

Just-in-Time Adaptive Interventions

Susan A Murphy & Daniel Almirall

INSTITUTE FOR SOCIAL RESEARCH
UNIVERSITY OF MICHIGAN

MD2K
Center of Excellence for Mobile Sensor Data-to-Knowledge

The Methodology Center
advancing methods, improving health

30 min.

Introduce HeartSteps as a motivating example

What is a Just-in-Time Adaptive Intervention (JITAI)?

JITAI principles

Q&A and discussion

Outline

- HeartSteps
- Just-in-Time Adaptive Intervention (JITAI)
 - What are they, Motivation
 - Components,
 - Some Principles

Introduce HeartSteps as a motivating example

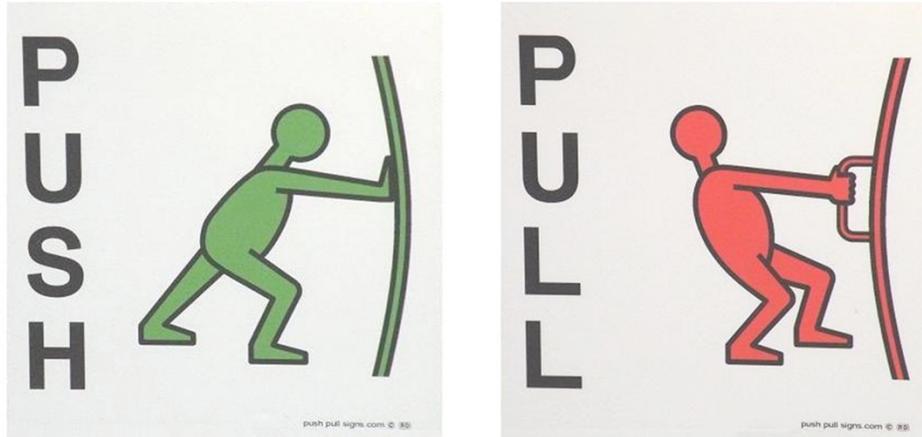
What is a Just-in-Time Adaptive Intervention (JITAI)?

JITAI principles

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

Types of mHealth Intervention Components



As a reminder, we can think of mHealth as enabling two broad classes of interventions: push and pull.

Pull Interventions

Made available to users on the phone but accessed at will

- Graphs and charts for self-monitoring
- Coping strategies, educational materials
- “Help” button to receive coping support



Pull Interventions

- Allow inclusion of many components
- Put user in control of access
- Low burden

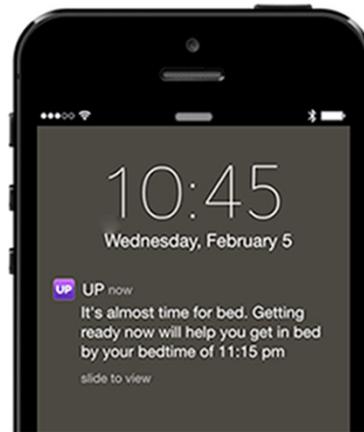
But...

- Depend on users to know when to access them and remember to do it

Push Interventions

Delivered based on time, context, user's state and activities

- Reminders
- Suggestions, tips, motivational messages
- Prompts to set goals, complete self-report...
- Rewards for goal attainment



Push Interventions

- Can use sensing and user modeling to determine right delivery time
- Don't rely on user's awareness of times of need or remembering to access

But...

- High burden

HeartSteps Design Goal

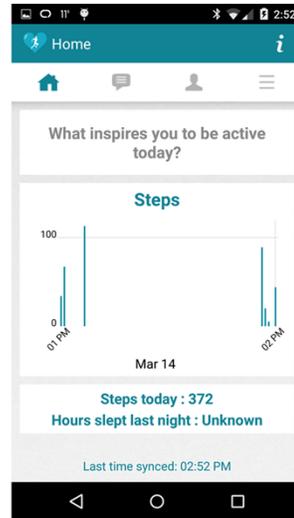
Develop a mobile app intervention that includes the right combination of...

