Developing mHealth Interventions to Improve Mood, Activity, and Sleep for Medical Interns

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In collaboration with....

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Overview

• Background
• Trial Design
• Missing data issues
• Results
• Conclusions and Future Work
Background- Intern Health Study
Intern Health Study-population

- A year long study on medical interns – medical doctors in their first year of residency

Intern Health Study-data collection

• In 2018, for 2,111 medical interns we collect data using:
  • Fitbit
  • Phone - Self-reported mood
  • Survey (baseline + every 3 months) – PHQ 9 + more
In 2018, we also wanted to intervene

• Can we inspire positive behavior change in interns to help them during their internship year?
  • Maintain a positive mood
  • Have healthy sleep habits
  • Stay physically active
Intervention component: Data dashboard

• All interns have access to an application developed by Arbormoon

• The app gives data summaries
Intervention component: Push Notifications

(2 x 3 = 6 kinds of messages):

- **Category:**
  - Mood
  - Activity
  - Sleep

- **Type:**
  - Life insight – Data-driven message
  - Tip – General Advice, non data driven
Try to get 6 to 8 hours of sleep each night if possible. Notice how even small increases in sleep may help you function at peak capacity & better manage the stresses of internship.
Research questions about these messages:

• How do different categories of messages affect mood, activity, and sleep?
• How do the effects of messages change based on previous mood, activity, and sleep?
• Do life insights affect interns differently than tips?
• How do messages affect long-term mental health of interns?
To answer these questions, we designed a micro-randomized trial

• Micro-randomized trials vs randomized control trial
  • Randomize each person many times throughout the trial

• Advantages of micro-randomized trial
  • Estimate short-term effects
  • Discover real-time moderators

Randomization scheme

- Trial goes from June 30, 2018 - Dec 31, 2018 (6 months).
- Messages sent at 3 pm every day, mood scores typically entered around 8pm
Randomization 1: Pre-internship

- How do messages affect long-term mental health of interns (as measured by quarterly PHQ-9)?
Randomization 2: Weekly message category

• How do different categories of messages affect mood, activity, and sleep?
• How do the effects of different categories change based on previous mood, activity, and sleep?
Randomization 3: Daily randomization

For message weeks:

- Prevents burden and loss of engagement
- We can answer: How do life insights or tips compare to no message?
Sample size and trial data

- Data collection started in April
  - Interventions were sent on June 30-Dec 31, 2018 (6 months or 26 weeks)
- 2111 interns in trial, 1565 are sent messages
Missing Data Issues

• Missing data is an issue with self-reported outcome
• Missing data is a problem in large mobile health studies
• I will give an overview of our missingness and proposed solution
Missingness over time
Number of mood scores for per week
Imputation algorithm - Sequential Imputation
Imputation algorithm - Treatment group separation

T1: Mood message
T2: Mood week no message
T3: Activity message
T4: Activity week no message
T5: Sleep message
T6: Sleep week no message
T7: No message week
Imputation algorithm-Treatment group separation

Impute day 1 with $\mathcal{B}_1$

Impute day 2 with $\mathcal{B}_2$

$\cdots$

Impute day $t$ with $\mathcal{B}_t$

$\cdots$

Impute day 182 with $\mathcal{B}_{182}$

$T_1$: Mood message

$T_2$: Mood week no message

$T_3$: Activity message

$T_4$: Activity week no message

$T_5$: Sleep message

$T_6$: Sleep week no message

$T_7$: No message week
Imputation-Update History

Impute day 1 with $\hat{A}_1$

Impute day 2 with $\hat{A}_2$

... 

Impute day t with $\hat{A}_t$

... 

