Geeks and Gadgets:
Using wireless technology to improve the assessment and intervention of physical activity and diet

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{acknowledgements}

• Eric Hekler (Arizona State University)
• Aaron Coleman (Small Steps Lab, San Diego)
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• John Froehlich (U Maryland)
• Jacqueline Kerr (UCSD)
• Anjali Gupta (UCSD)
What is a geek?
Conclusions

✓ Stop chasing gadgets (you’ll lose).
✓ Don’t rely on PA or diet researchers to build gadget-based solutions.
✓ Talk nerdy to me.
✓ Data are King. Theory is Queen.
✓ Someone you’ve never heard of has probably done 50% of the work already. Find them.
<table>
<thead>
<tr>
<th>Disease</th>
<th>mHealth Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alzheimer’s</td>
<td>Wireless sensors can track the vital signs of patients as well as their location, activity, and balance</td>
</tr>
<tr>
<td>Asthma</td>
<td>Wireless devices can track respiratory rate and peak flow so patients can use inhalers before an attack occurs</td>
</tr>
<tr>
<td>Breast Cancer</td>
<td>Women can use a wireless ultrasound device at home and send the scan to the doctor—won’t have to go in for a mammogram</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disorder</td>
<td>Wireless can monitor FEV1, air quality and oximetry</td>
</tr>
<tr>
<td>Depression</td>
<td>Wireless can monitor medication compliance, activity and communication</td>
</tr>
<tr>
<td>Diabetes</td>
<td>Wireless can monitor blood glucose and hemoglobin</td>
</tr>
<tr>
<td>Heart Failure</td>
<td>Wireless can monitor cardiac pressures, fluids, weight and blood pressure</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Wireless can continuously monitor blood pressure and track medication compliance</td>
</tr>
<tr>
<td>Obesity</td>
<td>Wireless scales can track weight and wireless sensors can track energy expenditure</td>
</tr>
<tr>
<td>Sleep disorders</td>
<td>Wireless sensors can monitor each of the phases of sleep for quality of rest, detect apnea and track vital signs</td>
</tr>
</tbody>
</table>

Adapted from Topol, E (2010). The future of wireless medicine.
WENT TO THE MOON
TOOK 5 PHOTOS

WENT TO THE BATHROOM
EATLIVER.COM
TOOK 37 PHOTOS

www.pewresearch.org/millennials
we’re increasingly connected...

Do You Have a Profile on a Social Networking Site?
% saying “yes”

All 41

Millennial (18-29) 75
Gen X (30-45) 50
Boomer (46-64) 30
Silent (65+) 6

Based on 2010 data from a nationally representative sample of 2,020 US adults (www.pewresearch.org/millennials)
...perhaps ‘tethered’ is more appropriate?

Based on 2010 data from a nationally representative sample of 2,020 US adults (www.pewresearch.org/millennials)
But can behavioral science keep up?
“It takes 17 years to turn 14 per cent of original research to the benefit of patient care” (Balas & Boren, 2000).

Annu. Rev. Public Health. 30:151–74
1 billion users

775,000 apps in App Store; >1,000,000 Google Play

Adapted from Eric Hekler, Arizona State University; http://www.designinghealth.org/
In less time than it takes to complete a standard research grant, we’ve gone from zero to >1 million apps.

Adapted from Eric Hekler, Arizona State University; http://www.designinghealth.org/
We will never keep up.
Like, ever.
Get qualified medical advice when you need it.

12 weeks

Get qualified medical advice when you need it.

Help college students lose weight responsibly.

6 years

NIH grant - design & deliver RCT.

Urgent Care is #1 Medical App

Lean Start Up & Agile Develop. Iteratively tested.

Results of RCT (n=404) available 2014.
Goal Getter

Your Goal

Friends

Setting

- Design a mobile app to help people set SMART goals and robust implementation intentions to assist weight-related behavior change
- Theory-driven, packed with evidence-based strategies
- Embedded social support via FB
- Created our own API
The tragedy of science is a beautiful hypothesis slain by an ugly fact

Thomas Huxley
The Science of Human Computer Interactions (HCI)

Goal: the design and creation of useful and useable technologies

“If it needs instructions, it’s too complicated”

today's PA/Diet gadget research is about yesterday's technology

academic research
✓ idea generation
✓ pilot study
✓ grant application
✓ grant funding
✓ intervention trial
✓ publication

industry
✓ idea generation
✓ idea screening
✓ concept development
✓ rapid prototyping
✓ test marketing
✓ commercialization

3-18 years
3 weeks - 3 years
We need to start asking better questions...