- pull interventions
- push components, *delivered at the right times* to encourage activity throughout the day, as context changes

HeartSteps V1

Pull components:

- Feedback on steps
- Daily "what motivates me" message
- Library of previous activity suggestions



Heartsteps



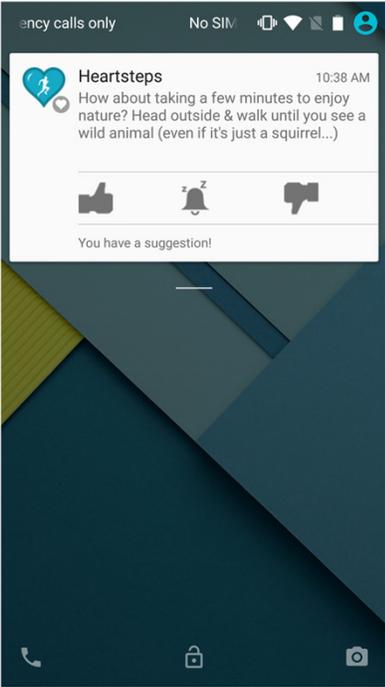
Push components:

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



Help sedentary individuals increase—and sustain—their physical activity levels

Increase activity by supporting *opportunistic* physical activity—activity that people can do throughout the day



Suggestions

Suggestions tailored on:

- time of day
- weekday vs. weekend
- location
- weather

Two types of suggestions:

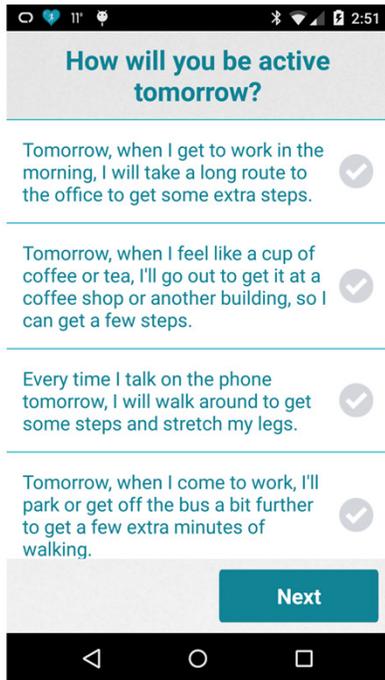
- to walk
- to interrupt sitting

Other 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!

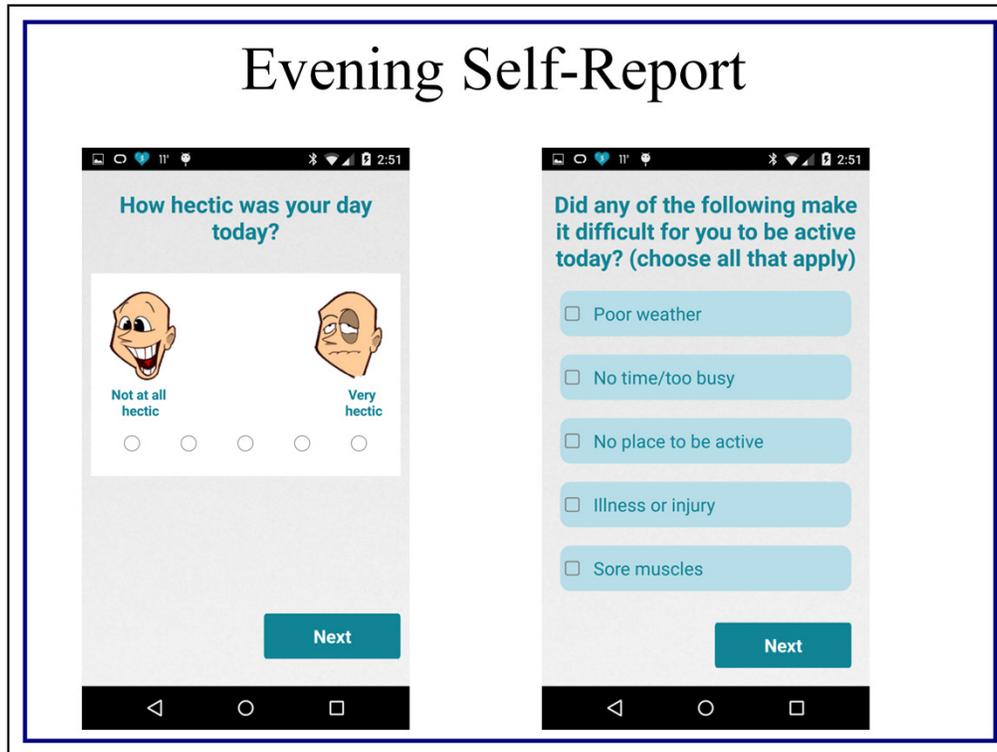


Planning

Two types of planning:

- Generate a new plan
- Select a plan from a list of previous and suggested plans

Evening Self-Report



Question 1 (asked every evening)

Question: How hectic was your day today?

