Micro-randomized Trials in Mobile Health

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Center of Excellence for Mobile Sensor Data-to-Knowledge

The Methodology Center
advancing methods, improving health

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MICHIGAN STATISTICS

Outline

- Adaptive Interventions and Just-in-Time Adaptive Interventions

- HeartSteps
- Micro-Randomized Trial
- Sample Size Considerations

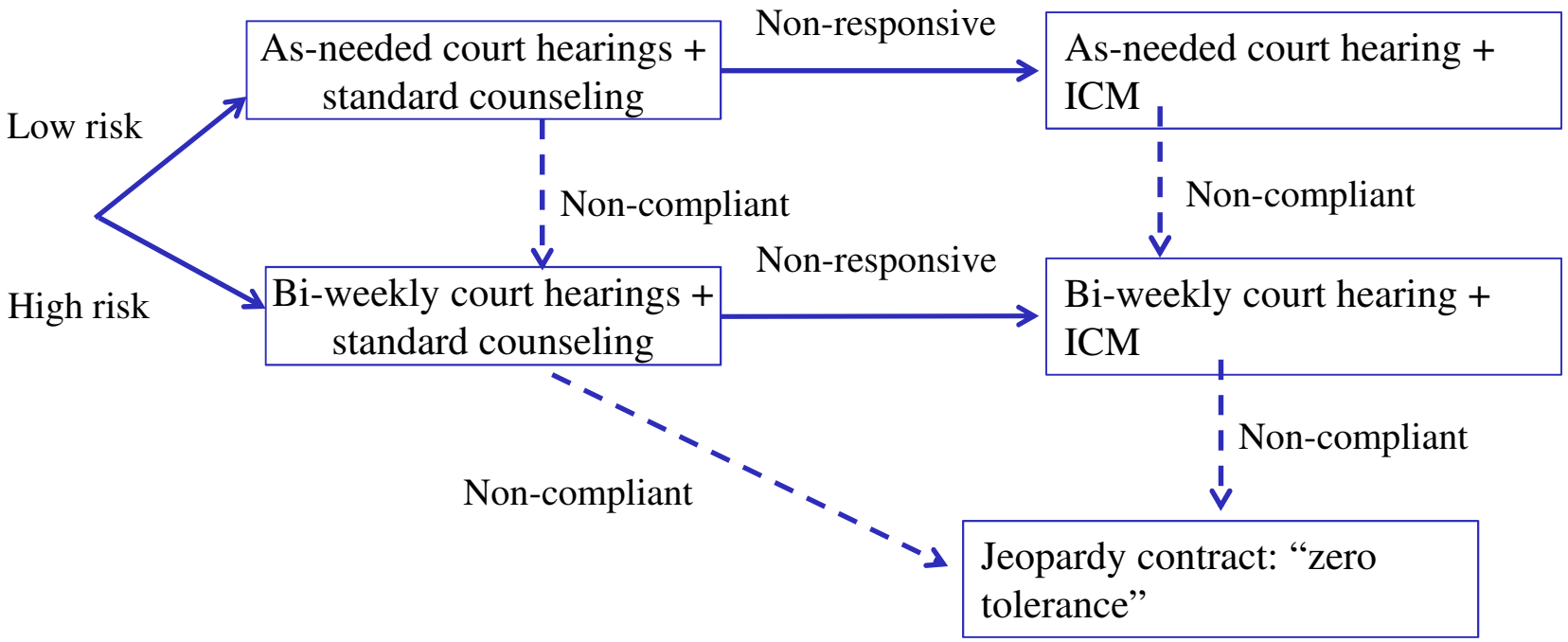
Adaptive Interventions

- Intervention design that takes advantage of systematic response heterogeneity by individualizing intervention options to individuals

- Example: Adaptive drug court program for drug abusing offenders

Marlowe et al., 2008; 2009; 2012

Adaptive Drug Court Program



Adaptive Intervention: 5 Elements

The adaptation is guided by consideration of

(1) Distal Outcome and Proximal Response

The adaptation process is composed of

(2) Tailoring Variables,

(3) Decision Rules and

(4) Intervention Options

The adaptation is triggered at

(5) Decision Points

JITAIs: Just-in-Time Adaptive Interventions

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

(Kaplan & Stone, 2013; Spruijt-Metz & Nilsen, 2014)

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)

Commonalities?

- Both adaptive interventions and JITAIs are time-varying and adaptive
- However in JITAIs technology plays a critical role
  - Information can be obtained when/where needed
  - Interventions can be delivered when/where needed

Just-in-Time Adaptive Intervention
5 Elements

The adaptation is guided by consideration of

(1) Proximal Response and Distal Outcome

The adaptation process is composed of

(2) Tailoring Variables,

(3) Decision Rules and

(4) Intervention Options

The adaptation is triggered at

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Distal Outcomes

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

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

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

Proximal Responses

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

Intervention options

- Intervention options:

  - Behavioral strategies, cognitive strategies, self-monitoring, social linkages, motivational,…
  - Nudges to access an intervention
  - Prompt self-monitoring
  - How to provide an intervention option
  - “Provide nothing” option

Tailoring variables

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

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

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.

