



Sciences Economiques et Sociales de la Santé
& Traitement de l'Information Médicale

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Data, Personalization, Digital Health!

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Data, Personalization, Digital Health!

Oralytics



JOOHEALTH



BEFORE AFTER AFTER AFTER
BariFit



ADAPTS



HeartSteps



SARC



SARA

Susan A Murphy



Sense²STOP



Conflicts of Interest

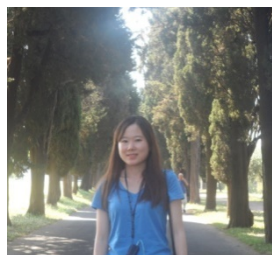
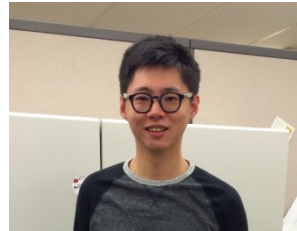
- None to Disclose

Educational Objectives

- Learn about “micro-randomized trials” and how they can be used to improve mobile health
- Learn about an artificial intelligence method, “reinforcement learning” and how it might be used to personalize mobile health interventions.
- Learn about how to operationalize personalization in mobile health

Collaborators!

Peng Liao



Outline

- mHealth
- Micro-Randomized Trials
- AI: Reinforcement Learning
- Some Person-Specific Results

Two Types of Digital Health Treatments

P
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push pull signs.com © (R)

P
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push pull signs.com © (R)

Personalize Interventions

- When is it most useful for the digital device to initiate contact with the person to provide help?
- Should the type of help vary based on the person's current state and setting?
- Do the answers to these questions change as a person's experience with the digital intervention grows or as their life circumstances change?

Combination of Behavioral, Health & Data
Science

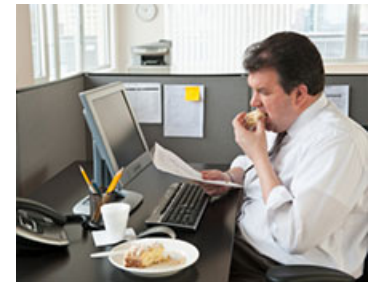
HeartSteps (Klasnja)



Goal: Develop an mobile activity coach for individuals who are high risk of heart disease

Three studies to build the activity coach:

- 42 day micro-randomized study,
- 90 day personalized study,
- 270 day personalized study



HeartSteps V1



Individual's current state provided via data from:

Wearable band → activity and sleep quality;

Smartphone sensors → busyness of calendar, location, weather, app usage;

Self-report → stress, user burden

How might the smartphone help you plan your physical activity tomorrow?

In which context/state should the smartphone provide you with an activity suggestion that you can use right now?

Outline

- mHealth
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What is a “Micro-Randomized” Trial?

A study that is used to provide data for constructing an intervention-- in our case-- a digital intervention.

On each individual, randomize delivery of the intervention each time that intervention *may be* delivered.

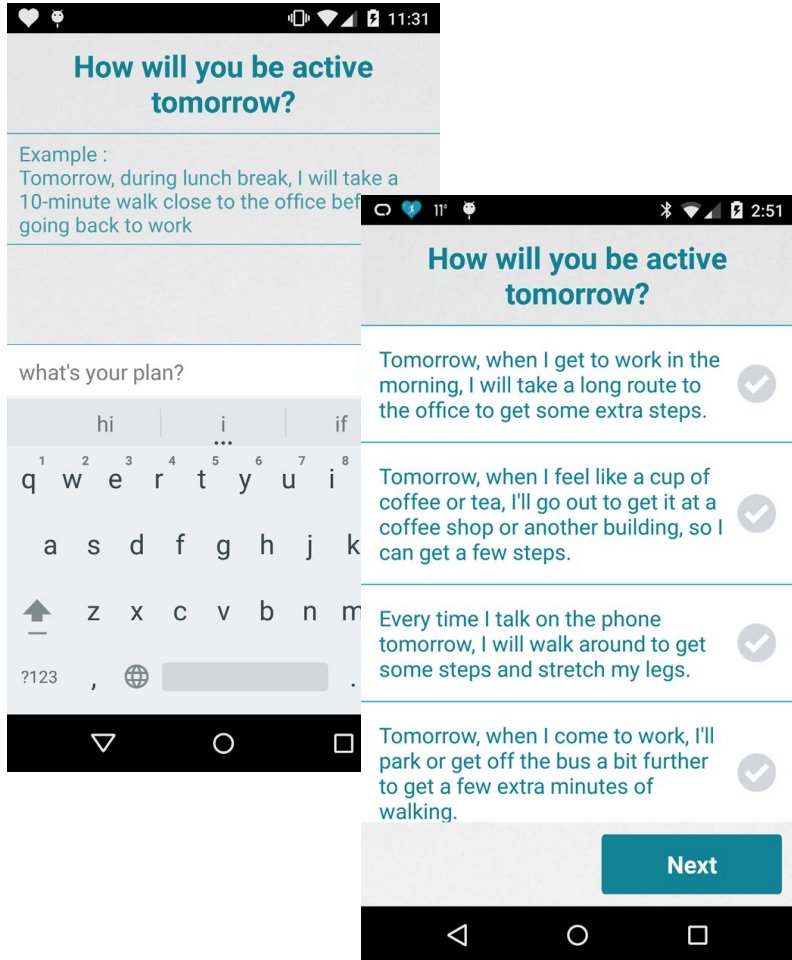
--Each individual is randomized many times during the study