Answer choices: "Not at all hectic" to "Very hectic" radio buttons

Question 2 (asked every evening)

Question: How stressful was your day today?

Answer choices: "Not at all stressful" to "Very stressful" radio buttons

Question 3 (asked every evening)

Question: How typical was today for a workday/weekend?

Answer choices: "Not at all typical" to "Completely typical" radio buttons

Question 4 (asked every evening)

Question: Did you do any of the following today? (choose all that apply)

Answer choices:

Cardio exercise (running, swimming...)

Strength training (weights...)

Flexibility training (yoga, Pilates...)

Heavy housework (scrubbing bathtub...)

Question 5 (only asked if the previous evening the participant was asked to plan how he/she would be active the following day)

Question: Last night you made the following plan to be active today: [PLAN FROM LAST NIGHT]. How did you do with it today?

Answer choices:

I followed my plan completely

I followed my plan in part

I intentionally did another physical activity instead of the one I planned

I did not follow my plan or intentionally did a substitute activity

Question 6 (only asked if the participant received a suggestion that day which then he/she rated thumbs down)

Question: At [TIME OF MESSAGE], you received the suggestion [SUGGESTION MESSAGE] and rated it thumbs-down. Why did you rate it this way? (check all that apply)

Answer choices:

The message did not motivate me to be active

The message was not sufficiently actionable

The suggested activity was too difficult to carry out

The suggested activity was not doable when the message arrived

The suggestion came at a bad time (e.g. I was too busy, too stressed)

The suggestion came too soon after I was last active

Other (FREE FORM RESPONSE)

Question 7 (only asked if the participant received a suggestion that day which then he/she rated thumbs up)

Question: At [TIME OF MESSAGE], you received the suggestion [SUGGESTION MESSAGE] and rated it thumbs-up. Why did you rate it this way? (check all that apply)

Answer choices:

The message motivated me to be active

The suggested activity was easy to carry out

The suggested activity was doable when it arrived

The message piqued my interest

The message made me feel good about working on my health

Other (FREE FORM RESPONSE)

The following questions are used to keep the total number of evening survey questions to 7 if Questions 5, 6, or 7 are not appropriate to ask that evening (see rules for asking them above).

RESEARCH QUESTION 1

Question: Did any of the following make it difficult for you to be active today? (choose all that apply)

Answer choices:

Poor weather

No time/too busy

No place to be active

Illness or injury

Sore muscles

Social obligations

Traffic safety

Personal safety

Other (FREE FORM RESPONSE)

None of the above

RESEARCH QUESTION 2

Question: Did any of the following make it easier for you to be active today? (choose all that apply)

Answer choices:

Others joined me

Others encouraged me

Good weather

I scheduled it in

Facilities/exercise equipment

Location/scenery

Other (FREE FORM RESPONSE)

None of the above

RESEARCH QUESTION 3

Question: How energetic did you feel today?

Answer choices: “Not at all” to “Very energetic” radio buttons

RESEARCH QUESTION 4

Question: At least once today I felt an urge to get up and take a walk

Answer choices: “Strongly disagree” to “Strongly agree” radio buttons

Outline

- HeartSteps
- Just-in-Time Adaptive Intervention (JITAI)
 - What are they, Motivation
 - Components,
 - Some Principles

Introduce HeartSteps as a motivating example

What is a Just-in-Time Adaptive Intervention (JITAI)?

JITAI principles

Designing a Mobile App Intervention

We should aim to develop systems that...

- Have effective components
- For each person, deliver right components at the right times and in the right context
- Can be used long-term
- Adapt to an individual's changing goals, capabilities, and circumstances

If the promise of mobile health is to be fulfilled, we need to do better. We need to design apps that contain effective components, and that deliver those components at the right time and contexts. Just as importantly, we want to be able to design tools that can be used long-term, since that's what is needed to provide support for the long terms behaviors that are core to effective health promotion and risk reduction. This means, though, that we need to desing technologies that can adapt to changing goals, circumstances, and capabilities.