Decision Rules

Link individual information 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.

Decision Rules

At 1 minute intervals

If current accumulated computer activity > P_0

Then, IO= {recommend movement}

Else if current accumulated computer activity ≤ P_0

Then, IO = {do nothing}

Summary of JITAI elements

1. Outcomes
    - Distal (scientific/clinical goal) & Proximal Response (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

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HeartSteps

- Goal: Develop a Just-in-Time Adaptive Intervention for Encouraging and Maintaining Physical Activity

+

HeartSteps

Distal Outcome:
Activity over the 42 day study.

Proximal Response:
Proximal activity (step count) over next 30 minutes.

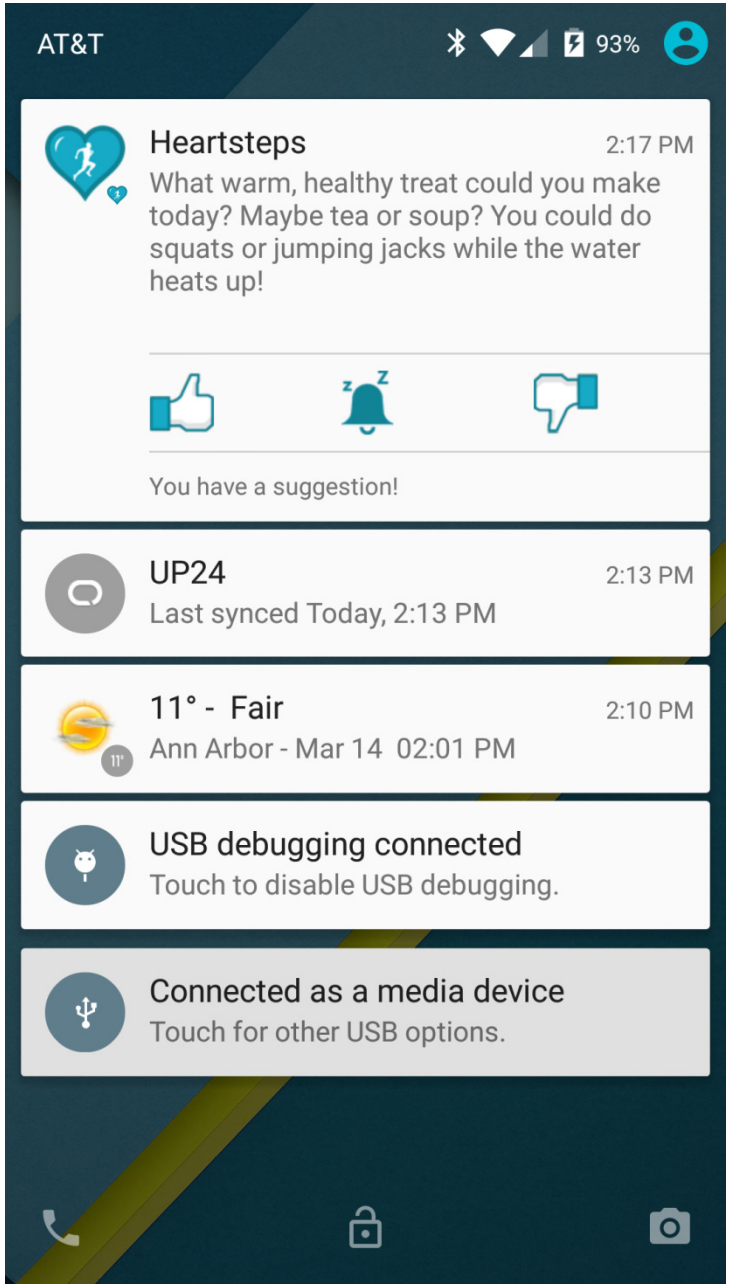
HeartSteps

Intervention Options:
Whether to provide Tailored Activity Recommendation? Yes/No

Decision points:
Approximately every 2-2.5 hours

Tailored Activity Recommendation

No Message or



HeartSteps

Potential Tailoring Variables:
Sensor data: activity recognition (walking, driving, standing/sitting), weather, location, busyness of calendar, adherence, step count
Self-report: usefulness, burden

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Micro-Randomized Trial

Randomize each participant between intervention options at each decision point

→ Each person may be randomized 100's or 1000's of times.

These are sequential, "full factorial," designs.

Extension of A/B testing & Single Case Designs

Why Micro-Randomization?

- Randomization (+ representative sample) is a gold standard in providing data to assess the causal effect of an intervention.

- Sequential randomizations will enhance replicability of data analyses (moderation, decision rule development) .