HeartSteps

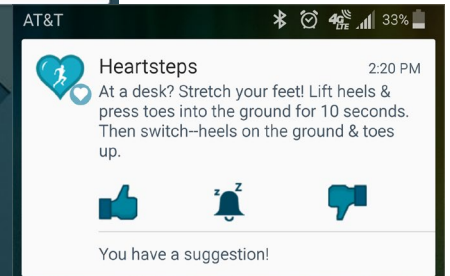
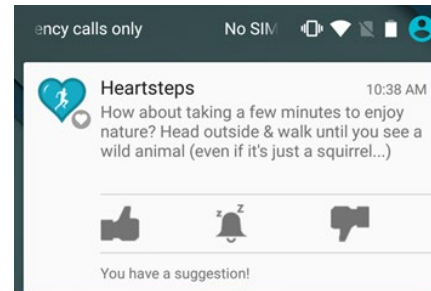
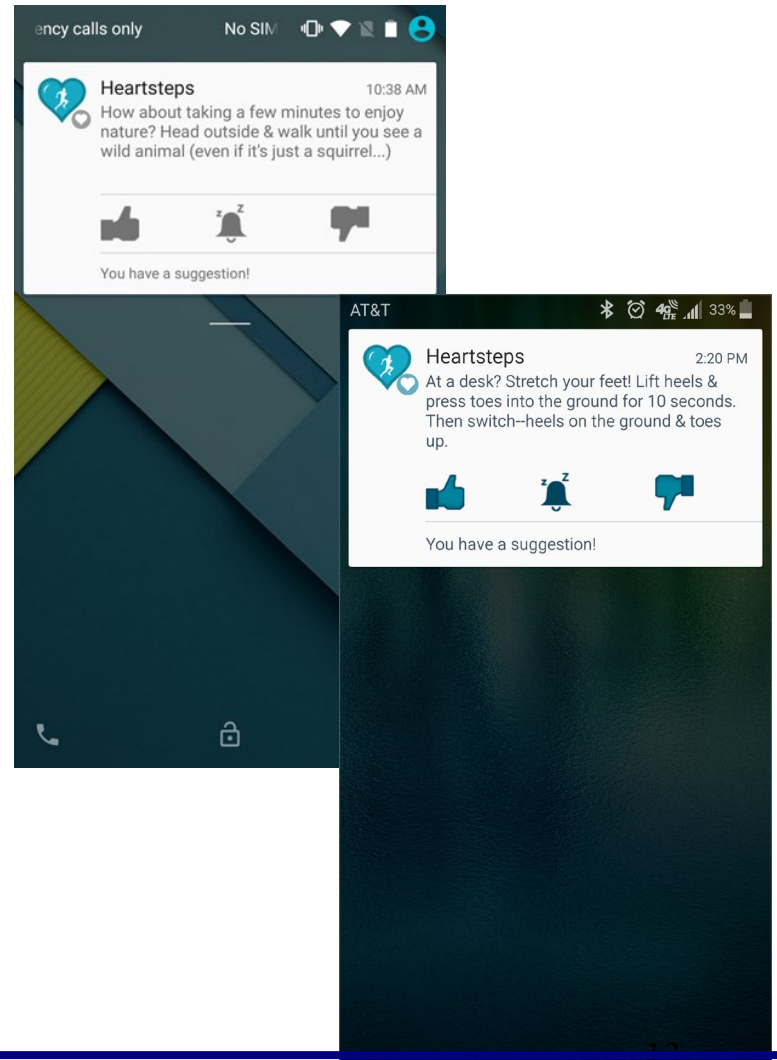
42 Day Micro-Randomized Trial

- Activity suggestion randomized @ 5 times per day
 - 5 Person-specific times: morning, mid-day, mid-afternoon, early evening, after dinner
 - Deliver an activity suggestion 60% of the time & no suggestion 40% of the time.
- Evening planning randomized @ 1 time per day
 - Prompt the person to plan on 50% of the days

