mHealth[4]:
Monitoring, Modelling, Modifying and Maintaining health-related behavior in a digital world

Donna Spruijt-Metz, MFA PhD
Director, USC mHealth Collaboratory
Research Professor, Psychology & Preventive Medicine
University of Southern California

Presented at the Mobile and Electronic Health ARC's
2nd Annual Symposium, Boston University, Nov 2017

USC Dornsife
Center for Economic and Social Research

USC
mHealth Collaboratory

Before I start: Thanks to

FUNDERS

- **NIMHD** P60 002564
- **NSF** (IIS-1217464, 1521740)
- **NCCAM** 1RO1AT008330

Imagine Health TEAM

- Marc Weigensburg, Bas Weerman, Cheng Kun Wen, Stefan Schneider

KNOWME TEAM

- Murali Annavaram, Giselle Ragusa, Gillian O'Reilly, Adar Emken, Shri Narayanan, Urbashi Mitra, Gautham Thatte, Ming Li, Sangwon Lee, Cheng Kun Wen, Javier Diaz, Luz Castillo

M2FED TEAM

- Jack Stankovic, John Lach Kayla De La Haye, Brooke Bell

mHealth Collaboratory, Institute for Creative Technology teams:

- Bill Swartout, Skip Rizzo, Arno Harthold, Shinyi Wu, Marientina Gotsis

Multiscale, Computational Modeling TEAMS

- Misha Pavel, Steven Intille, Wendy Nilsen, Benjamin Marlin, Daniel Rivera, Eric Hekler, Pedja Klasnja,

IoT mHealth^4:

This Generation Sensing
IoT

- The internet of things:
  - On-body,
  - Chemical,
  - Implantable,
  - Deployable,
  - Persistent user interface,
  - Connected

Mobile Technologies: Data-Hungry and Ubiquitous

Integration w/wearable+ deployable sensors

- Ambient light
- Proximity
- Cameras
- Accelerometry
- Gyroscopes
- GPS
- Microphones
- Compass. Apps
- Phone, email, text
- Internet, Social networks
- Real-time data transfer

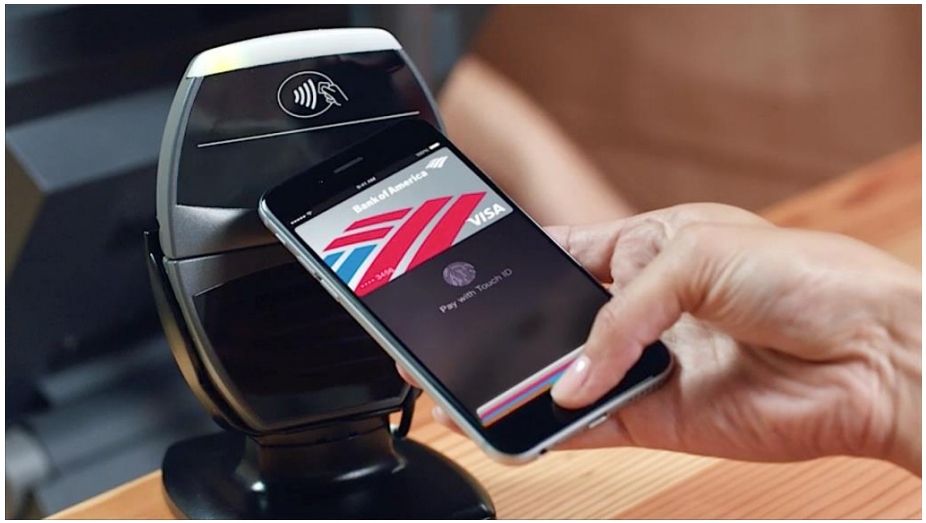
mHealth^3: Monitor, Model & Modify Behavior

MONITORING

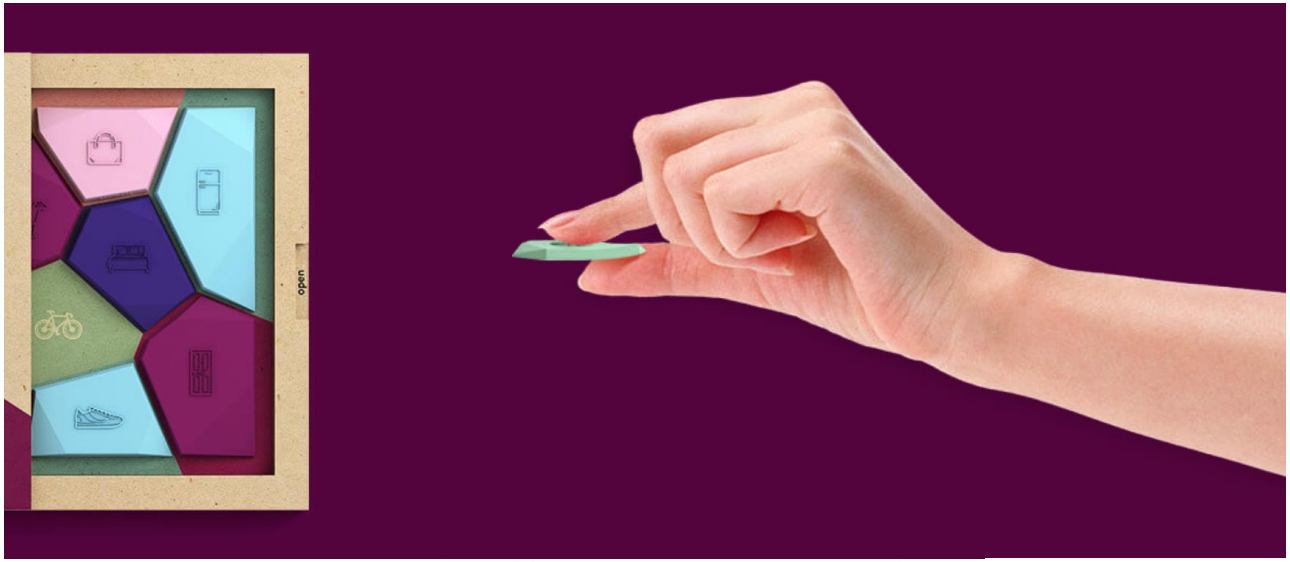
M2FED: Monitoring and Modeling Family Eating Behaviors