- What are the most potent behavioral strategies and how do we get them embedded in new technology?
- Are our behavioral theories relevant in a mobile, always-on environment?
- How do we integrate existing data sources to better predict behavior ‘in the wild’?
How do you change PA & Diet behavior?
(an evidence-based approach)

40 strategies seem to work**
5 strategies work well**

Self-monitoring Feedback
Prompt intention formation
Prompt goal setting
Prompt goal review

Potency


How e-relevant are our behavioral theories?

...in an age of Big Data
(high temporal resolution in real time)
static, linear, between-subject focus (OLD) vs. dynamic, non-linear, within-subject focus (NEW)

An approach that is gaining momentum...

Control systems engineering
Example of control systems engineering model applied to intervening on smoking urges

\[ \frac{dy}{dt} = K_{d1} d_1(t) - K_{u1} u_1(t) - K_{u2} u_2(t) - K_{d2} d_2(t) \]

Illustration of control systems dynamical model for smoking urge

Research Challenge 1:
How can we collect and integrate sensor data to accurately infer behavior and context?

Research Challenge 2:
How and when do we give you feedback about this data? What sensory mechanisms are most receptive?

Research Challenge 3:
Can we detect that you are changing your behavior due to the feedback? Under what conditions is the likelihood of behavior change the greatest?

adapted from John Froehlich, U Maryland
We need to start asking better questions

...and adapt our way of doing science
Science 2.0 = Team Science
(aka transdisciplinary science)

by collaborating in new ways...
“Our highest priority is to develop and use the most resource effective funding, research, and dissemination methods possible, with particular emphasis on time effectiveness, to positively impact complex societal problems through solutions focused research”

The agile science manifesto; bit.ly/agilescience
two agile-science-friendly methods

The Multiphase Optimization Strategy (MOST) and the Sequential Multiple Multiple Assignment Randomized Trial (SMART)

New Methods for More Potent eHealth Interventions

Linda M. Collins, PhD, Susan A. Murphy, PhD, Victor Strecher, PhD

Abstract: In this article two new methods for building and evaluating eHealth interventions are described. The first is the Multiphase Optimization Strategy (MOST). It consists of a screening phase, in which intervention components are efficiently identified for inclusion in an intervention or for rejection, based on their performance; a refining phase, in which the selected components are fine tuned and issues such as optimal levels of each component are investigated; and a confirming phase, in which the optimized intervention, consisting of the selected components delivered at optimal levels, is evaluated in a standard randomized controlled trial. The second is the Sequential Multiple Assignment Randomized Trial (SMART), which is an innovative research design especially suited for building time-varying adaptive interventions. A SMART trial can be used to identify the best tailoring variables and decision rules for an adaptive intervention empirically. Both the MOST and SMART approaches use randomized experimentation to enable valid inferences. When properly implemented, these approaches will lead to the development of more potent eHealth interventions.

two agile-science-friendly methods

**Multiphase Optimization Strategy Testing (MOST)**

**Convention**: RCT 1.0 → Post hoc analysis → Intervention revision → RCT 2.0

**Problem**: time consuming, expensive, inefficient, biased

**Solution**: Use series of short randomized experiments prior to the RCT to:

i. Determine candidate strategies

ii. Fine tune strategies

iii. Confirm efficacy

**Sequential Multiple Assign. Randomized Trial (SMART)**

**Convention**: Intervention is written in stone @ baseline.

**Problem**: some strategies may be more or less effective for certain people.

**Solution**: Progress with intervention is assessed iteratively and adjustments (new group assignment) made in systematic controlled manner.
<table>
<thead>
<tr>
<th>Physical Activity/SB</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Narrative reviews</td>
<td>• Narrative reviews</td>
</tr>
<tr>
<td>• Accelerometry &amp; GPS</td>
<td>• Dietary biomarkers</td>
</tr>
<tr>
<td>• Phone-based sensing</td>
<td>• Augmented self-reports (web, mobile, interactive)</td>
</tr>
<tr>
<td>• Activity classification via machine learning</td>
<td>• Camera-based assessment of nutrient intake and eating</td>
</tr>
<tr>
<td>• Context aware measures</td>
<td>• Chew and swallow detection</td>
</tr>
<tr>
<td>• Shift from waist to wrist?</td>
<td></td>
</tr>
<tr>
<td>• compliance</td>
<td></td>
</tr>
<tr>
<td>• 24 hour monitoring</td>
<td></td>
</tr>
</tbody>
</table>
METHODS OF MEASUREMENT IN EPIDEMIOLOGY

Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology

A-K Illner, H Freisling, H Boeing, I Huybrechts, SP Crispim and N Slimani

1Dietary Exposure Assessment Group, Nutrition and Metabolism Section, International Agency for Research on Cancer (IARC), Lyon, France and 2Department of Epidemiology, German Institute of Human Nutrition Potsdam-Rehbruecke, Nuthetal, Germany

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Food Intake Visual and voice Recognizer (FIVR) using photographs to reduce measurement error of food records

One of the biggest challenges we face: objective monitoring of eating behavior during free living.

Swallowing frequency (times per min)

- No intake
- Pizza
- Yogurt
- Apple
- Peanut butter
- Liquid
- No intake

Time (s)
Using the SenseCam to Improve Classifications of Sedentary Behavior in Free-Living Settings

Jacqueline Kerr, PhD, Simon J. Marshall, PhD, Suneeta Godbole, MPH, Jacqueline Chen, BS, Amanda Legge, BS, Aiden R. Doherty, PhD, Paul Kelly, MS, Melody Oliver, PhD, Hannah M. Badland, PhD, Charlie Foster, PhD

Background: Studies have shown relationships between important health outcomes and sedentary behavior, independent of physical activity. There are known errors in tools employed to assess sedentary behavior. Studies of accelerometers have been limited to laboratory environments.

Purpose: To assess a broad range of sedentary behaviors in free-living adults using accelerometers and a Microsoft SenseCam that can provide an objective observation of sedentary behaviors through first person—view images.

Methods: Participants were 40 university employees who wore a SenseCam accelerometer for 3–5 days. Images were coded for sitting and standing posture and were merged and aggregated to a 60-second epoch. Accelerometer counts per minute were compared with coded behaviors. Sensitivity and specificity analyses were collected in June and July 2011 and analyzed in April 2012.

Results: TV viewing, other screen use, and administrative activities were the highest accelerometer counts. However, standing behaviors also fell under this threshold. Multiple behaviors occurred simultaneously. A nearly 30-minute interval was found in sedentary behavior estimates based on the accelerometer versus images.

Conclusions: Researchers should be aware of the strengths and weaknesses of the accelerometer cutpoint for identifying sedentary behavior. The SenseCam may be a useful tool in free-living conditions to better understand health behaviors such as sitting.

International SenseCam & Pervasive Imaging Conference 2013

Ethics, Analysis, and Applications of Life Log Imaging to Health and Related Behaviors

November 18 – 19, 2013
Qualcomm Institute at CALIT2
UC San Diego

Deadline for Submissions: June 30, 2013
Contact: jkerr@ucsd.edu
sensecam.ucsd.edu

Organizers: Jacqueline Kerr (UCSD), Kevin Patrick (UCSD), Simon Marshall (UCSD), Serge Belongie (UCSD), Deb Forster (UCSD), Nadir Weibel (UCSD), Mingui Sun (Pittsburgh), Tom Baranowski (Baylor), Cathal Gurrin (Dublin), Charlie Foster (Oxford)

shameless plug
## The status of the technology-focused intervention literature

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Physical Activity</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Years behind. Web-based is high tech??</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Emergence of novel strategies (e.g., EARLY trials in USA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reviews of theory and/or behavioral strategies embedded in commercially available apps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Efficacy data dominated by text messaging</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Time-insensitive (context ignorant)</td>
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</tr>
</tbody>
</table>
Apps of Steel: Are Exercise Apps Providing Consumers With Realistic Expectations? A Content Analysis of Exercise Apps for Presence of Behavior Change Theory

Logan T. Cowan, MPH (c)¹, Sarah A. Van Wagenen, MPH (c)¹, Brittany A. Brown, MPH (c)¹, Riley J. Hedin, MPH (c)¹, Yukiko Seino-Stephan, MPH (c)¹, P. Cougar Hall, PhD¹, and Joshua H. West, PhD¹