Just-in-Time Adaptive Interventions

- A JITAI is an adaptive intervention
- That is
 - delivered when needed
 - & where-ever needed



(Spruijt-Metz & Nilsen, 2014; Nahum-Shani et al. 2016)

The same elements that we used to describe an adaptive intervention can be used to describe JITAIs, only that now all these elements are in-the-moment.

Dynamic Models of Behavior for Just-in-Time Adaptive Interventions

Donna Spruijt-Metz, University of Southern California Wendy Nilsen, National Institutes of Health

PERVASIVE computing, 1536-1268/14/2014 IEEE

Nahum-Shani, I., Smith, S.N., Spring, B.J., Collins, L.M., Witkiewitz, K., Tewari, A., & [Murphy, S.A.](#) (2016). Just-in-Time Adaptive Interventions (JITAI) in Mobile Health: Key Components and Design Principles for Ongoing Health Behavior Support. *Annals of Behavioral Medicine*. doi:10.1007/s12160-016-9830-8, PMID: PMC5364076

Different terms have been used in various fields to describe a JITAI, including dynamic tailoring, intelligent real-time therapy, and dynamically and individually tailored EMI

Just-in-Time Adaptive Intervention 5 Elements

The adaptation is guided by consideration of

(1) Near-time, Proximal Outcome and Distal Outcome

The adaptation process is composed of

(2) Tailoring Variables,

(3) Decision Rules and

(4) Intervention Options

The adaptation is triggered at

(5) Decision Points

18

Operationalizes an intervention with the goals on prior slide

Distal Outcomes

The goal is to improve a longer-term, distal, outcome

- Substance use cessation; maintain increased activity level; maintain lower weight; maintain adherence to meds

To improve the distal outcome, the intervention options are formulated to target proximal outcomes

In heartsteps the distal outcome might be average steps per day over study duration
In MD2K smoking study the distal outcome might be time to relapse.

Proximal Outcomes

Mediators that may be critical to achieving the long-term goal

- 1) Short term targeted behavior
 - Substance use over x hours
 - Physical activity over x minutes
 - Adherence over next hour
- 2) Short term risk
 - Current craving, stress
- 3) Engagement with mobile app/intervention burden

Likely multiple proximal outcomes

In MD2k study the proximal outcome might be stress over next x minutes.

Intervention options

- Intervention options:
 - Behavioral strategies, cognitive strategies, self-monitoring, social linkages, motivational messages, engagement strategies, reminders
 - Whether to provide an intervention or whether to prompt self-monitoring
 - How to provide an intervention option
 - “Provide nothing” option
- Theoretically/scientifically driven (Klein et al., 2011; West & Michie, 2016)



Intervention options are typically designed to impact distal outcome via the proximal outcome.

In MD2K study the intervention option might be a recommendation to access one of the three stress-regulation apps (headspace; mood-surfing; and ?) residing on the smartphone vs. no recommendation.

Intervention options in JITAIs include types of support, sources of support (e.g., automated sources, social sources); and modes of support delivery.

Recommendations

Reach out recommendation
(contact a friend)

Behavioral strategies (exercise;
stay in locations that are
supportive of change)

Cognitive strategies (relaxation;
reframing)

Motivational messages (reasons
for behavior change; barriers for
change);

Setting goals; modifying goals

Feedback (often with
visualization: fish; flower; garden)

Distractions (game, music, etc.)

Michel Klein et al. have a nice review of health behavior change theories used to inform EMIs

Klein, M., Mogles, N., & van Wissen, A. (2011). Why won't you do what's good for you? Using intelligent support for behavior change. In *Human Behavior Understanding* (pp. 104-115). Springer Berlin Heidelberg.

West, R., & Michie, S. (2016). *A Guide to Development and Evaluation of Digital Interventions in Healthcare*. London: Silverback

Tailoring variables

Tailoring variables are moderators that inform which intervention option is best when, where and for whom.

- Often past proximal outcomes: stress, activity
- Risk, protective, receptivity factors: busyness of calendar, current mood or craving, location, social context, current use of phone
- Adherence & burden

In MD2K smoking study tailoring variables might be current classification of stressed or not and location (home, work), time of day (before work, during work, after work). Also weather.

indicate risk or vulnerability. --internal risk factors , external risk factors: behaviors, social context, geographical location,

When user ignores assessment requests or ignores intervention

Decision Points

Typical decision points in JITAIs:

- Intervals in time (every x seconds, every x minutes, every x hours)
- When user requests help (presses “help” button”)

Frequency is guided by the dynamics of the tailoring variables and “in-the-moment nature” of the intervention effect.