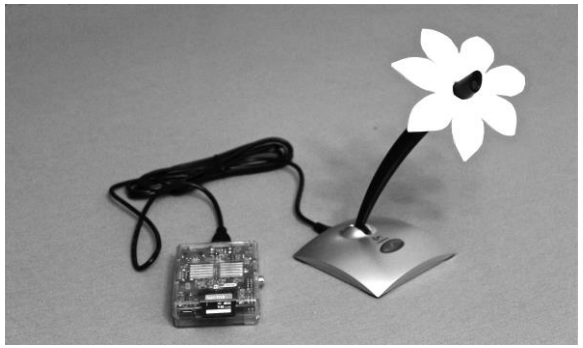
Premise: Measuring dietary intake is *the* 'wicked problem' of obesity research

- Ask people
- Observe people
- Sense people
- Biological measures
- Grab 'small' data



People as Complex Systems Embedded within Complex Systems Sensed Continuously in Context

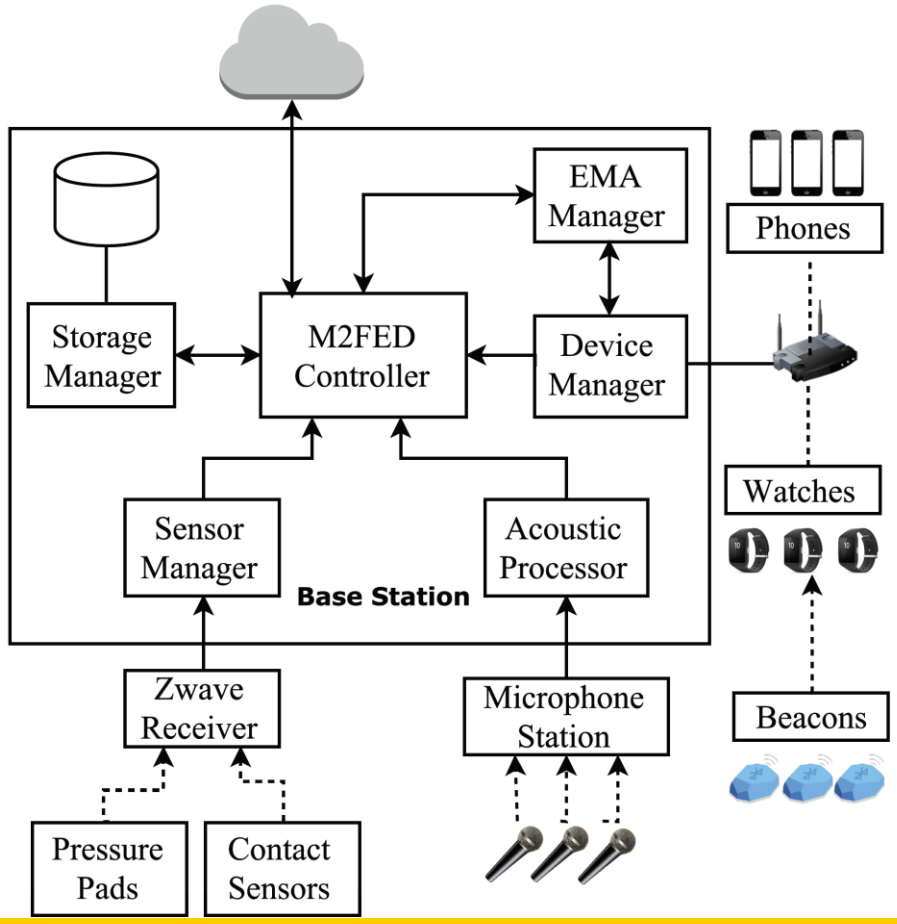




M2FED CyberPhysical System

- Smart watches
- Smart phones
- Microphones
- Beacons
- EMA
- Cloud (Internet)

- ML (including deep learning)



Ubiquitous measures

- Eating (Smartwatch)
- Who is in the room (Smartwatch ID & Beacons)

- Speed of eating (Smartwatch)