HeartSteps (42 day study)

- Whether to provide a tailored activity recommendation at the decision points.
- 210 decision points for the tailored activity recommendations.

Tailored Activity Recommendation?	Randomization Probability
Yes	$^{2}/_{5}$
No	$^{3}/_{5}$

Micro-Randomized Trial

These sequential factorial trials are used to build JITAIs…

First Question to Address: Do the intervention options differentially impact the proximal response? AKA: is there a signal here?!

--Test for *main effects* of the intervention options on the proximal response.

Micro-Randomized Trial

Time varying potentially intensive/intrusive interventions → potential for accumulating habituation and burden

→

Allow main effect of the interventions on proximal response to vary with time

Availability & the Main Effect

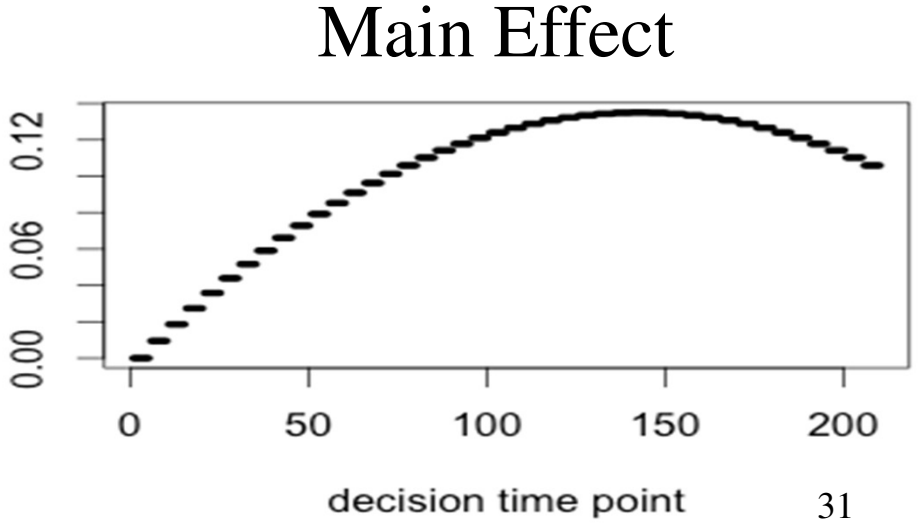
- Intervention options can only be delivered at a decision point if an individual is *available*.

- The main effect of an activity recommendation at a decision point is the difference in proximal response between *available* individuals assigned an activity recommendation and *available* individuals who are not assigned an activity recommendation.

Main Effect

Main effect of activity recommendation on proximal response is likely time-varying $\beta(t)$, $t=1,\ldots,T$

- What does $\beta(t)$ this main effect mean?



Micro-Randomized Trial Elements

1. Record outcomes
   - Distal (scientific/clinical goal) & Proximal Response
2. Record potential tailoring variables
3. Randomize among Intervention Options at decision points
4. At End of Trial use Resulting Data to assess effects, moderation, construct decision rules

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Sample Size Calculation

- We calculate the number of participants to test H_0: no effect of the intervention, i.e.,

$$H_0 : \beta(t) = 0, t = 1, 2, ...T$$

- Determine sample size to detect a low dimensional, smooth alternate H_1.
  - Example: H_1: $\beta(t)$ 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

- Our test statistic uses estimators from a "generalization" of linear regression.
- The test statistic is quadratic in the estimators of the β terms.
- Given a specified power to detect the smooth alternative, H_1, a false-positive error prob., and the desired detectable standardized effect size, we use statistics to derive the sample size.

Sample Size Calculation

Alternative is low dimensional → assessment of the effect of the activity recommendation uses contrasts of *between participant responses* **+** contrasts of *within participant responses.*

--The required number of participants will be small.

Specify Alternative for Sample Size Calculation

SPECIFY:

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

HeartSteps (42 day study)

Standardized effects:

- initial effect: 0
- average standardized main effect over trial duration: ?
- day of maximal effect: 28
- average availability: ?

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

Average Standardized Main 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

Micro-Randomized Trial

1) Be conservative in planning the trial!
    1) Under-estimate the amount of time participants are available for the intervention.
    2) Under-estimate the average main effect

Micro-Randomized Trial

2) Power to detect the main effect is robust to interactions and to delayed effects (e.g., burden)

3) Secondary data analyses concern time varying effect moderation and data analyses to construct data-driven decision rules for the JITAI

Micro-Randomized Trials: When are they (not) useful?

- NOT USEFUL: When malleable circumstances are rare: Want to learn the best type of alert to prevent suicide attempt
- USEFUL: When malleable circumstances occur frequently: Stress, urges to smoke, adherence, physical activity, eating
- NOT USEFUL: Proximal response cannot be feasibly assessed.
- USEFUL: Proximal response can be unobtrusively sensed or unobtrusively self-reported.

Collaborators