Personalizing JITAIs "pJITAIs"
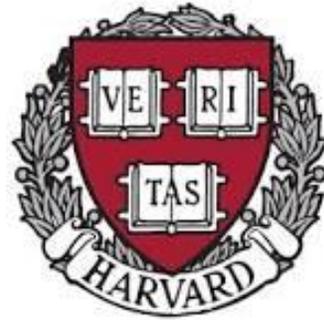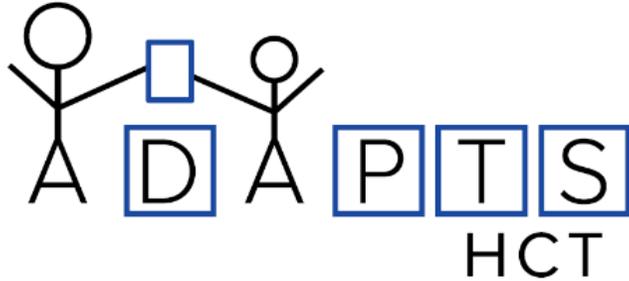
Susan A Murphy

HeartSteps

MiWaves

HCT

Oralytics

optimizing adaptive interventions, by design

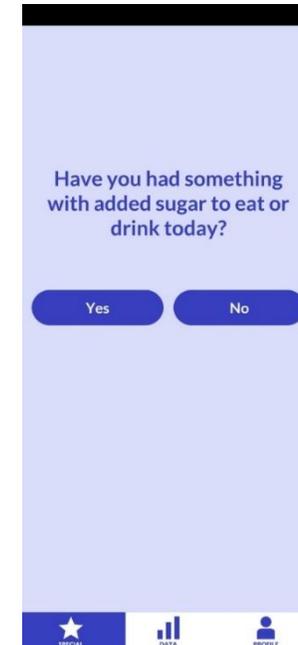Kempner INSTITUTE

Outline

- What is a pJITAI?
  - Why a pJITAI?!

- An Online Learning & Decision-Making Algorithm

- Oralytics!

Oralytics Oral Health Coach

- Two intervention components
  - Self-monitoring
  - Engagement

- Oralytics used a pJITAI to personalize when engagement messages are delivered to individuals.

JITAI

- JITAIs adapt to an individual
  - Via a decision rule that inputs the individual's current tailoring variables (time of day, recent engagement, recent brushing quality) and outputs an intervention option.
  - JITAI decision rules are the same for all individuals regardless of that individual's responsivity to the intervention options.

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  - The updates are to optimize the JITAI decision rules

Why pJITAIs?

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  - The updates are to optimize the JITAI decision rules

- Why pJITAIs?
  - Society, technology (new sensors, software operating systems), access to other treatments, behavioral science, are changing rapidly resulting in potentially differing responsivity between deployments of the digital intervention.

pJITAI: Personalizing JITAI

- pJITAI decision rules are probabilistic:
  - IF recent brushing quality is poor and the current time is morning THEN send an engagement strategy with probability 0.70.

- pJITAIs use *online learning and decision-making algorithms* to alter the probabilities according to evidence in individuals' accruing data.

pJITAI: Personalizing JITAI

Example:

- Accruing data indicates that sending an engagement strategy improves brushing quality when recent brushing quality is poor, and the current time is morning. As a result, the algorithm increases the message delivery probability from 0.70 to 0.85

  - IF an individual's recent brushing quality is poor, and the current time is morning

    THEN an engagement strategy is sent to the individual with probability 0.85

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Data Used by a pJITAI

- At decision point t,
  - State: Prognostic Variables + Tailoring Variables: $S_{1,t}$ = recent brushing quality; $S_{2,t}$ = current time of day

  - Indicator of Intervention Option: $A_t = 1$ if engagement strategy is delivered; $A_t = 0$, if not

  - Proximal Outcome: R_{t+1} = brushing quality after decision point t

pJITAI = JITAI + Algorithm

- At decision point t,
  - State: Prognostic Variables + Tailoring Variables: $S_{1,t}$ = recent brushing quality; $S_{2,t}$ = current time of day

  - Algorithm's selected option: $A_t = 1$ if engagement strategy is delivered: $A_t = 0$, if not

  - Algorithm's reward from the individual: R_{t+1}= brushing quality after decision point t

Reinforcement Learning (RL) Algorithm

Two Elements

- <u>Learning Algorithm</u>: Estimates parameters in statistical model for the individuals' data.
  - Input: data prior to decision point t data
  - Output: statistical inference, forecast of treatment effect at decision point t for each value of the tailoring variables

Reinforcement Learning (RL) Algorithm

Two Elements
- <u>Learning Algorithm</u>:
  - Input: data prior to decision point t data
  - Output: statistical inference, forecast of treatment effect at decision point t for each value of the tailoring variables

- <u>Optimization Algorithm</u>:
  - Input: statistical inference/forecast + the individual's values of the tailoring variables, $S_t = s$
  - Output: selects intervention option: $A_t = a$

$$S_t = (S_{1,t}, S_{2,t})$$

Element 1: Example Online Learning Algorithm

- Mean reward: $r(s, 1) = E[R_{t+1}|S_t = s, A_t = 1]$,
$$r(s, 0) = E[R_{t+1}|S_t = s, A_t = 0]$$

