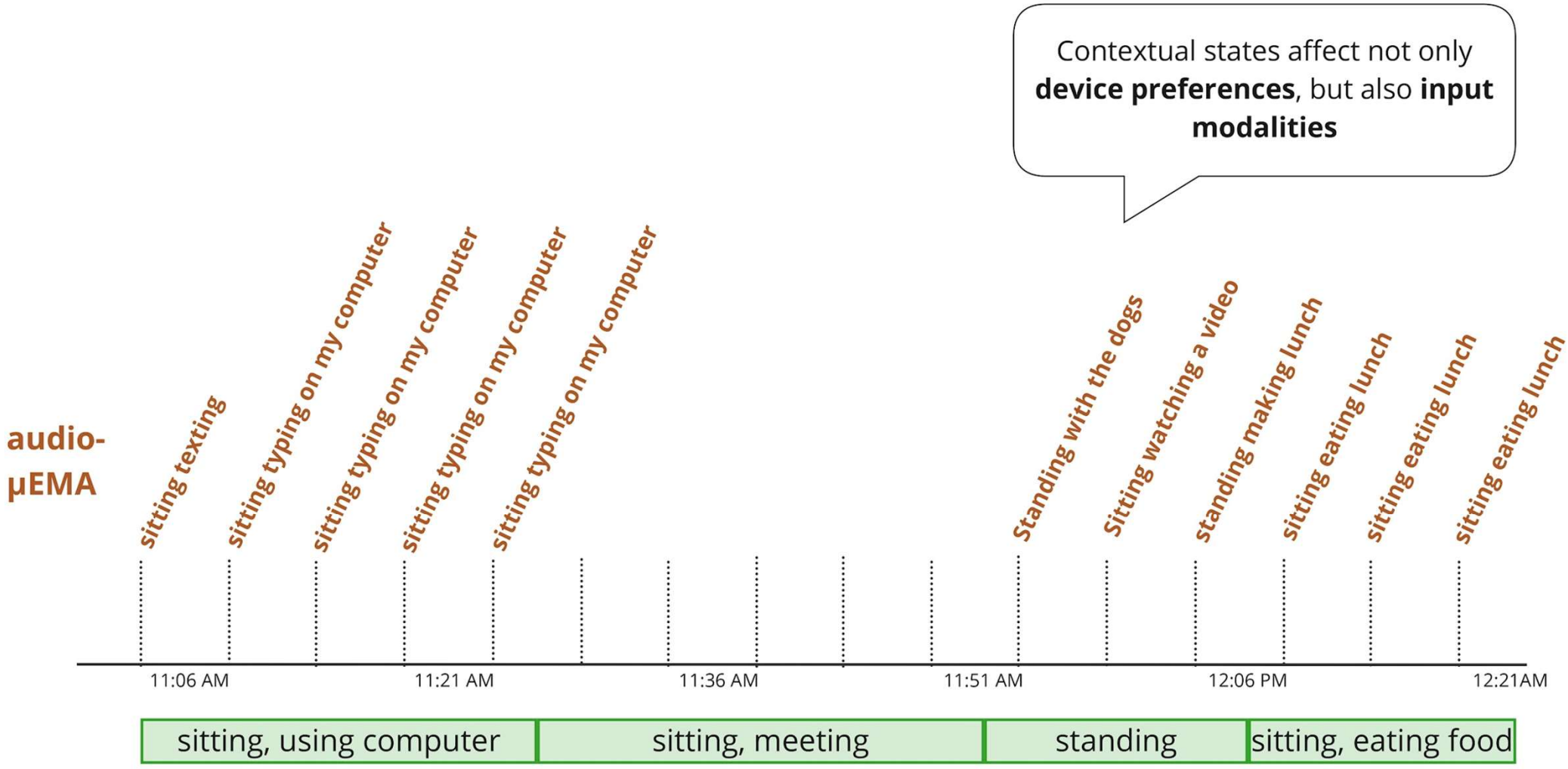
bone-conduction headsets

smartwatch

bone-conduction headsets

Le et al. Collecting self-reported physical activity and posture data using audio-based ecological momentary assessment. IMWUT 2024.