Recall that a decision point is the time in which we need to make critical decisions about the intervention options based on patient information.

decision points can result in the “do nothing intervention option,” hence a decision point every 3 minutes does not imply an intervention every 3 minutes.

Decision Rules

Link tailoring variables to intervention options at decision points

- A decision rule is implemented at each decision point
- A JITAI often includes many different decision rules
- Development of decision rules is guided by an integration of empirical evidence, theory and clinical experience.

• 24

The decision rules are constructed with the aim to impact a proximal outcome.

We can use the data from the micro-randomized study along with behavioral science to construct decision rules.

Decision Rule Example

Physical Activity

- User's activity and current location is monitored
- Ideas for improving current walk in a location delivered by the mobile device *only* if user is currently walking in this location.

(follows Rabbi et al., 2015)

MyBehavior: Automatic Personalized Health Feedback from User Behaviors and Preferences using Smartphones Mashfiqui Rabbi¹, Min Hane Aung¹, Mi Zhang², Tanzeem Choudhury¹

UbiComp '15, Sept 7-11, 2015, Osaka, Japan. Copyright 2015 ACM 978-1-4503-1770-

Automated Personalized Feedback for Physical Activity and Dietary Behavior Change With Mobile Phones: A Randomized Controlled Trial on Adults Mashfiqui Rabbi¹, MS; Angela Pfammatter², PhD; Mi Zhang³, PhD; Bonnie Spring², PhD; Tanzeem Choudhury¹, PhD

Decision Rules: Example 1

At a each minute
If sensors detect walking,
 Then, IO = {push idea for improving walk in current location}
Else if not walking
 Then, IO = {do nothing}

Intervention
option

Tailoring
Variable

Proximal Outcome: Activity

Decision
Point

© 26

Decision Rule Example

Reducing Sedentary Behavior by Office Workers

- Software on the computer measures uninterrupted computer time via mouse and keyboard activity
- Smartphone delivers a message to encourage a walking activity *only* if 30 min. of uninterrupted computer activity occurs



(Dantzig et al., 2013)

Quote from paper: whenever 30 min of nearly uninterrupted computer activity was recorded, a short text message (SMS) containing a hyperlink was sent to the participant's smart phone. When participants clicked on this hyperlink, they were shown a message persuading them to be more active. Although all messages contained the same general advice, this advice was phrased in various ways, using four different persuasive strategies. The four strategies are a subset of the six social influence strategies defined by Cialdini [22].

Dantzig, S., Geleijnse, G., & Halteren, A. T. (2013). Toward a persuasive mobile application to reduce sedentary behavior. *Personal and ubiquitous computing*, 17(6), 1237-1246.

Decision Rules: Example 2

At 1 minute intervals

If current accumulated computer activity $> P_0$

Then, IO = {recommend movement}

Else if current accumulated computer activity $\leq P_0$

Then, IO = {do nothing}

Summary of JITAI elements

1. Outcomes

- Distal (scientific/clinical goal) & Proximal Outcome (guided by mediational theories pinpointing the necessary processes needed to achieve the distal outcome)

2. Intervention options

- Guided by the proximal responses

3. Tailoring variables

- Guided by theory concerning moderation.

4. Decision points

- Guided by the dynamics of the tailoring variable and in-the-moment nature of the effect of the intervention option.

5. Decision rules

© 20

Why a JITAI for HeartSteps?



- Opportunities for physical activity and salience of PA goals vary by situation
- Phones know users' location, state of calendar, weather, and current and recent activity, and can thus know what activities are currently possible and appropriate
- A JITAI can support opportunistic activity by
 - Suggesting specific, doable, and appropriate activities people can do in their current situation throughout the day, as context changes
 - Increasing repertoire of cognitively-accessible activities people can do in different contexts

We decrease barriers to being active by (1) giving them something they can do right now, without them having to remember or think about what the options are; (2) over time increase range of accessible ideas for how to be active in the situations people find themselves

Motivation for JITAIs

1. Individuals may need support when it is difficult or expensive to provide
2. Individuals are not always aware of when they need support
3. Intervention options may have negative effects (burden, habituation)

Collaborators!