Impute day 182 with $\hat{A}_{182}$

$\hat{A}_{t+1} = \{\hat{A}_t, \}$

### Mood, Steps, Sleep, Treat.

<table>
<thead>
<tr>
<th>Mood</th>
<th>Steps</th>
<th>Sleep</th>
<th>Treat.</th>
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</table>

$T_1$: Mood message

$T_2$: Mood week no message

$T_3$: Activity message

$T_4$: Activity week no message

$T_5$: Sleep message

$T_6$: Sleep week no message

$T_7$: No message week
Imputation algorithm-Multiple imputation

Impute day 1 with $\hat{A}_1$ → Impute day 2 with $\hat{A}_2$ → ... → Impute day $t$ with $\hat{A}_t$ → ... → Impute day 182 with $\hat{A}_{182}$

repeat M times
Concerns when imputing in micro-randomized trials

- Separating treatment groups vs sample size
- Sharing information over time
- Flexible imputation vs stable imputation
  - How to choose variables for imputation model
Analysis techniques for estimating proximal treatment effects

- Weighting and centering approach
- Estimating equation with robust standard errors
- Combine across imputation methods using Rubin’s rules

Main effects

• How do different messages perform overall on the category of interest?
How do messages affect long-term mental health of interns?
### How do messages affect mood, activity, sleep?

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<th>Activity</th>
<th>Sleep</th>
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<tbody>
<tr>
<td>General</td>
<td>-.029  (p = .003)</td>
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<tr>
<td>Mood</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
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**Outcome**
- Mood: -.029 (p = .003)
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<td></td>
<td>.088 (p = .075)</td>
<td></td>
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123 steps increase in average daily activity per week
How do messages affect mood, activity, sleep?

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<td></td>
<td></td>
<td>.051 (p = .073)</td>
</tr>
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2 minutes of sleep in average daily sleep per week
Moderators analysis

- Moderator - a variable collected prior to intervention delivery that ‘moderates’ (or changes) the efficacy of an intervention

- How do these effects differ based on previously collected data?
Are the effects of messages (in general) on mood moderated by previous week’s mood?

slope = -.052, p-value = .001
The negative moderation is true across all message categories

Mood
  slope = -.051, p-value = .004
Activity
  slope = -.050, p-value = .006
Sleep
  slope = -.053, p-value = .001
Are the effects of activity messages on activity moderated by previous week’s activity?

Activity Message Effect (compared to no message)  
on Average Daily Step Count

Change in average daily steps

Previous Week’s Average Daily Step Count

Slope = -.038  
(on cube root scale),  
p-value = .033
Are the effects of sleep messages on sleep moderated by previous week’s sleep?

slope = -0.074  
(on square root scale)  
p-value = 0.007
How do life insights compare to tips?

95% Confidence Intervals for Effects on Daily Outcomes

- Activity
- Mood
- Sleep

Treatment Group
- Life Insight
- Tip
Conclusions

• Main effects are there, but effect sizes are small
• Moderator effects indicate that messages should be tailored
• No big difference between life insights and tips
• No big change on long-term mental health
Informing the 2019 Trial Design

• Changes for 2019:
  • Including a new (sub)category: Circadian
  • Message tailoring
  • Eliminating weekly level randomization
  • Obtain work schedule data
Future work

• Causally valid + practical + low variance imputation scheme
• Extend methods to ordinal data
• Share information over several cohorts
Thanks!
References


• Sen, Srijan et al. “A prospective cohort study investigating factors associated with depression during medical internship” *Archives of general psychiatry* (2010)
Extra slides
Imputation algorithm -

For t in 1:183:

Create groups for each daily treatment group:

\[ G_1 = \{ \text{individuals s.t. get mood message on day } t \} \]
\[ G_2 = \{ \text{individuals s.t. in mood week, but get no message day } t \} \]
\[ G_3 = \{ \text{individuals s.t. get activity message on day } t \} \]
\[ G_4 = \{ \text{individuals s.t. in activity week, but get no message day } t \} \]
\[ G_5 = \{ \text{individuals s.t. get sleep message on day } t \} \]
\[ G_6 = \{ \text{individuals s.t. in sleep week, but get no message day } t \} \]
\[ G_7 = \{ \text{individuals s.t. in no message week} \} \]

Impute groups separately

For k in 1:7:

For all i in \( G_k \), impute \( Mood_{it}^0, Activity_{it}^0, Sleep_{it}^0 \) using

\{ \( H_{jt}, Mood_{jt}^1, Activity_{jt}^1, Sleep_{jt}^1 \) for j in \( G_k \) and \( H_{jt} \) \},

\( H_{jt} \) is complete, imputed historical data

\( Mood_{jt}^1 \) is non-missing mood values

\( Mood_{jt}^0 \) are missing mood values