Evening Planning



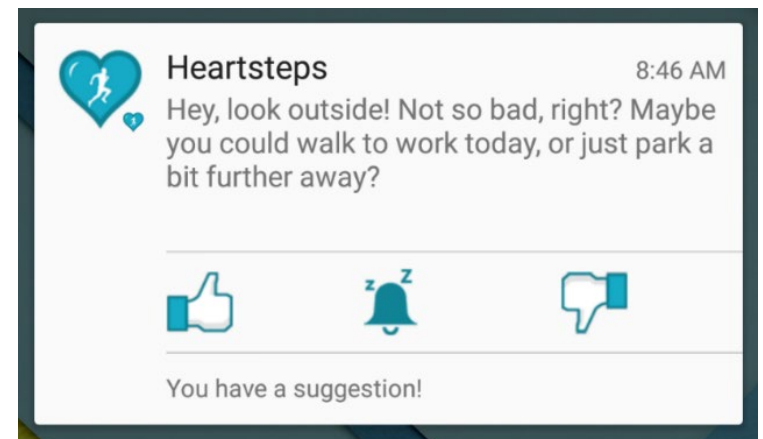
Activity Suggestion



HeartSteps

42 Day Micro-Randomized Trial

- Activity suggestion randomized @ 5 times per day
 - Activity suggestion are delivered an average of 3 times per day



Goals of Activity Suggestions

- Should have immediate impact on step count over subsequent 30 minutes.
- Combined with other interventions should
 - have longer term impact by building up a set of ideas for being more active in every-day life
 - over even longer time periods, contribute to a reduction in heart attacks and other heart diseases.

Availability

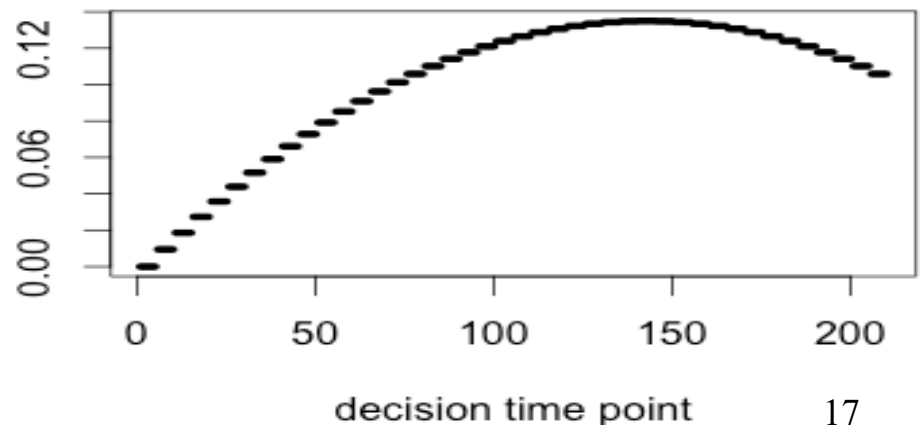
- Activity suggestions can only be delivered at one of the 5 times if the individual is currently *available*.
 - individuals are unavailable if sensors indicate that the individual may be operating a vehicle, **is walking** or has turned off the intervention.
- Individuals are only randomized if they are available at that time.

Treatment Effect

Effect of activity suggestion on 30 min step count is likely time-varying

What does this effect mean?

Effect of Activity Suggestion versus No Suggestion



What did we learn?

The data indicated that individuals are responsive to activity suggestions with an increase in subsequent 30 min step count.

- This effect is primarily due to the higher burden walking activity suggestions.
- This effect deteriorates with time
- The walking activity suggestion initially increases step count over succeeding 30 minutes by approximately 271 steps but by day 20 this increase is minimal.
- Some indication that effect is greater in home/work settings

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- **AI: Reinforcement Learning**
- Some Person-Specific Results

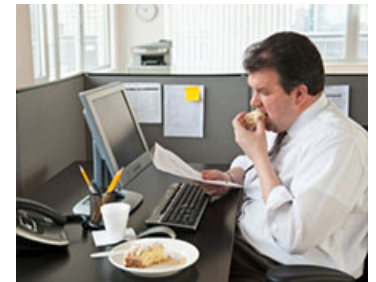
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Three studies to optimize the activity coach:

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Micro-randomized Trial

- Micro-randomized trial = each user is randomized many times = “sequential experimentation”
- Sequential experimentation may use AI algorithms: online predictions as well as “reinforcement learning”
- Reinforcement learning personalizes as it experiments

What does Personalization Mean?

