Developing Personalized Mobile Health Interventions

S.A. Murphy

Symposium on Big Data, Human Health and Statistics

mHealth

MD2K Smoking Cessation Coach

- Wearable bands measure activity, stress, cigarette smoking, sleep quality…….
- Smartphone provides four types of support 24/7
- Wrist band provides supportive “cue” and smartphone activates to highlight associated support when stress reaches a criterion

mHealth

HeartSteps Activity Coach

- Wearable bands measure activity, phone sensors measure busyness of calendar, location,.....
- Smartphone pings and lockscreen delivers activity ideas when user is receptive and user's calendar is not too busy

Data from wearable devices that sense and provide treatments

$$S_1, A_1, Y_2, \ldots, S_j, A_j, Y_{j+1}, \ldots$$

S_j : Context at jth decision time (high dimensional)

A_j : Action at jth decision time (treatment)

Y_{j+1} : Proximal Response (time-varying response)

Examples

1) Decision Times (Times at which a treatment can be provided.)
    1) Regular intervals in time (e.g. every 10 minutes)
    2) At user demand

HeartSteps includes two sets of decision times

1) Momentary: Approximately every 2-2.5 hours
2) Daily: Each evening at user specified time.

Examples

2) Context S_j
   1) Passively collected (location, stress, busyness of calendar, social context, activity on device, physical activity)
   2) Actively collected (self-report)

HeartSteps includes activity recognition (walking, driving, standing/sitting), weather, location, calendar, adherence, step count, whether momentary intervention is on, self-report: usefulness, burden, self-efficacy, etc.

Examples

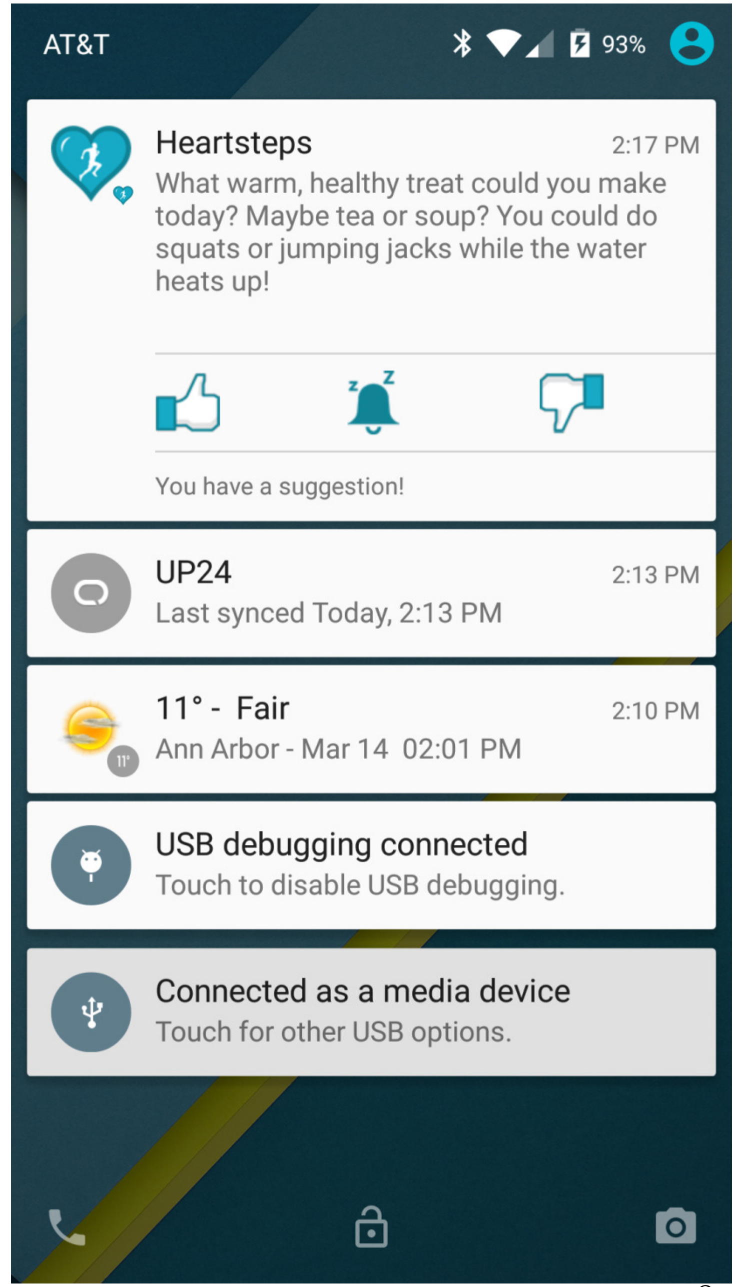
3) Actions A_j
   1) Treatments that can be provided at decision time
   2) Whether to provide a treatment