Abstract

Objective. To quantify the presence of health behavior theory constructs in iPhone apps targeting physical activity. Methods. This study used a content analysis of 127 apps from Apple’s (App Store) Health & Fitness category. Coders downloaded the apps and then used an established theory-based instrument to rate each app’s inclusion of theoretical constructs from prominent behavior change theories. Five common items were used to measure 20 theoretical constructs, for a total of 100 items. A theory score was calculated for each app. Multiple regression analysis was used to identify factors associated with higher theory scores. Results. Apps were generally observed to be lacking in theoretical content. Theory scores ranged from 1 to 28 on a 100-point scale. The health belief model was the most prevalent theory, accounting for 32% of all constructs. Regression analyses indicated that higher priced apps and apps that addressed a broader activity spectrum were associated with higher total theory scores. Conclusion. It is not unexpected that apps contained only minimal theoretical content, given that app developers come from a variety of backgrounds and many are not trained in the application of health behavior theory. The relationship between price and theory score corroborates research indicating that higher quality apps are more expensive. There is an opportunity for health and behavior change experts to partner with app developers to incorporate behavior change theories into the development of apps. These future collaborations between health behavior change experts and app developers could foster apps superior in both theory and programming possibly resulting in better health outcomes.
<table>
<thead>
<tr>
<th>App</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workout Free</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>in Masters</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>No Fitness Tracker and Timer</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>o dy</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Workout</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Bar</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Workout</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>it</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Bio Workout</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Free</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Workout Free</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Free Log</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Bio Workout Free</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Workout Free</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Mean theoretical potency score = 10.1 ! (/100) Range = 1-28!

Middelweerd et al. ISBNPA 2013, oral presentation

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Number of Apps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prompt self-monitoring of behavior</td>
<td>48</td>
</tr>
<tr>
<td>Provide feedback on performance</td>
<td>30</td>
</tr>
<tr>
<td>Prompt specific goal setting</td>
<td>30</td>
</tr>
<tr>
<td>Plan social support or social change</td>
<td>26</td>
</tr>
<tr>
<td>Provide contingent rewards</td>
<td>22</td>
</tr>
<tr>
<td>Provide instruction</td>
<td>22</td>
</tr>
<tr>
<td>Provide information about behavior health link</td>
<td>16</td>
</tr>
<tr>
<td>Prompt practice</td>
<td>16</td>
</tr>
<tr>
<td>Provide opportunities for social comparison</td>
<td>16</td>
</tr>
<tr>
<td>Model or demonstrate the behavior</td>
<td>12</td>
</tr>
<tr>
<td>Prompt intention formation</td>
<td>12</td>
</tr>
<tr>
<td>Set graded tasks</td>
<td>12</td>
</tr>
<tr>
<td>Prompt review of behavioral goals</td>
<td>10</td>
</tr>
<tr>
<td>Use follow-up prompts</td>
<td>10</td>
</tr>
<tr>
<td>Time management</td>
<td>8</td>
</tr>
<tr>
<td>Teach to use prompts or cues</td>
<td>8</td>
</tr>
<tr>
<td>Agree on behavioral contract</td>
<td>8</td>
</tr>
<tr>
<td>Stress management</td>
<td>6</td>
</tr>
<tr>
<td>Relapse prevention</td>
<td>6</td>
</tr>
<tr>
<td>Prompt self-talk</td>
<td>6</td>
</tr>
<tr>
<td>Prompt identification as a role model</td>
<td>6</td>
</tr>
<tr>
<td>Prompt barrier identification</td>
<td>6</td>
</tr>
<tr>
<td>Motivational interviewing</td>
<td>6</td>
</tr>
</tbody>
</table>

# apps with evidence based behavior change strategies embedded (Abrahams & Michie taxonomy)
Direct to consumer ‘smart wearables’

- Estimated ~$1.5bn in 2014

www.fitbit.com

✓ Biggest user base
✓ Waist & wrist devices
✓ Triaxial accel & vib. mtr
✓ Bluetooth 4.0 synch
✓ ~5 dys on single charge
✓ Wrist = no display/altim.
✓ Tracks steps, sleep
  • ↓ EE ~28%\textsuperscript{1}
  • ↑ sleep efficiency ~15%\textsuperscript{2}

✓ App enables social comparison
✓ Open API to developers

\textsuperscript{2}Montgomery-Downs et al (2012) Sleep Breath. 6:913–917
NIKE FuelBand

• Part of NIKE+ suite
• Wrist accelerometer
• On-board display of ‘normalized’ PA score (NIKE Fuel)
• Compare and compete in FB and Twitter
• Bluetooth
• iOS/Web only, no Android
Jawbone UP

