Micro-Randomized Trials: The Design for Optimizing Just-in-Time Adaptive Interventions

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97,000+ mobile apps for health & fitness

$20 billion: mHealth industry size by 2018
Ubiquitous Computing Technology for Just-in-Time Motivation of Behavior Change

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Abstract

This paper describes a new "just-in-time" user interface that can be used to actively consume information or consequences of behavior. It can also present messages to encourage behavior change. Together, new ubiquitous computer systems that can permit information to be conveyed to users at just the right time and place. In combination, computer systems that present messages at the right time and place can be developed to motivate physical activity and healthy eating. Computational sensing technologies can also be used to measure the impact of the motivational technology on behavior.

Keywords:
computer, behavior change, ubiquitous computing, preventive health, nutrition, physical activity

There are four components to an effective strategy to prompt behavior change:
- Present a simple message that is easy to understand
- At just the right time
- At just the right place
- In a non-annoying way.

These sensors typically monitor for a very specific medical situation, such as an irregular heartbeat or a sudden fall followed by immobility.

Systems that detect declines in health

Detecting a gradual change in health status will generally require multiple, multi-modal sensors. For instance, based on interviews with medical professionals at MIT we have developed a prototype system to automatically monitor an individual in the home for congestive heart failure using input from sensors in the environment and devices worn by the person such as a wristband with accelerometers.
When I was tucking myself to sleep, my new apple watch suddenly shook itself and told me this. #applewatchnoslackphysicalactivity
mHealth Design Goals

We should aim to develop systems that...

• Have effective components
• For each person, deliver right interventions at the right times and in the right context
• Can be used long-term
• Adapt to an individual’s changing goals, capabilities, and circumstances
We Need Methods to Determine...

• *Whether* individual intervention components are effective and how their effectiveness changes over time
• *When* individual interventions should be delivered to optimize effectiveness
• To *whom* and in *what contexts* they should be delivered
• How to dynamically manage user *burden* and perceived *value*
HeartSteps Goals

• Help individuals increase—and sustain—their physical activity levels
• Increase activity by supporting *opportunistic* physical activity—activity that people can do throughout the day
HeartSteps Intervention Components

• Actionable, context-aware suggestions for walking
• Planning of when, how, and where one will be active the next day
Suggestions

Suggestions tailored on:
- time of day
- weekday vs. weekend
- location
- weather

Two types of suggestions:
- to walk
- to interrupt sitting
Message Examples

Have a long conference call today? Walking in place or pacing while you talk can keep you engaged and increase your step count!

There's no better way to spend a weekend evening than taking a walk around the neighborhood! Are you up for it?

It’s important to hydrate. If you walk to the water fountain now, you can refill your bottle while also stretching your legs!
Planning

Two types of planning:

• Generate a new plan
• Select a plan from a list of previous and suggested plans
Questions to Optimize HeartSteps Suggestions

• Do contextual suggestions have an effect at all?
• Do active and sedentary suggestions work equally well?
• Does the effect of suggestions change over time? (e.g., do people get tired of them after a while?)
• When should we send suggestions for optimal effect?
  • Do they work better during certain parts of the day?
  • Do they work better when weather is good vs. bad?
• Is the suggestion effectiveness, including contexts in which they work, different for different types of people?
Micro-randomized trials

MRTs in a Nutshell

1. Randomize delivery of a push intervention component each time that component *may be* delivered

2. Capture at each randomization...
   - Proximal outcome for randomized component
   - Contextual factors that may influence response

3. Model
   - Component’s time-varying causal effects
   - Time-varying contextual moderators of those effects
Decision Times

Times when a push intervention component can be delivered, based on...

• Theory and prior experience
• User’s context
• Level of activity of interest
Decision times

- morning commute
- lunch time
- mid-afternoon
- evening commute
- post-dinner
Availability

• Only deliver suggestions when the user is available to receive treatment:
  • Not driving (safety)
  • Not already walking or running (annoyance)
Proximal Outcomes

Most immediate intended outcomes of an intervention component
Proximal Outcomes for Activity Suggestions

Ideal outcome
Did the person do suggested activity?

Chosen outcome
Step count in the 30 minutes from intervention offering/randomization
Proximal & Distal Outcomes

• Proximal outcomes are presumed mediators of desired distal outcomes
  • Micro versions of distal outcome
    15-min walk for walking 10,000 steps a day
  • Part of causal pathway to distal outcome
    Interactions with abstinence-supporting friends for remaining drug-free

• Different components in an intervention can target different proximal outcomes
Unintended Outcomes

Intervention components can also have unintended outcomes

• Burden
• Annoyance
• Alert fatigue
Contextual Moderators
Randomization in MRTs

• A component is randomized at each decision point for each participant
• During a study, each person randomized many times
• Multiple components can be randomized concurrently
• MRTs are sequential, full factorial designs
What Can Be Randomized

• Whether a component is delivered or not
• What version of a component is delivered
• Combination of the two
  50% No-intervention, 25% Type A, 25% Type B
Micro-Randomization in the HeartSteps Pilot Study

• Both components micro-randomized:
  • Suggestions randomized 5 times a day:
    • No-suggestion (40%), active suggestion (30%), sedentary suggestions (30%)
  • Planning randomized every night:
    • No-planning (50%), new plan (25%), pick-a-plan (25%)

• Data captured during the study:
  • Steps, location, weather, calendar, phone application use, user burden, answers to daily questionnaires
What We Learn From MRTs

• Does a component have a proximal main effect and how does that effect change over time?
• Does a component have unintended effects and how they change over time?
• How is a component’s effect moderated by time-varying contextual factors (e.g., location, weather, level of busyness)?
• Does a component have a lagged effect?
Potential Paybacks

• Interventions that can be used long-term to support effective behavior change

• Detailed and precise models of intervention functioning and of human behavior more generally