Signal-Driven & Scheduled Ecological Momentary Assessment

Trigger: Sensed mood

Cause of stress, anger, happiness, sadness

Trigger: Sensed eating event

Eating in the absence of hunger

Self-regulation

Mindfulness

Rule-based schedule

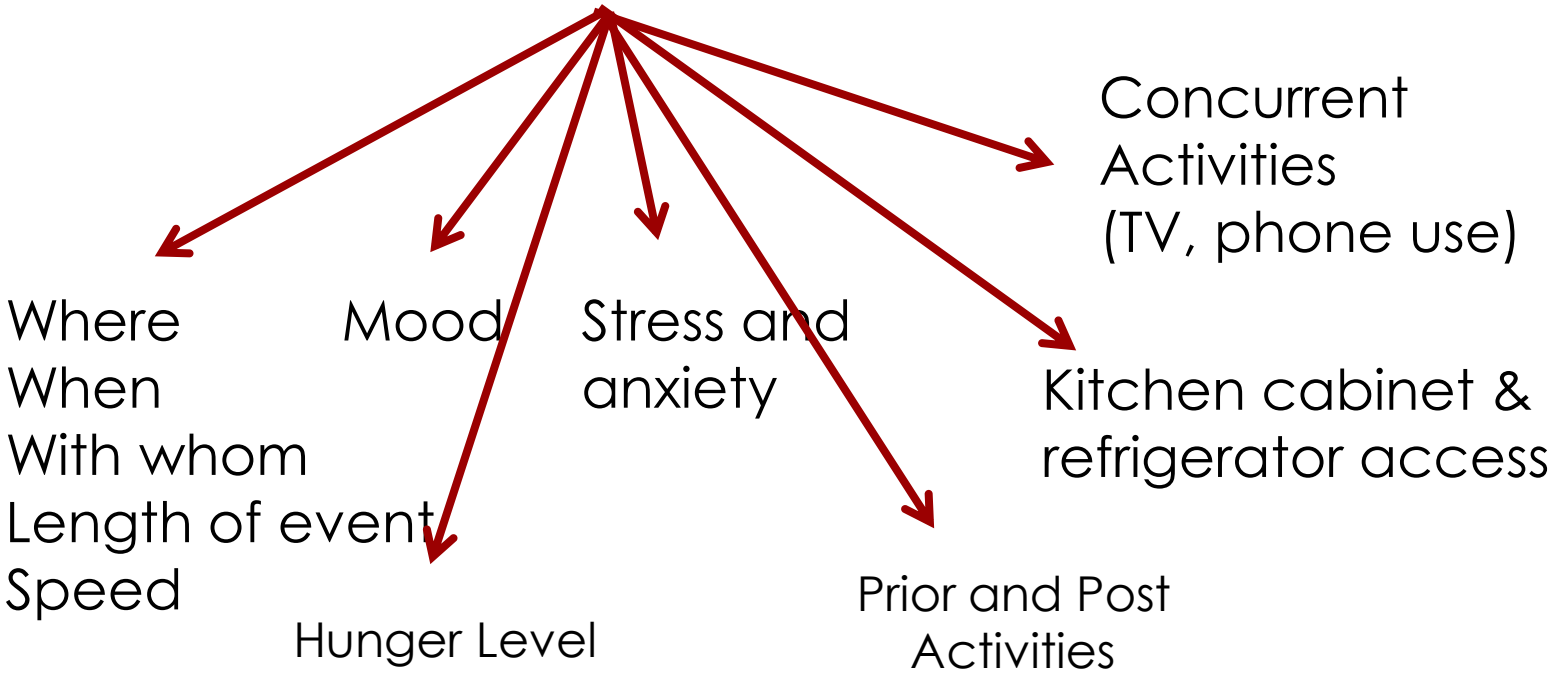
Vigor, Fatigue,

Anxiety, positive affect

Trigger: Participant – reported event or mood

Text, picture, or sound recording

What we want to know about eating



mHealth^4: Monitor, Model, Modify & Maintain Behavior

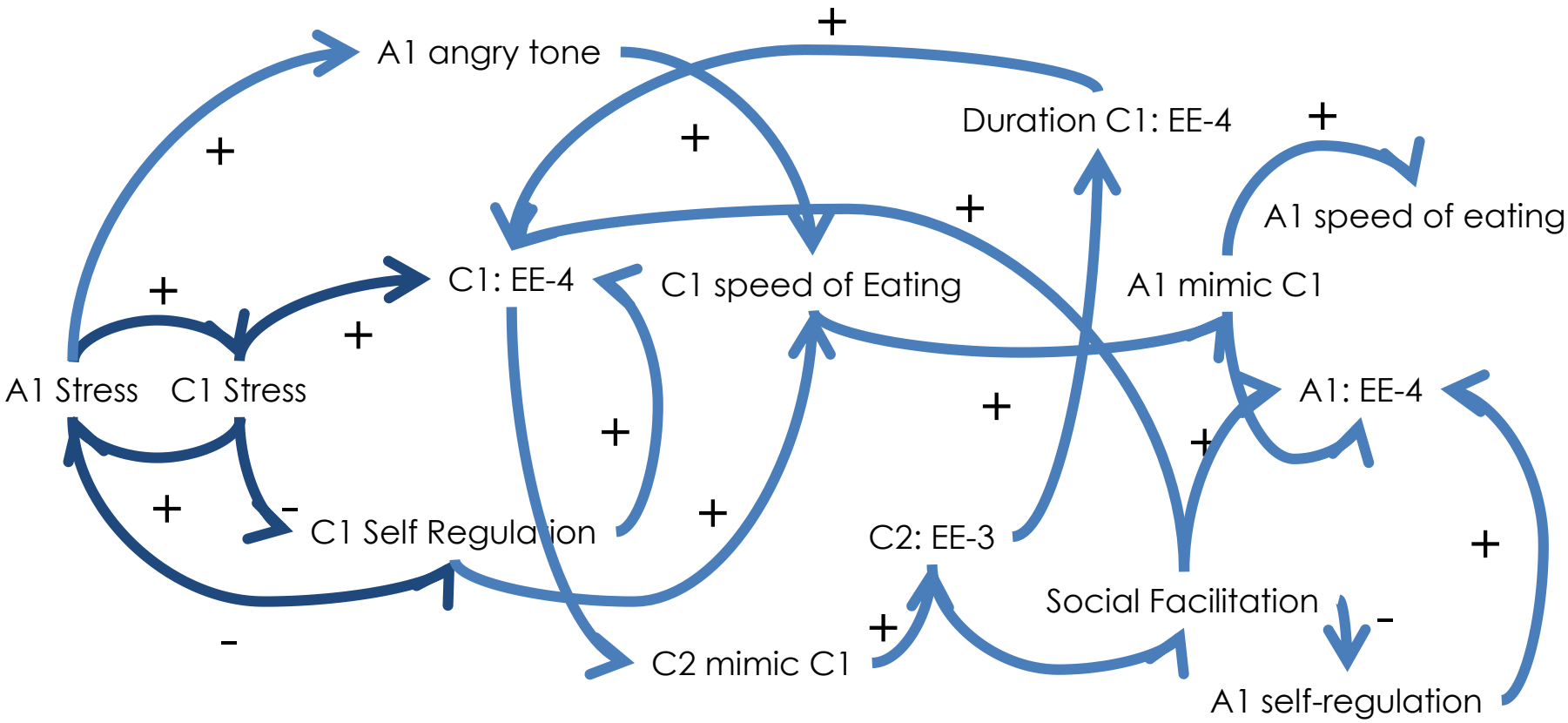
MODELING

TBM

Health behavior models in the age of mobile interventions: are our theories up to the task?