- Sequential experimentation may use AI algorithms:
 - Reinforcement learning personalizes as it experiments
- Personalization means that if you are more responsive to a type of suggestion in a particular context/state, then you will get that type of suggestion with higher chance as compared other types of suggestions/no suggestion.

Two Online “Micro-Randomization” Algorithms

1) Sequential Risk Time Sampling Algorithm

- Goal is to achieve equal chance of receiving an anti-sedentary message across all of an individual’s sedentary times.

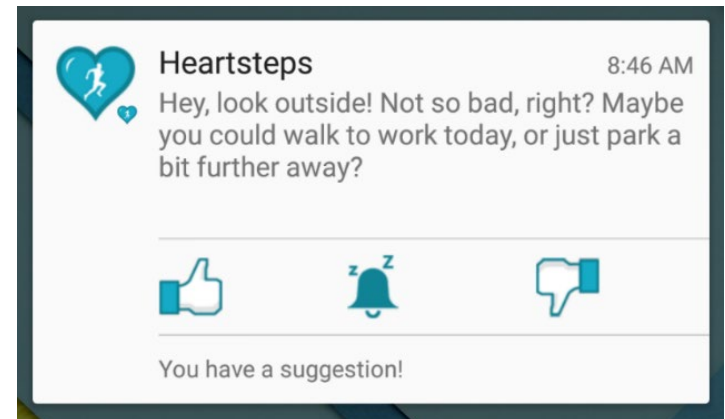
2) *Reinforcement Learning “RL” Algorithm*

- Goal is to personalize delivery of activity suggestions. When should an activity suggestion be sent? When should an activity suggestion not be sent?

Reinforcement Learning Algorithm

HeartSteps V2-3

- When to send or not send an activity suggestion?



- 5 time points per day (morning, mid-day, mid-afternoon, early evening, after dinner)
- Assess impact of activity suggestion on subsequent 30 minute step count.

A Digital Health Challenge to RL

Treatments (e.g. activity suggestions) tend to have positive effects on immediate step counts but negative impact on future outcomes ----
Habituation & Burden.

→ Delayed Negative Intervention Effects

Reinforcement Learning Algorithm

Two elements:

1. *“Learning Algorithm”*: Uses a Bayesian statistical model to repeatedly update the estimate of the treatment effect of the activity suggestion on the individual’s steps.
2. *“Experimentation Strategy”*: Send the activity suggestion based on the posterior probability that

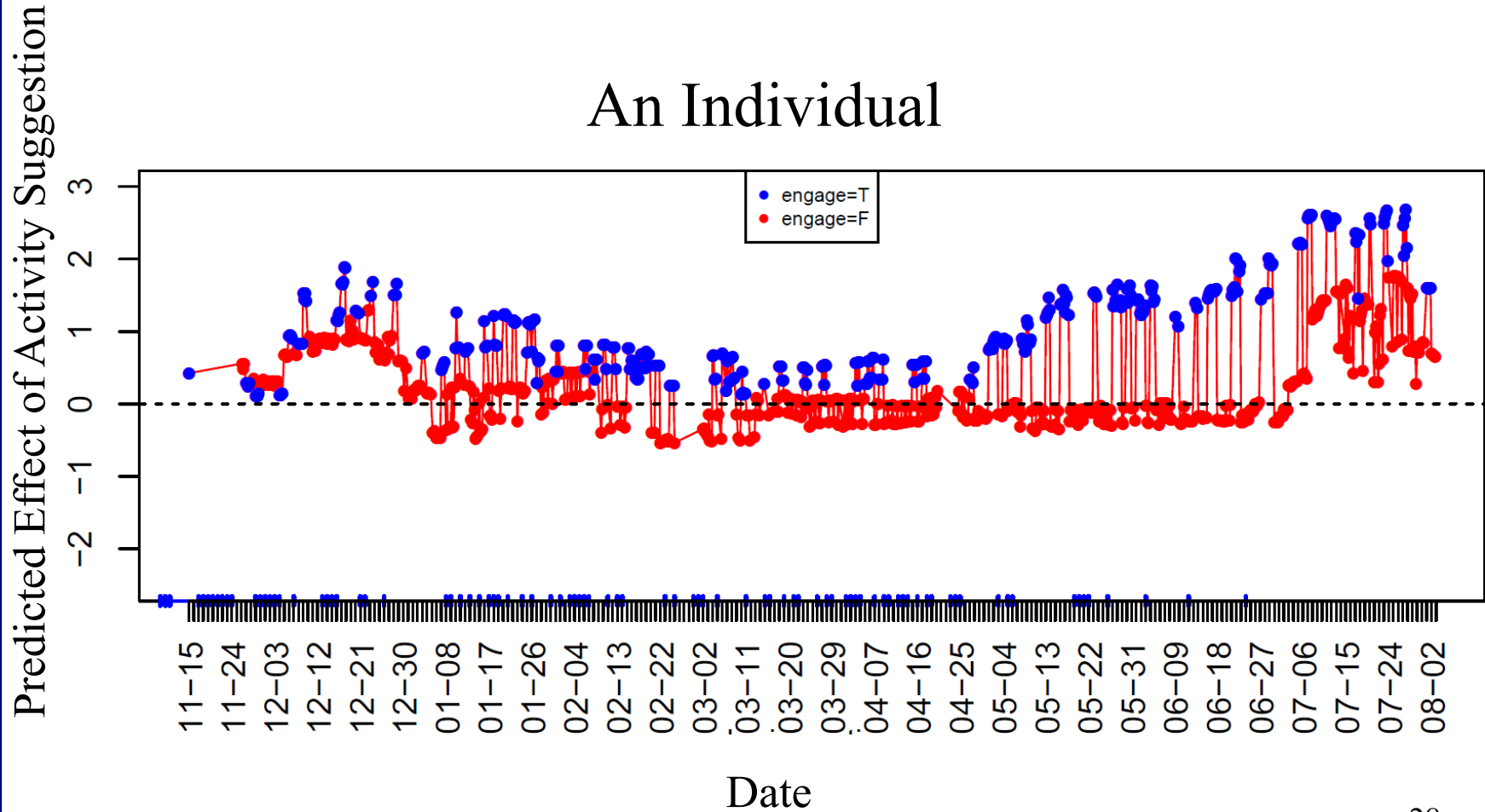
“treatment effect + delayed effect > 0 ”