HeartSteps includes two types of treatments

1) Momentary Lock Screen Recommendation
2) Daily Activity Planning

Momentary Lock Screen Recommendation

No Message or



Examples

4) Proximal Response Y_{j+1}

HeartSteps: Activity (step count) over next 60 minutes.

Smoking Cessation: Stress level over next x minutes.

Our Group's Scientific Goals

1) Develop trial designs/data analytics for assessing if there are proximal effects of the actions on the response.

2) Develop data analytics for assessing if there are delayed effects of the actions; assess if the effects vary by context.

3) Develop data methods for constructing a treatment policy that inputs observations and delivers actions via phone.

4) Develop online training algorithms that will result in a Personalized Continually Learning mHealth Intervention

Experimental Design: Micro-Randomized Trial

Randomize between actions at decision times → Each person may be randomized 100's or 1000's of times.

These are sequential, "full factorial," designs.

Micro-Randomized Trial Elements

1. Record outcomes
   – Distal (scientific/clinical goal) & Proximal Response
2. Record context (sensor & self-report data)
3. Randomize among intervention options at decision points
4. Use resulting data to assess treatment interactions, construct decision rules

Why Micro-Randomization?

- Randomization (+ representative sample) is a gold standard in providing data to assess the causal effect of an intervention option.
- Sequential randomizations will enhance replicability and effectiveness of data-based decision rules.

HeartSteps (42 day study)

- Focus on whether to provide a Momentary Lock Screen Recommendation at the decision times.
- 210 decision times for the lock-screen activity recommendations.

Randomization Probability

Lock-screen activity Recommendation?		
	Yes	$^{2}/_{5}$
	No	$^{3}/_{5}$

Micro-Randomized Trial

First Question to Address: Do the intervention options have an effect on the proximal response?

--Test for proximal *main effects* of the intervention

Micro-Randomized Trial

Time varying potentially intensive intervention delivery → potential for accumulating habituation and burden

→

Allow proximal main effects of the intervention components to vary with time

Sample Size for a Micro-Randomized Trial

Determine sample size to detect a *time-varying proximal main effect* of the Lock Screen Recommendation on Activity

Availability & The Main Effect

- Interventions can only be delivered at a decision time if an individual is *available*.

- The proximal main effect of treatment at a decision time is the difference in proximal response between *available* individuals assigned a lock-screen message and *available* individuals who are not assigned a lock-screen message.