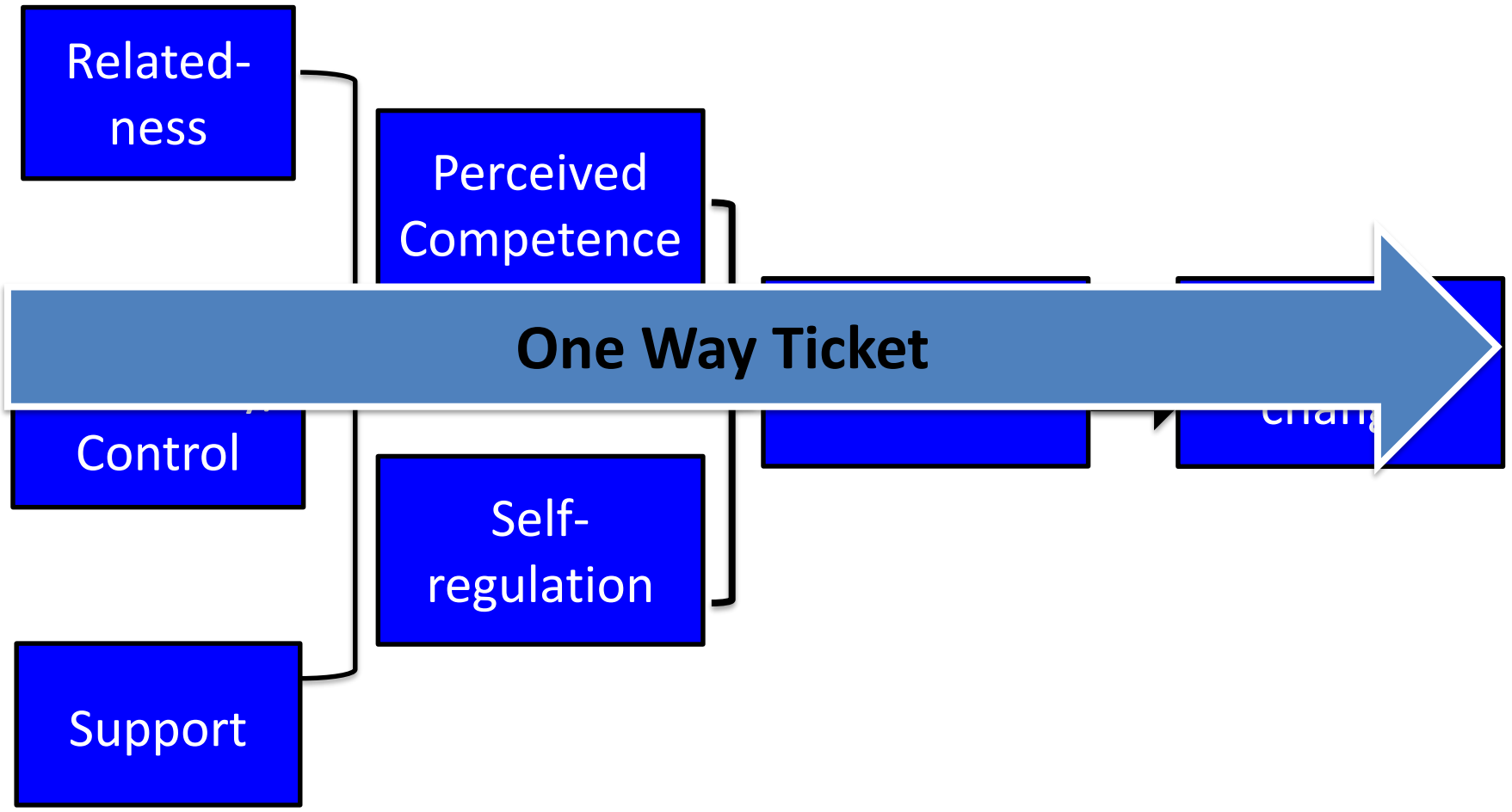
William T Riley, PhD,[1] Daniel E Rivera, PhD,[2] Audie A Atienza, PhD,[3] Wendy Nilsen, PhD,[4] Susannah M Allison, PhD,[5] Robin Mermelstein, PhD [6]

M2FED: Monitoring and Modeling Family Eating Dynamics



Spruijt-Metz, Lach, Stankovic & de la Haye

Our Current Theories are Static



TBM

ESSAY

Building new computational models to support health behavior change and maintenance: new opportunities in behavioral research

Donna Spruijt-Metz, MFA, PhD,[1] Eric Hekler, PhD,[2] Niilo Saranummi, PhD,[3] Stephen Intille, PhD,[4] Ilkka Korhonen, PhD,[5] Wendy Nilsen, PhD,[6] Daniel E. Rivera, PhD,[2] Bonnie Spring, PhD,[7] Susan Michie, PhD,[8] David A. Asch, PhD,[9] Alberto Sanna, PhD,[10] Vicente Traver Salcedo, PhD,[11] Rita Kukakfa, PhD,[12] Misha Pavel, PhD[3]

Dynamic, Multiscale Model Requirements

- Dynamic, temporally dense, ***multiscale*** relationships
- In context
- Identify *multidimensional generalization spaces*
- Individual (or idiographic) models
- Learning and adaptive
- Modular & robust
- Conceptually seeded, yet data driven

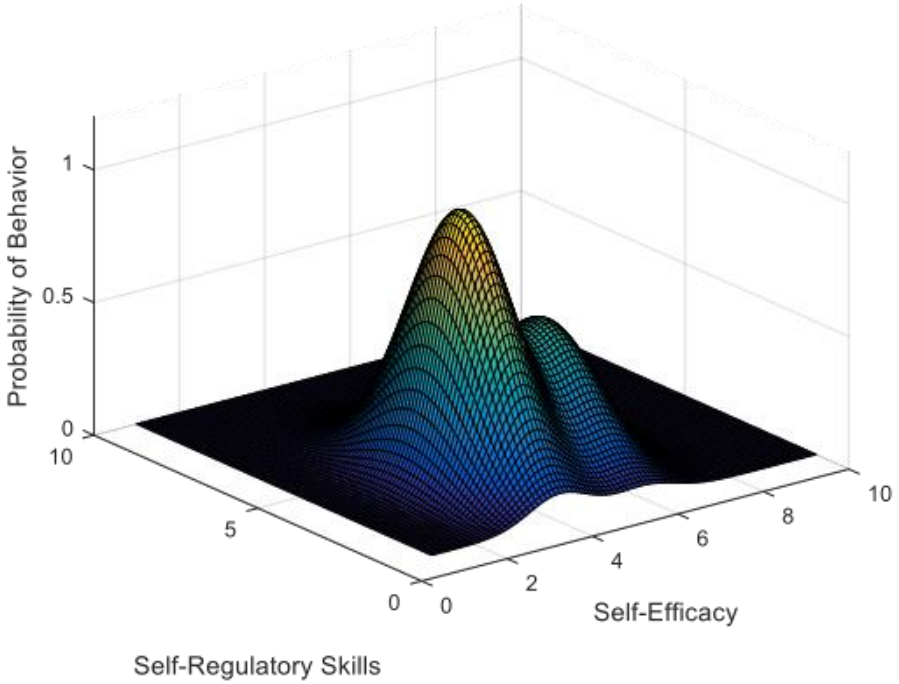
Spruijt-Metz & Nilsen, 2014,
Marlin, Hekler, Rivera, Pavel, Jimison, Klasnja, Buman, Spruijt-Metz, (HOTP)

Multidimensional generalization spaces

- When?
- Where?
- For whom?
- In which state?
- Which dose?
- Which particular intervention?