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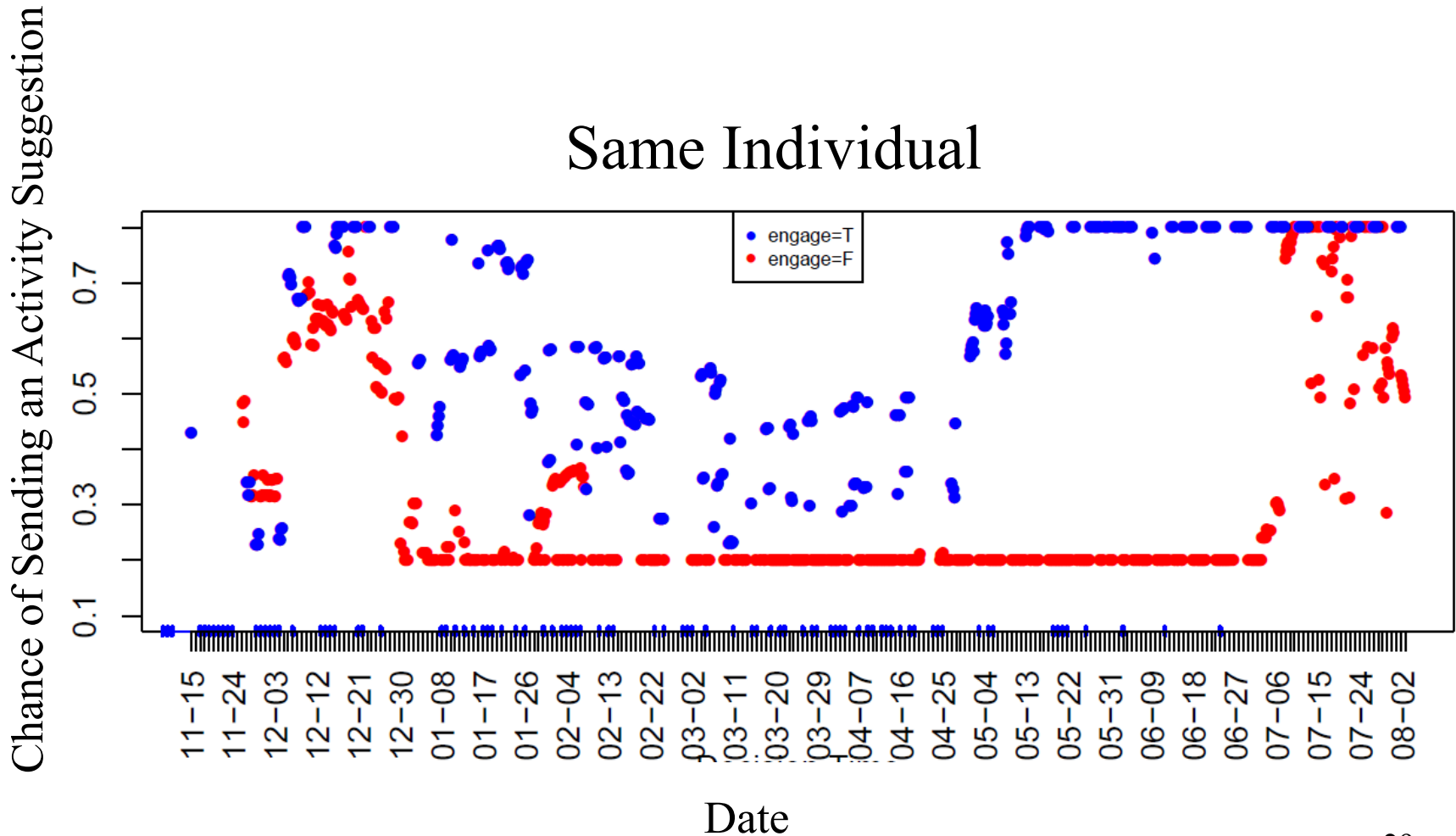
Real-time Predicted Effect on Steps