- Use Bayesian linear regression model for treatment effect
$$r(s, 1) - r(s, 0) = \beta_0 + \beta_1 s_{1,t} + \beta_2 s_{2,t}$$

R_{t+1} = subsequent brushing quality; $s = (s_{1,t}, s_{2,t})$, $s_{1,t}$ = recent brushing quality; $s_{2,t}$ = current time of day

Element 1: Example Online Learning Algorithm

- Mean reward: $r(s, a) = E[R_{t+1} | S_t = s, A_t = a]$ for $a = 1$ or 0

- Use Bayesian linear regression model for treatment effect

$$r(s, 1) - r(s, 0) = \beta_0 + \beta_1 s_{1,t} + \beta_2 s_{2,t}$$

  - Model implies that if $\beta_0 + \beta_1 s_{1,t} + \beta_2 s_{2,t} > 0$ then sending an engagement strategy ($a = 1$) will increase brushing quality

R_{t+1} = subsequent brushing quality; $s = (s_{1,t}, s_{2,t})$, $s_{1,t}$ = recent brushing quality; $s_{2,t}$ = current time of day; a = intervention option

Element 2: Example Optimization Algorithm

- Optimization Algorithm calculates Bayesian posterior probability,

$$p(s, Data) = P(\beta_0 + \beta_1 s_{1,t} + \beta_2 s_{2,t} > 0 | Data)$$

   – and decides whether to deliver intervention option $a = 1$ or $a = 0$

   High $p(s, Data) \rightarrow$?????

$$s = (s_{1,t}, s_{2,t})$$

pJITAI = JITAI + RL Algorithm

Reinforcement Learning (RL) Algorithm =

<u>Learning Algorithm</u> + <u>Optimization Algorithm</u>

pJITAI = JITAI + RL Algorithm

Reinforcement Learning (RL) Algorithm =

Learning Algorithm + Optimization Algorithm

IF the values of the tailoring variables are $s_{1,t}$= recent brushing quality is poor, $s_{2,t}$ =the current time is morning),

THEN deliver engagement strategy, $(a = 1)$ with posterior probability $p(s, Data)$

$$s = (s_{1,t}, s_{2,t})$$

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Oralytics
Oral Health Coach

10-week intervention to improve oral self-care behaviors; $n = 79$

- Two intervention components in digital intervention
  - Self-monitoring
  - Engagement pJITAI
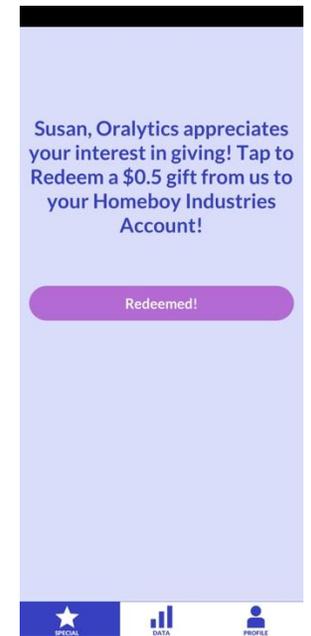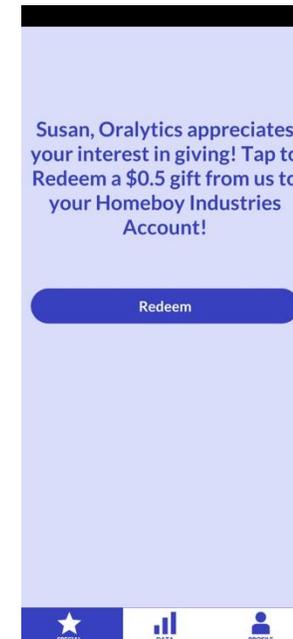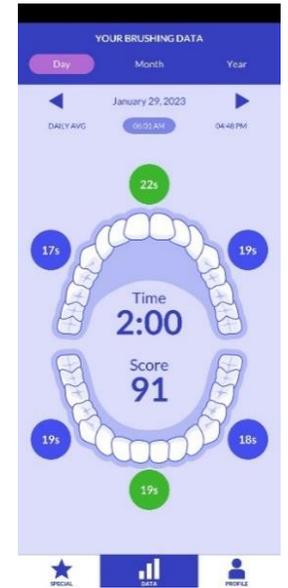
Oralytics Engagement component