Multidimensional generalization spaces: state-space representations of behavior

- An individual's state represented in a multidimensional state space defined by variables that either:
- predict future states or future behaviors (or both)
- or the probability that a particular intervention will be effective
- (or both ☺)



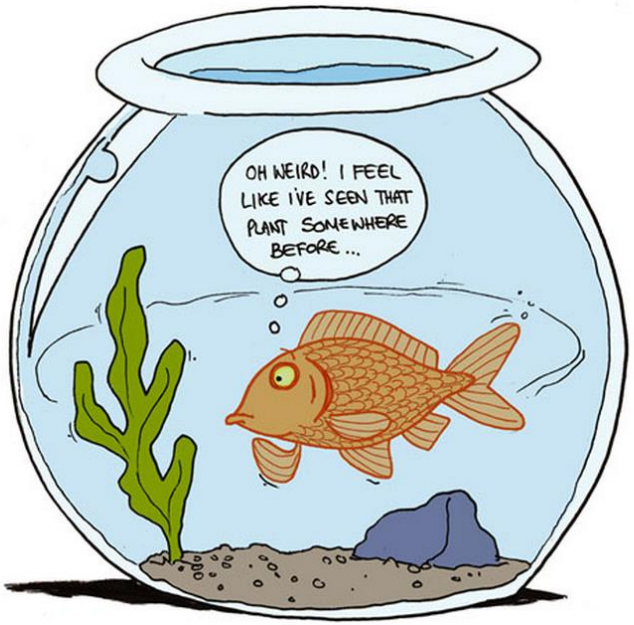
Intervention response surface for intervention 'A' for two state variables