• v1.0 was disaster. v2.0 is good.
• Accelerometer & vibration motor
• iOS and Android
• Tracks PA, SB, Sleep, & Diet
• ~10 days on single charge
• Can ‘Step UP’ to FB.
• Just launched new API for developers (May 2013)
• Purchased BodyMedia for >$100m last month
  • No Bluetooth or NFC
  • No on-board display
  • Entirely app-reliant
http://www.mybasis.com/

✓ B1 just released
✓ First wrist device to have triaxial accel. plus:
  • heart rate
  • skin temperature
  • GSR
✓ Integrates to predict PA/SED/Sleep
✓ Requires web-based portal to view data
X No on-board prompting
LiT device (NZNLabs.com)

- Crowd funded
- Triaxial accel. & gyroscope
- Plans to open API
- Accompanying iOS app merges HR, GPS, and image/video data
- Machine learning
- Bluetooth 4.0.
http://www.lumoback.com/

Crowd funded new device

- Designed for posture training but can also detect sitting time, breaks in sitting, walking and running
- Accel & vibration motor
- iOS only
- API coming
Queries FitBit database in real time
Runs data analytics on indiv. or grps
Goal = work with any device with open API

Aaron Coleman
@aarondcoleman
aaron@smallsteplabs.com
Growing research literature on phone-based sensing for activity classification

Triaxial accelerometer

Gyroscope
Example: SenSed

### Confusion Matrix (Android Data)

**J48 Decision Tree Classification**

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Classified as</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
</tr>
</thead>
<tbody>
<tr>
<td>96%</td>
<td>C1 = Walking</td>
<td>4007</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>169</td>
<td>0</td>
</tr>
<tr>
<td>97.6%</td>
<td>C2 = Sitting</td>
<td>1</td>
<td>3797</td>
<td>0</td>
<td>92</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>100%</td>
<td>C3 = Jogging</td>
<td>0</td>
<td>0</td>
<td>1024</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>98.2%</td>
<td>C4 = Standing</td>
<td>0</td>
<td>76</td>
<td>0</td>
<td>4235</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>89.8%</td>
<td>C5 = Upstairs</td>
<td>224</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1990</td>
<td>0</td>
</tr>
<tr>
<td>99.9%</td>
<td>C6 = Downstairs</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1946</td>
</tr>
</tbody>
</table>
What’s the next big trend in phone based sensing?
geofencing

a virtual boundary corresponding to a physical area

✓ Compatible with 92% of mobile phones
✓ No downloading or activating an app
The geo-fence hack. First context-aware platform for Android & iOS developers.

Powerful Gimbal™ analytics give you insight into real world activities.

https://www.gimbal.com/
http://www.moves-app.com/

Moves
Let your iPhone tell you how much you move.

Get the Free App
Storyline
Moves is an automatic diary of your life. Your daily storyline and maps show where, when and how much you move.

Step counter
Moves is a free iPhone pedometer that helps you get fit by walking more. See how many steps you take and aim for a healthy exercise goal of 10,000 steps a day.

What’s the benefit?
Seeing your everyday exercise helps you think about your life in a new way. Start with small changes that can lead to healthy habits and losing weight naturally.
A Simple Timeline Of Your Day

Created Automatically

Breadcrumbs.us
Mindful Eating

Enjoy Your Food with HAPIfork by JACQUES LÉPINE

Hapifork, Eat Slowly - Lose Weight - Feel Great

Lunch at Les Halles
Paris, January 15, 2013

Duration: 26:32
Fork Servings: 59
Average Interval: 12 sec
Success Rate: 77%

Success Rate:
- Not bad, but you can do better!
- Learn how

Overspeed Fork Servings:
- 14
- Overspeed Ratio: 23%

Meal Stats:
- Meal started: 29/06/2012 01:48 pm
- Meal ended: 29/06/2012 02:14 pm
- Healthy meal score: ★★★☆☆
- Tags: pasta, carbs, fine dining
- Description:
  Had a heavy pasta dinner at Les Halles. I think I ate too much, and too quickly. Next time I'll pace myself and try to eat more slowly.

Recommendations

Researchers: focus on the underlying mechanisms of how to measure and change behavior in real-time and work with others to embed them in new technologies

Practitioners: choose technologies that rely on evidence-based strategies
Join the tech ecosystem by finding thought leaders; learn nerd-talk
Read more. Watch more.
Let your ideas have sex
Dare to innovate science (methods, theory)
Have big ideas
WHATEVER YOU DO
ALWAYS GIVE
100% UNLESS YOU'RE
DONATING BLOOD

{end}