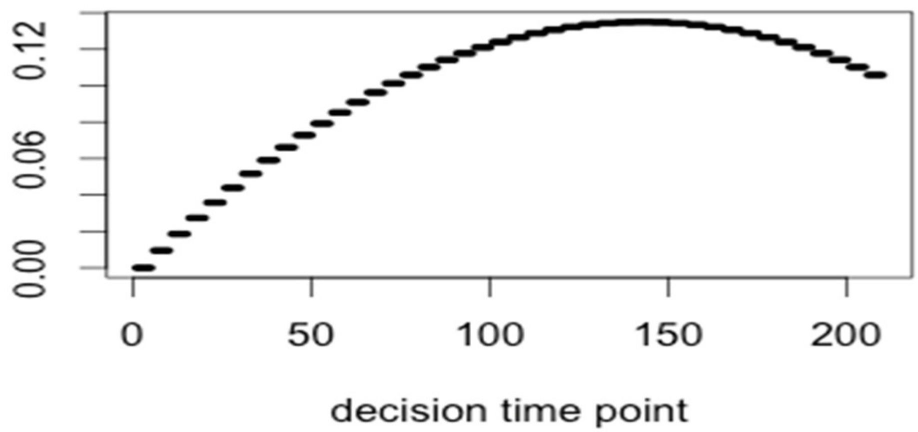
Proximal Main Effect

Main effect of lock-screen message on proximal response is likely time-varying

$\beta(j)$, $j=1,\ldots,J$

Main Effect

$\beta(j)$



Sample Size Calculation

- We calculate a sample size to test:

$$H_0 : \beta(j) = 0, j = 1, 2, \ldots .210$$

- A simple approach is to consider $\beta(j)$ as a quadratic with intercept, β_0, linear term, β_1, and quadratic term β_2

and test $\beta_0 = \beta_1 = \beta_2 = 0$

Sample Size Calculation

Because we assume the proximal main effect is approximately quadratic, assessment of the effect of the lock-screen message uses not only contrasts of *between person responses* but also contrasts of *within person responses*.

--The required sample size (number of subjects) will be small.

Sample Size Calculation

- Our test is based on GEE regression.
- To calculate a sample size we need to specify a clinically/scientifically important effect to detect.

Specify Alternative for Sample Size Calculation

SPECIFY:

- Standardized main effects:
  - proximal effect on first day,
  - average proximal effect over trial duration
- Day of maximal proximal effect.

HeartSteps (42 day study)

Standardized effects:

- initial proximal effect: $\boxed{0}$
- average standardized proximal effect over trial duration $\boxed{?}$
- day of maximal proximal effect: $\boxed{28}$

HeartSteps Sample Sizes
Power=.8, α=.05

Standardized Average Proximal Effect over 42 Days	Sample Size For 70% availability or 50% availability
0.06	81 or 112
0.08	48 or 65
0.10	33 or 43

A Micro-Randomized Trial

1) We also micro-randomize other components (e.g. Daily Activity Planning) to obtain a sequential, factorial design.

2) Further data analyses concern time varying effect moderation (interactions between treatment and context)

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mHealth

BASICS Mobile to curb heavy drinking and smoking in college students

- Context/observations: Smartphone sensors + self-report data (3 x per day)
- Actions: “Mindfulness Intervention” vs. General Health Info (2 x per day)
- Is the effect of providing a mindfulness-based intervention (vs general health info) on subsequent smoking rate moderated by increase in need to self-regulate?

BASICS Mobile

- $\tilde{S}_t$ includes 1 and urge to smoke, prior smoking rate, evening time (yes/no), provided prior self-report (yes/no), increase in need to self-regulate (yes/no),
- S_t includes 1 and self-regulation=1, if increase in need to self-regulate, otherwise =0
- I_t Availability: =1, if available, otherwise =0
- Y_{t+1} smoking rate over next 1/3 day

BASICS Mobile

Solve an "estimating equation" summed over i^{th} person, t^{th} decision time:

$$0 = \sum_{i=1}^{n} \left[\sum_{t=1}^{T} (Y_{i,t+1} - \tilde{S}_{it}^{T}\alpha - A_{it}S_{it}^{T}\beta) I_{it} W_{it} \begin{pmatrix} \tilde{S}_{it} \\ A_{it}S_{it} \end{pmatrix} \right]$$

for α, β

Intuition: Think "linear regression"

BASICS Results

The weight, W_{it}, is used to ensure

- robustness to misspecification of the α part of the regression and
- to consider both a small number of interactions with the treatment action, A_{it}, as well as a large number of interactions.

The weight, W_{it}, ensures unbiased estimation of treatment effects, β.

BASICS Results

Proximal	$\hat{\beta}$	95% CI
A_t	-2.6	(-5.0,-0.1)
$A_t\text{SelfReg}_t$	2.5	(0.4, 4.7)

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Collaborators