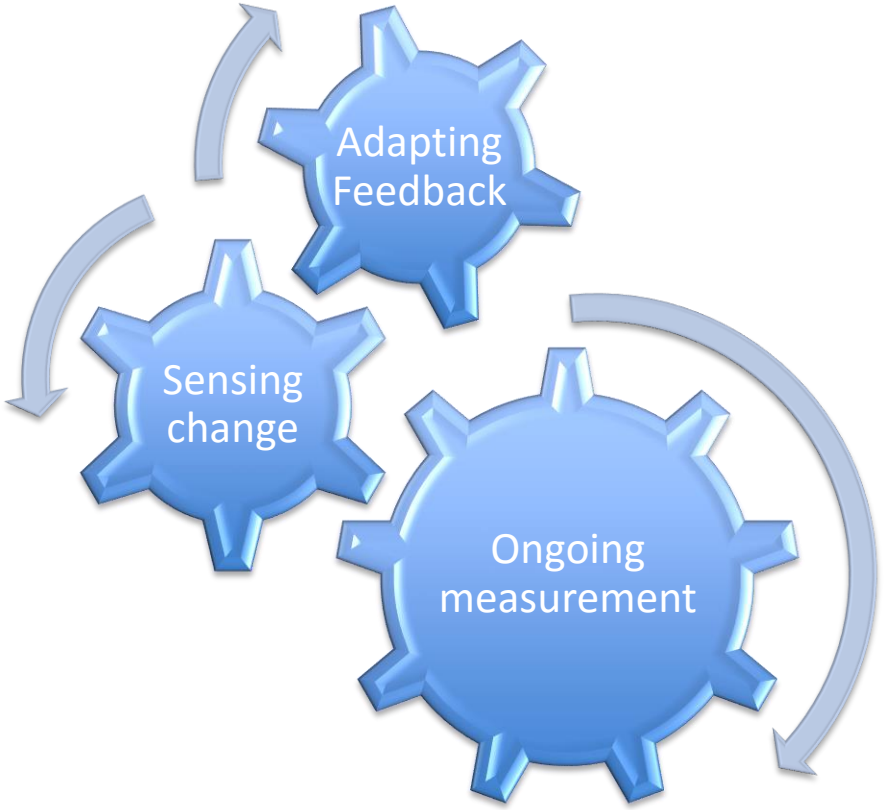
Idiographic vs. Nomothetic

Differences between individuals

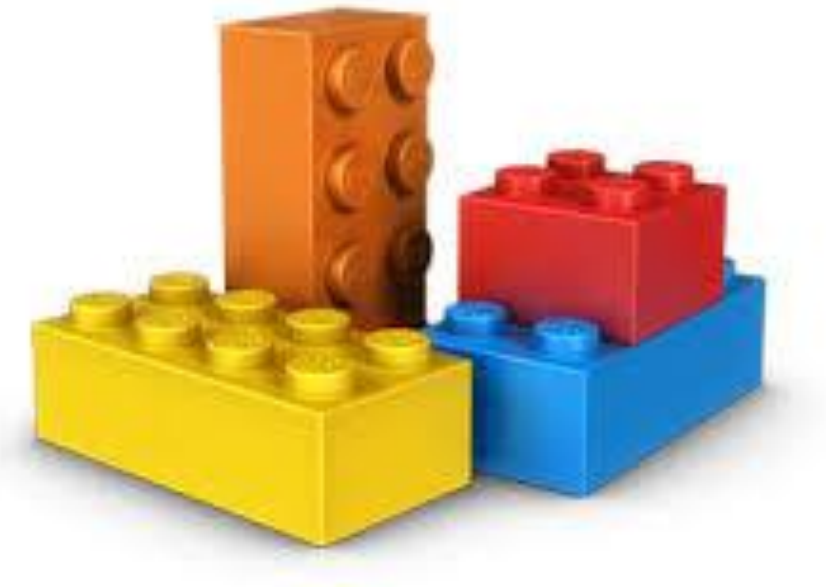
Patterns within one individual

Learning and adaptive

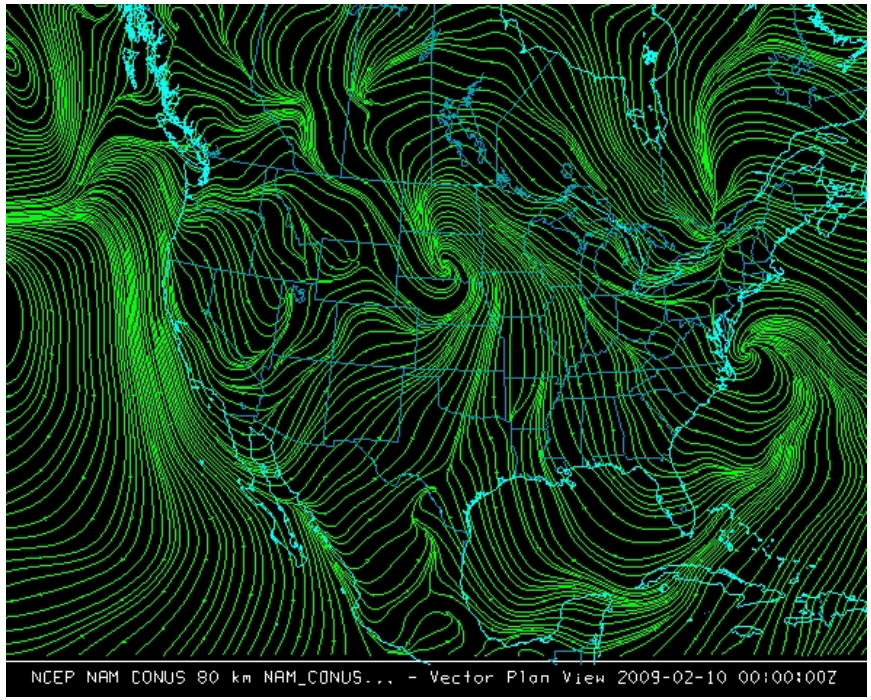




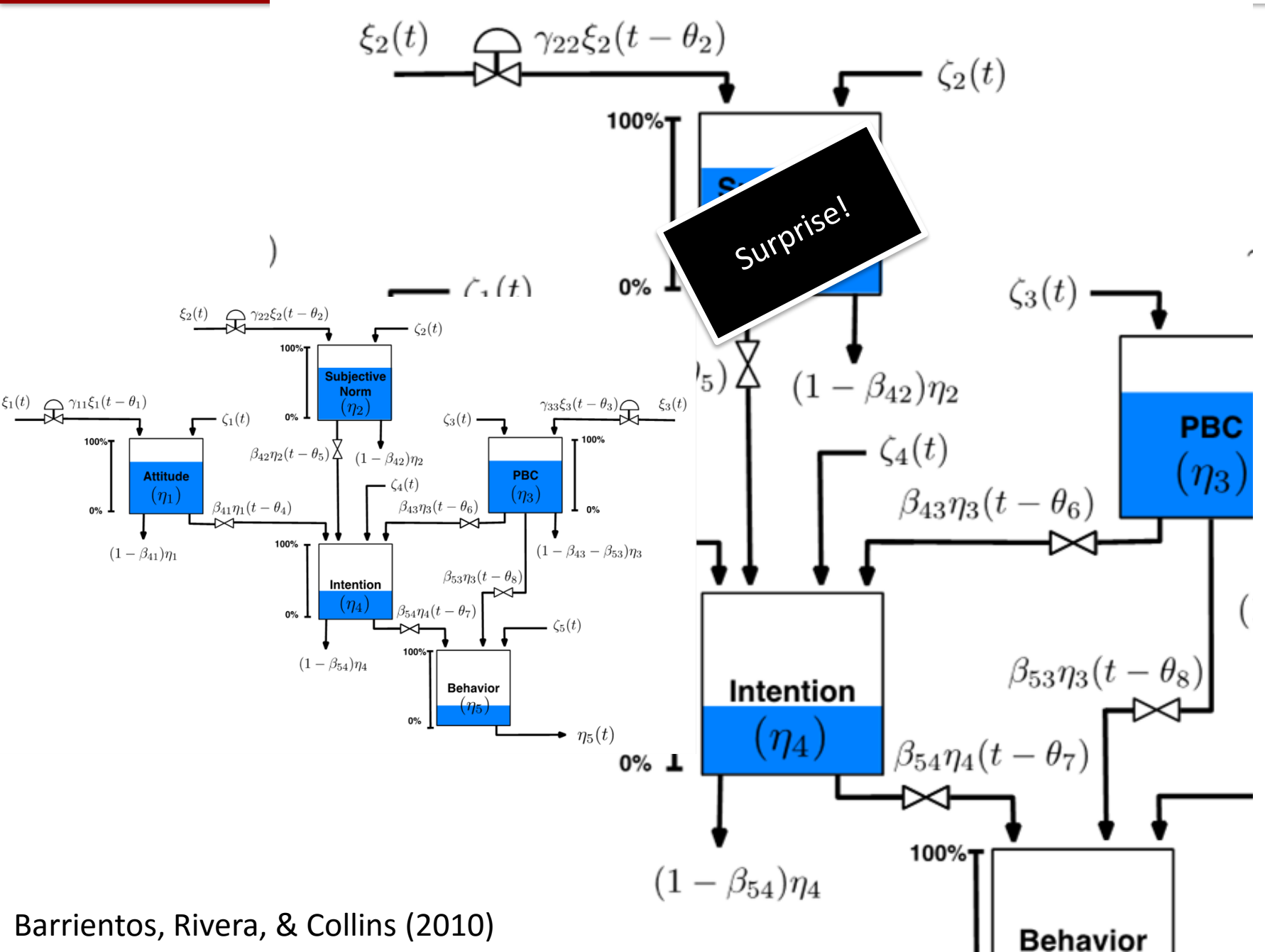
Modular & Robust



Conceptually seeded, yet data driven



- What new questions can transdisciplinary teams ask this data?
- Where are the useful signals in the current noise?
- A new search for meaningful mechanisms
- Personalizes adaptively as time-sensitive new data comes in.



