mHealth⁴: Monitoring, Modelling, Modifying and Maintaining health-related behavior in a digital world

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IoT mHealth⁴:

- Monitoring, modeling, modifying and maintaining health-related behaviors
- In Real-Time
- And in Context
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
- Gyrosopes
- GPS
- Microphones
- Compass. Apps
- Phone, email, text
- Internet, Social networks
- Real-time data transfer
mHealth\textsuperscript{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)

Stankovic et al, Ubicomp 2016
Ubiquitous measures

- Eating (Smartwatch)
- Who is in the room (Smartwatch ID & Beacons)
- Opening of cabinets, drawers, refrigerator (Beacons)
- Speaker Identification (Trained algorithms from sound)
- Mood (prosody)
- Length of meal (Smartwatch)
- Speed of eating (Smartwatch)
Signal-Driven & Scheduled Ecological Momentary Assessment

**Trigger: Sensed mood**
- Cause of stress, anger, happiness, sadness

**Rule-based schedule**
- Vigor, Fatigue,
  - Anxiety, positive affect

**Trigger: Sensed eating event**
- Eating in the absence of hunger
- Self-regulation
- Mindfulness

**Trigger: Participant-reported event or mood**
- Text, picture, or sound recording
What we want to know about eating

- Where
- When
- With whom
- Length of event
- Speed
- Mood
- Stress and anxiety
- Hunger Level
- Concurrent Activities (TV, phone use)
- Kitchen cabinet & refrigerator access
- Prior and Post Activities
mHealth^4: Monitor, Model, Modify & Maintain Behavior

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

William T Riley, PhD, Daniel E Rivera, PhD, Audie A Atienza, PhD, Wendy Nilsen, PhD, Susannah M Allison, PhD, Robin Merelstein, PhD
M2FED: Monitoring and Modeling Family Eating Dynamics

Spruijt-Metz, Lach, Stankovic & de la Haye
Our Current Theories are Static

- Relatedness
- Perceived Competence
- Control
- Self-regulation
- Support

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

Donna Spruijt-Metz, MFA, PhD, Eric Hekler, PhD, Niilo Saranummi, PhD, Stephen Intille, PhD, Ilkka Korhonen, PhD, Wendy Nilsen, PhD, Daniel E. Rivera, PhD, Bonnie Spring, PhD, Susan Michie, PhD, David A. Asch, PhD, Alberto Sanna, PhD, Vicente Traver Salcedo, PhD, Rita Kukakfa, PhD, Misha Pavel, PhD
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 😊)
Idiographic vs. Nomothetic

Differences between individuals

Patterns within one individual
Learning and adaptive

- Ongoing measurement
- Sensing change
- Adapting feedback
- Ongoing measurement
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 (JITAI)$^s$

(Nahum-Shani et al, Health Psych 2015)

Intensively Adaptive Interventions (IAI)$^s$

(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

Li et al, *IEEE trans. on neural syst. and rehab. engineering*, 2010;
Thatte et al, *IEEE transactions on signal processing*, 2011
Your Activity Meter

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

Battery Indicator for Each Device

Active Time in the Last 60 Minutes
Each bar = 30 seconds
20 bars = 10 minutes

Sedentary Time (since the last reset)
Total Active Time
Total Elapsed Time
Elapsed Time: 58

Total Active Time
Battery Indicator for Each Device
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)
Innovations in the Use of Interactive Technology to Support Weight Management

D. Spruijt-Metz¹ · C. K. F. Wen¹ · G. O’Reilly¹ · M. Li¹,² · S Lee¹ · B. A. Emken¹ · U. Mitra¹ · M. Annavaram¹ · G. Ragusa¹ · S. Narayanan¹
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

context

SUPPORT
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
• Simsensei: responds appropriately
• Moving to mobile

Open for Submissions

EDITORS-IN-CHIEF: Dr. Steven R. Steinhusl and Dr. Eric J. Topol


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Thank you! Any questions?
Please stay connected!

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