An Individual

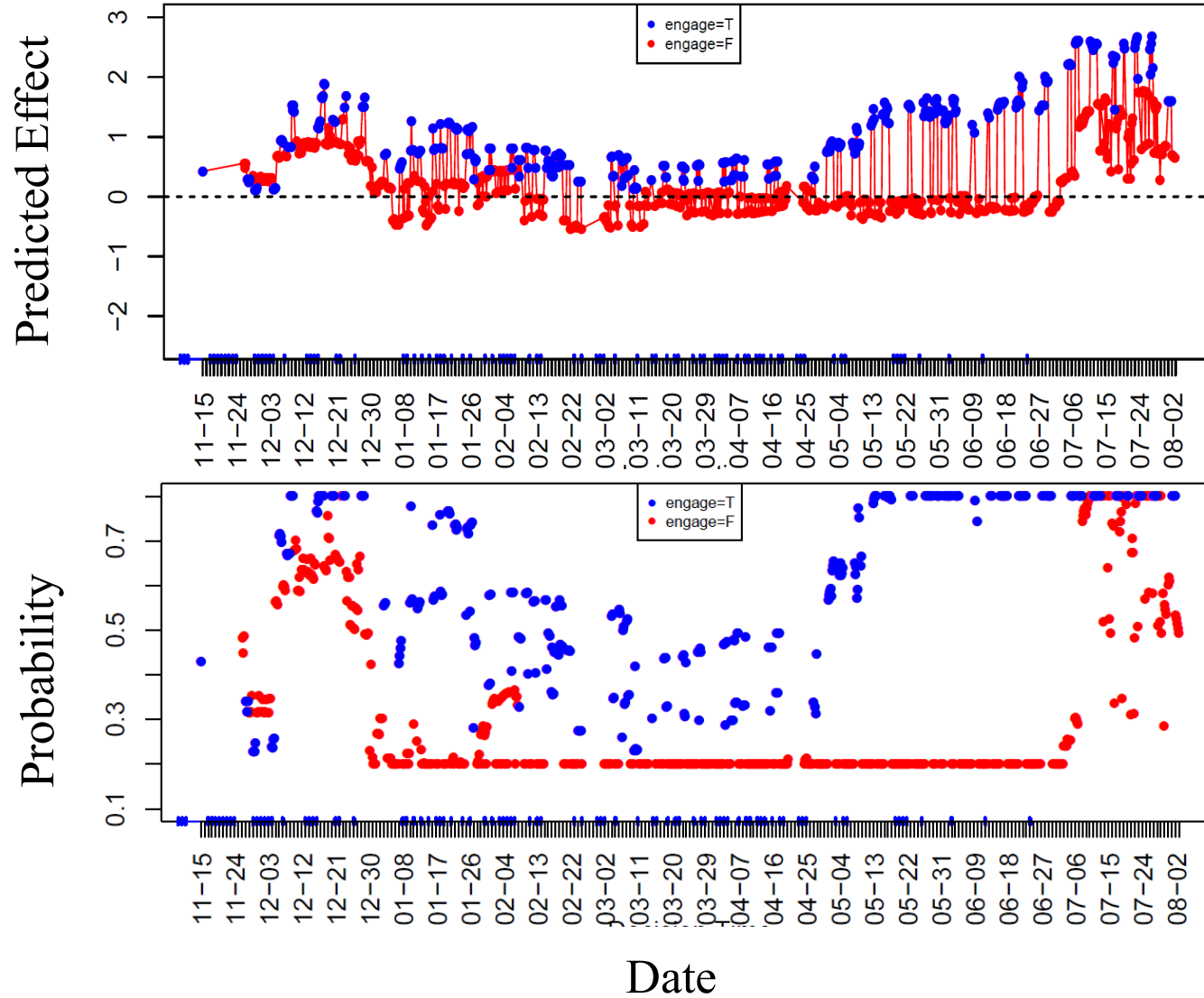


Chance that an Activity Suggestion is Sent to Individual