Barrientos, Rivera, & Collins (2010)

mHealth^3: Monitor, Model & Modify health-related behavior

Modifying

Just-In-Time, Adaptive Interventions (JITAIs)

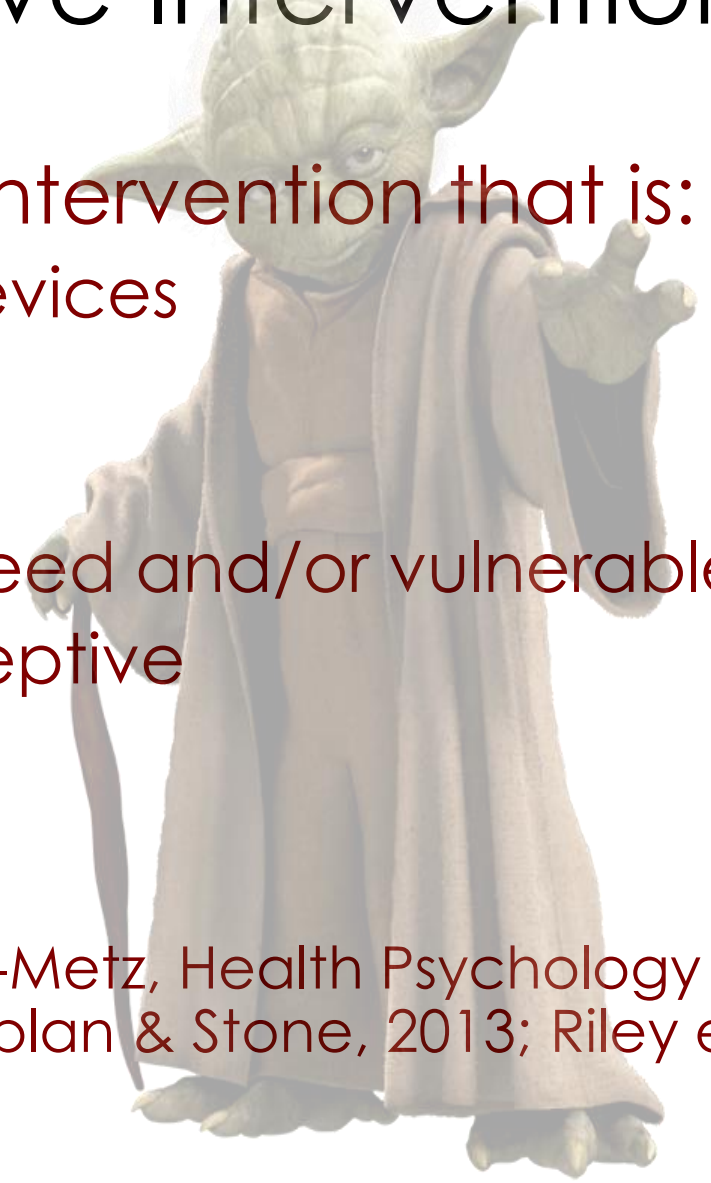
(Nahum-Shani et al, Health Psych 2015)

Intensively Adaptive Interventions (IAIs)

(Riley et al, Current Op Psych 2015)

Just In Time Adaptive Interventions

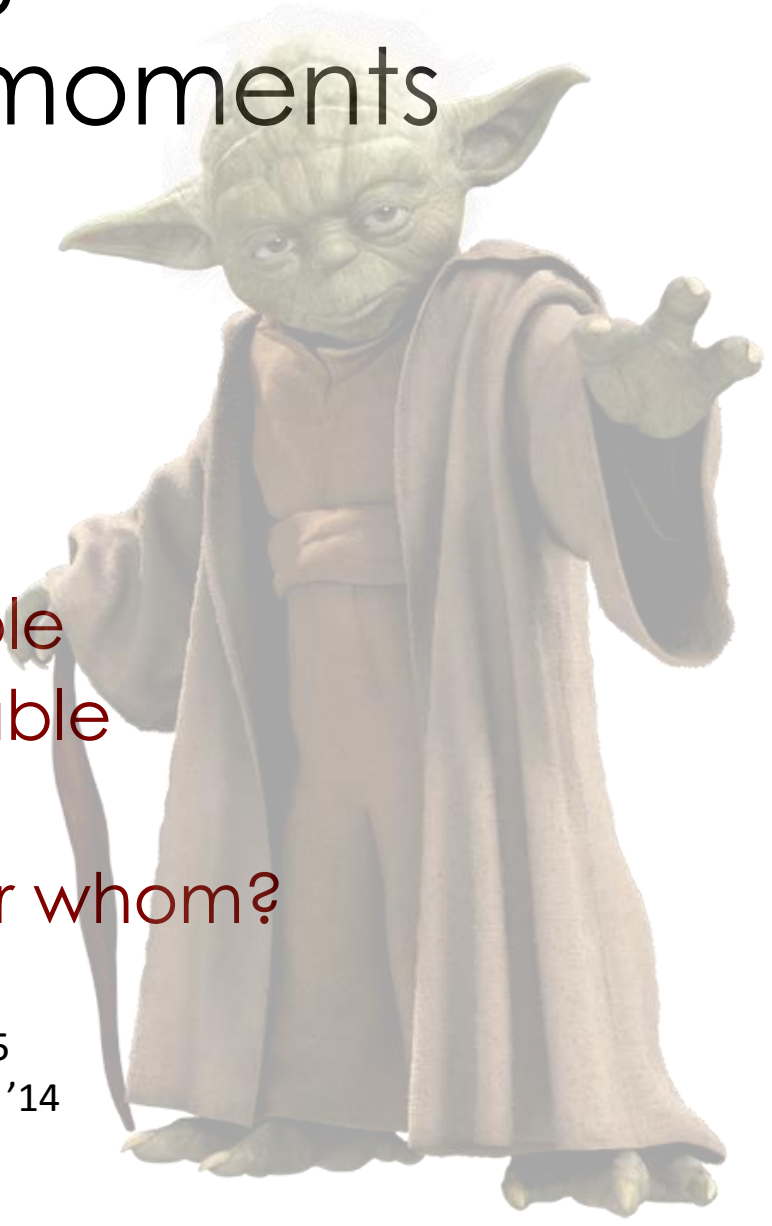
- A JITAI is an adaptive intervention that is:
  - Delivered via mobile devices
  - Anytime
  - Anywhere
  - When the person is in need and/or vulnerable
  - When the person is receptive
  - (Meaningful Moments)



(Nahum-Shani, Hekler & Spruijt-Metz, Health Psychology 2015; Heron & Smyth, 2010; Kaplan & Stone, 2013; Riley et al., 2011)

Learning algorithms: Meaningful moments

- Receptivity[1]
- Availability[2]
- Opportune moments[3]
- Threshold Conditions[4]
  - In need and/or vulnerable
  - Receptive and/or available
  - Motivated and/or able
  - What, when, where & for whom?