Context matters

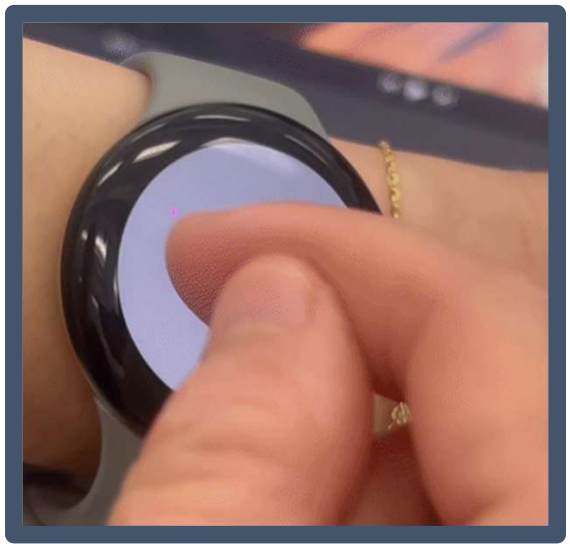


Social burden

Exploring multi-modal micro-EMA

Speech input

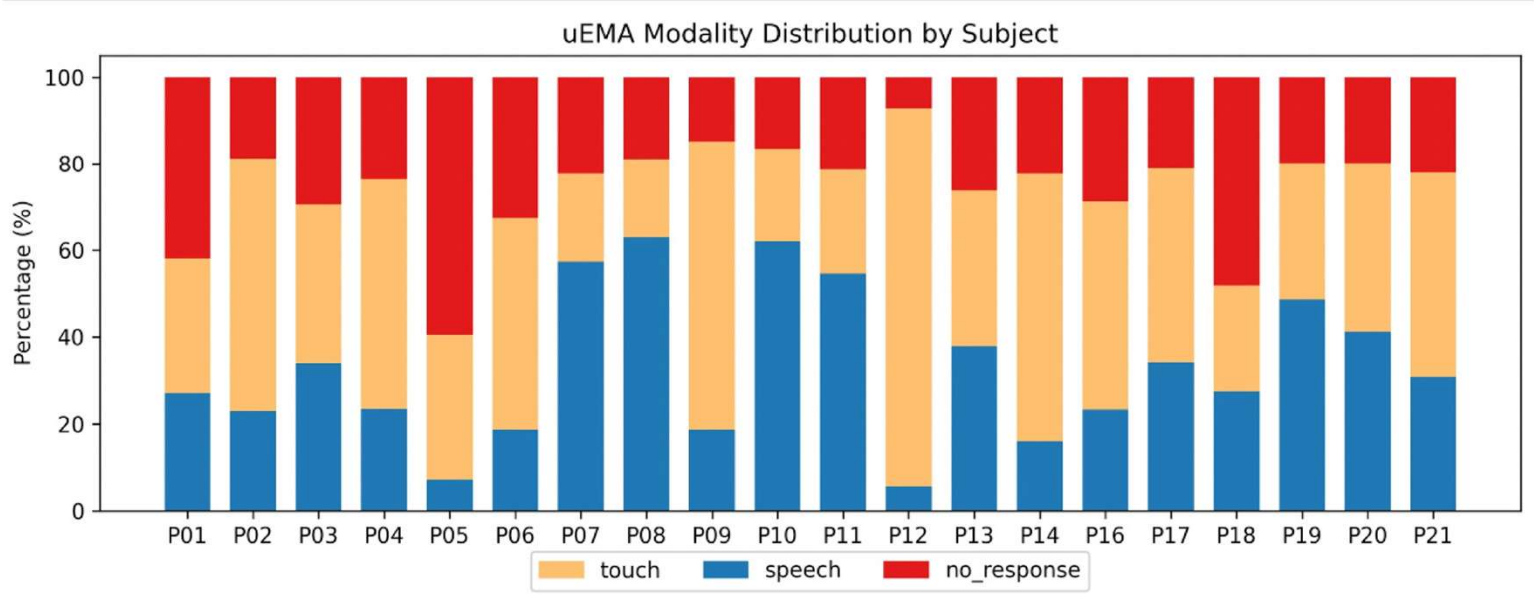
Tap top predictions (from sensing)



Draw selection (long lists)

Evaluating multimodal micro-EMA

- Pilot field deployment with 20 participants for 7 days:
  - 72.4% response rate
  - 54.7% touch interactions, 45.3% speech interaction
  - Large variance among participants:



Le et al. Feasibility and utility of multimodal micro ecological momentary assessment on a smartwatch. CHI 2025.

Future: Sensing + multi-modal µEMA

Short-term goal:
Validate recognition algorithms, provide training data for AI

Passive sensing

Motion + HR + Location

Real-time detection

"Walking to work"

Multi-modal µEMA prompting

Improve ML/AI recognition

Future: Sensing + multi-modal µEMA

Eventually: Longitudinally generate rich, person-specific models of people that can be used by AI-supported just-in-time adaptive interventions

Passive sensing

HR + Location + Calendar + Boss

Real-time detection + past situations

"Nervous"

Multi-modal µEMA prompting

Improve ML/AI recognition + Drive future JITAI behaviors

Stephen Intille
Contact: s.intille@northeastern.edu

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- NIH (R21 HL108018)
- NIH (UO1 HL091737)
- Google Glass Research Award
- Participants who have experienced over 1.5 million micro-EMA prompts