Same Individual

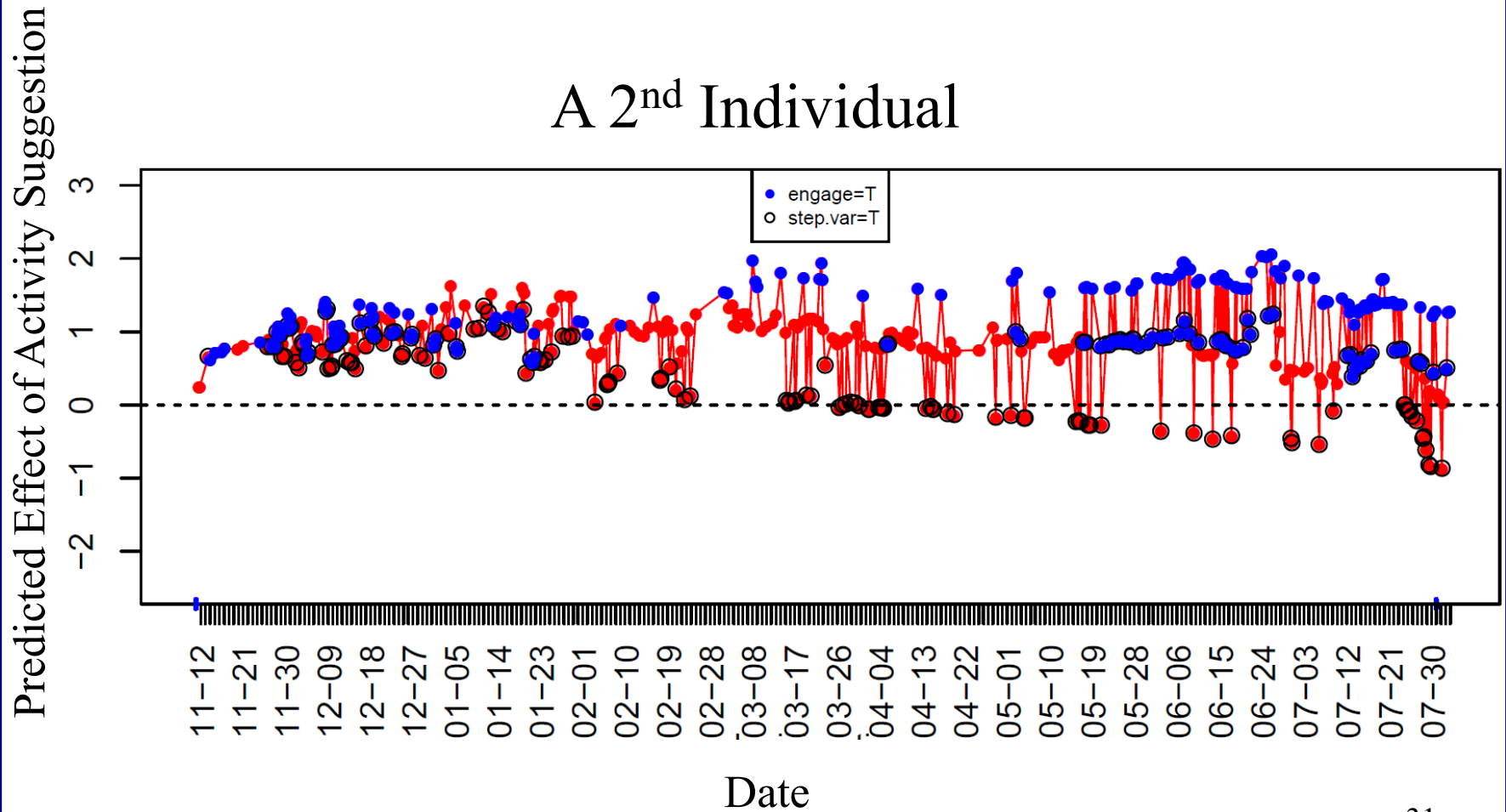


What do we mean by Personalization?