[1] Nahum-Shani, Hekler, Spruijt-Metz, Health Psych 2015
[2] Sharmin, Ali, Rahman, Bari, Hossain, Kumar, UbiComp '14
[3] Poppinga, Heuten, Boll, Pervasive Computing 2014
[4] Hekler, Michie, Spruijt-Metz et al *under review*

KNOWME Networks

- A suite of mobile, Bluetooth-enabled, wireless, wearable sensors
- That interface with a mobile phone and secure server
- To process data in real time,
- Designed specifically for use in overweight minority youth

Emken et al, *Journal of physical activity & health,* 2012;
Li et al, *IEEE trans. on neural syst. and rehab. engineering,* 2010;
Thatte et al, *IEEE transactions on signal processing,* 2011

Your Activity Meter

Active Time in the Last 60 Minutes

Each bar = 30 seconds
20 bars = 10 minutes

Sedentary Time (since the last reset)

Total Active Time

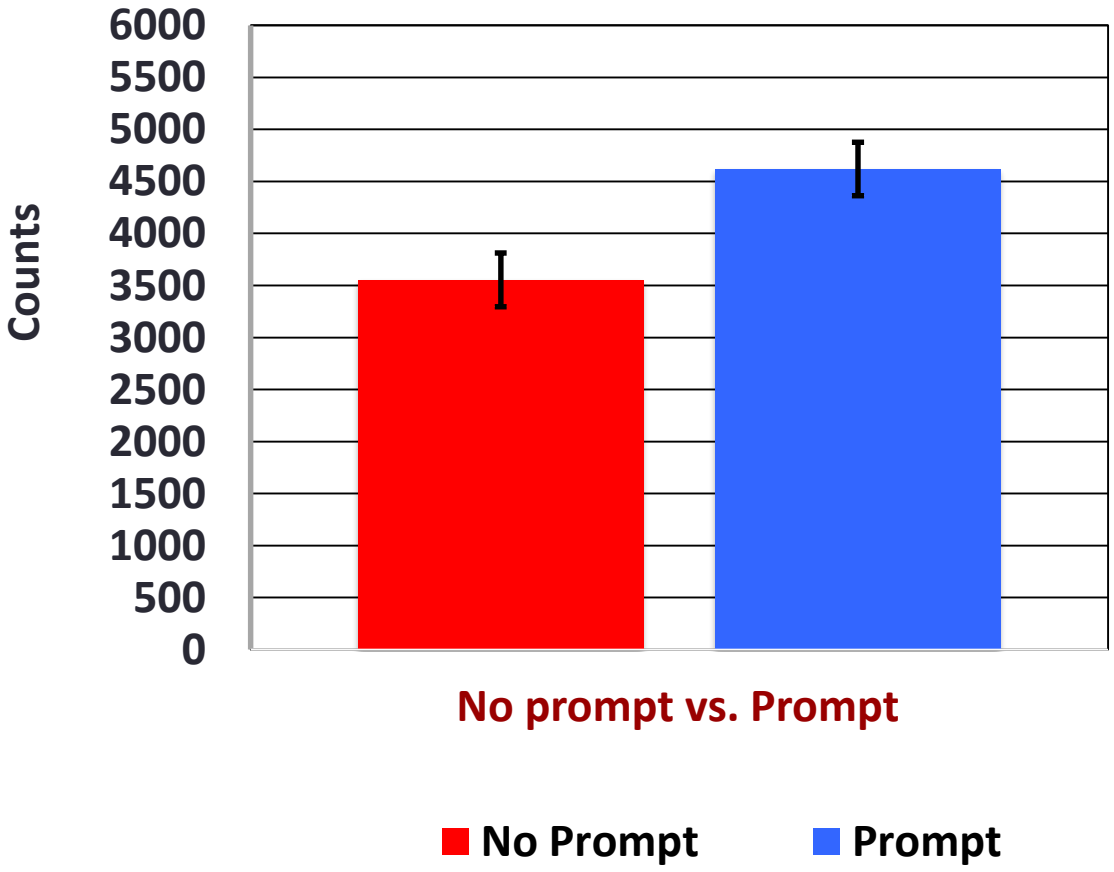
Elapsed Time : 58

Total Elapsed Time

Battery Indicator for Each Device

Sedentary = lying down, sitting, sitting & fidgeting, standing, standing & fidgeting
Active = standing playing Wii, slow walking, brisk walking, running

Did SMS Prompts Directly Impact Subsequent Activity?



- Accelerometer counts were 1,066 counts higher
- in the following 10 minute period
- compared to when SMS prompts were not sent ($p<0.0001$)

Curr Obes Rep
DOI 10.1007/s13679-015-0183-6

CrossMark

HEALTH SERVICES AND PROGRAMS (SFL KIRK, SECTION EDITOR)

Innovations in the Use of Interactive Technology to Support Weight Management

D. Spruijt-Metz[1] · C. K. F. Wen[1] · G. O'Reilly[1] · M. Li[1,2] · S Lee[1] · B. A. Emken[1] · U. Mitra[1] · M. Annavaram[1] · G. Ragusa[1] · S. Narayanan[1]

If behavior change is hard:

Maintaining that change is harder

- Behavior change methods tend to inhibit, rather than erase, the original behavior.
- Behavior change
  - specific to the "context" in which it is learned.
  - many ways to relapse
  - inherently unstable and unsteady process

Bouton, Prev Med 2014

King & Queen

Systems that are Aware of the User: SimSensei

- Shares with SimCoach the goal of providing information and support to returning veterans
- BUT much richer perception of user
  - Computer vision
  - Voice tracking
  - Speech recognition
- ***MultiSense:*** integrates diverse inputs & infers user state
- ***Simsensi:*** responds appropriately
- ***Moving to mobile***

Rizzo, Morency, Bolas, Forbell, Gratch, Hartholt, Marsella, Traum, Lucas et al, Comp in Human Beh, 2014.

a natureresearch journal

npj | Digital Medicine

Open for Submissions

Part of the Nature Partner Journal series, *npj Digital Medicine* is published in partnership between Springer Nature and the Scripps Translational Science Institute.

npj Digital Medicine will publish the highest quality digital medicine research, including the clinical implementation of digital and mobile technologies, virtual healthcare, data analytic methodologies and innovative sensor development to provide the necessary data and longitudinal monitoring to best inform the broadest medical community.

Find out more about the benefits of submitting your paper: nature.com/npjdigitalmed

In partnership with

Scripps Translational Science Institute

Part of the Nature Partner Journals series

npj nature partner journals

Thank you! Any questions? Please stay connected!

Donna Spruijt-Metz,
dmetz@usc.edu