Real-time Predicted Effect on Steps

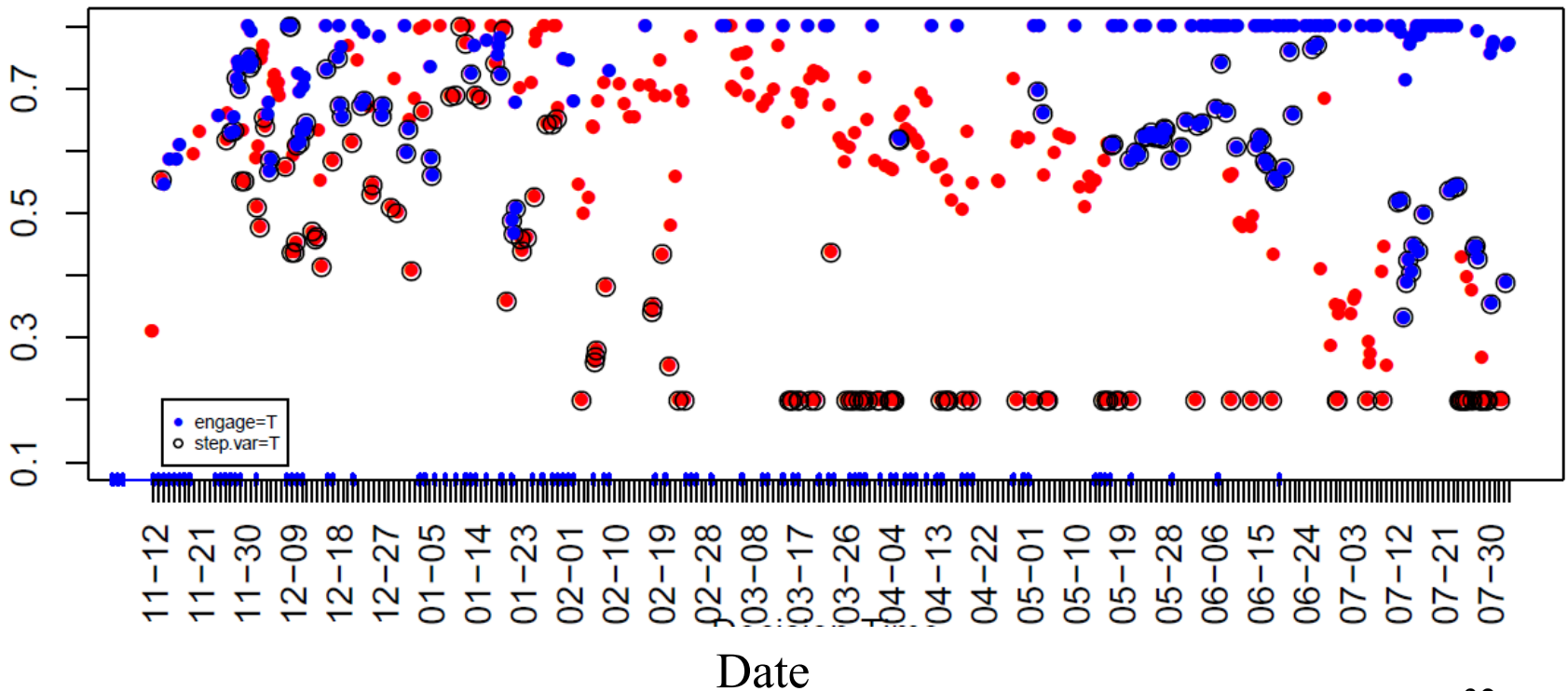
A 2nd Individual



Chance that an Activity Suggestion is Sent to 2nd Individual

The 2nd Individual

Chance of Sending an Activity Suggestion



Long Term Goal: Continually Learning Digital Health App

The RL algorithm is one of multiple intervention components in an digital health app

- Incorporate continual learning/personalization in the rollout of a digital health app.

Experiment to Continually Improve

- “Iterative nature of experimentation” (RA Fisher & G. Box)
- “At Google, experimentation is practically a mantra; we evaluate almost every change that potentially affects what our users’ experience.” (4 Google scientists)
- “Online experiments are widely used to compare specific design alternatives, but they can also be used to produce generalizable knowledge and inform strategic decision making. Doing so often requires sophisticated experimental designs, iterative refinement, and careful logging and analysis.” (3 Facebook scientists)

Cole Porter's "Experiment"

(Verse)

Before you leave these portals
To meet less fortunate mortals
There's just one final message
I would give to you

You all have learned reliance
On the sacred teachings of
science
So I hope, through life, you
never will decline
In spite of Philistine defiance
To do what all good scientists
do

(Chorus)

Experiment, make it your motto day
and night
Experiment and it will lead you to
the light
The apple on the top of the tree is
never too high to achieve
So take an example from Eve
Experiment

Be curious
Though interfering friends may
frown
Get furious
At each attempt to hold you down

If this advice you always employ
The future can offer you infinite joy
And merriment
Experiment
And you'll see