- pJITAI for engagement messages
    - Optimize delivery using an RL algorithm

- Engagement component
    - Decision points: 2 per day
    - Intervention options: interactive engagement messages
    - State: electronic toothbrush data, smartphone data
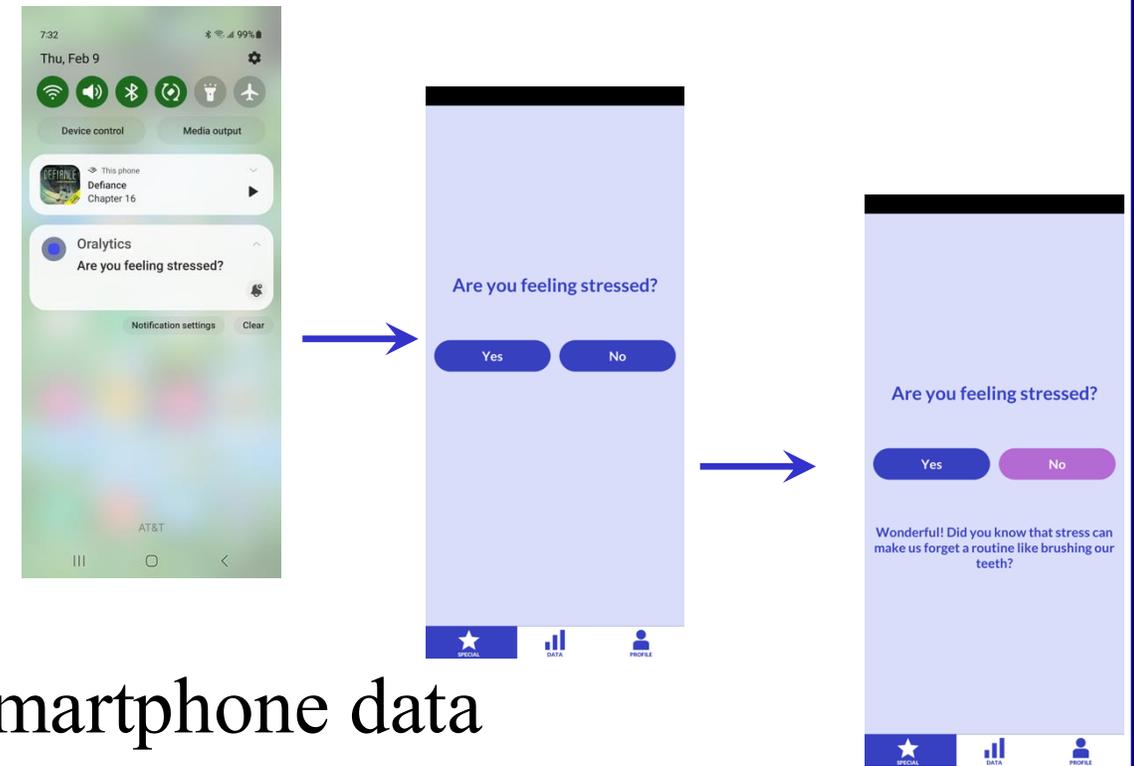
Oralytics RL Algorithm

- Data at decision point, $t = 1, \dots T = 140$

  - S_t: *recent oral self-care behaviors, dose of engagement messages, engagement in self-monitoring, time of day*

  - A_t: *send an engagement message versus do not send*

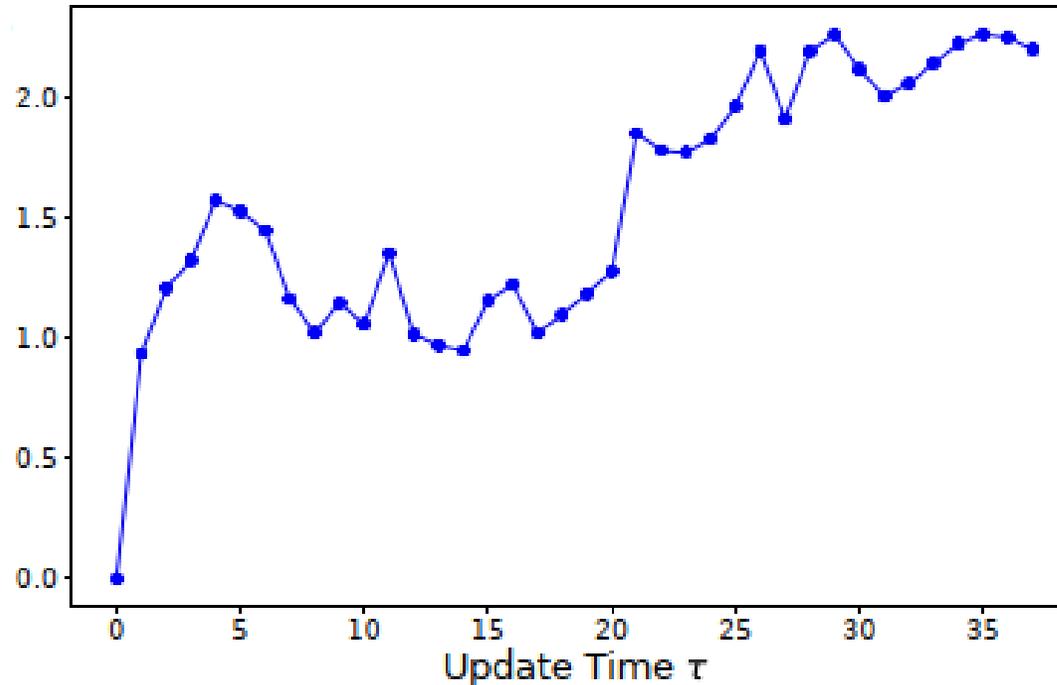 - R_{t+1}: *penalized oral self-care behaviors*
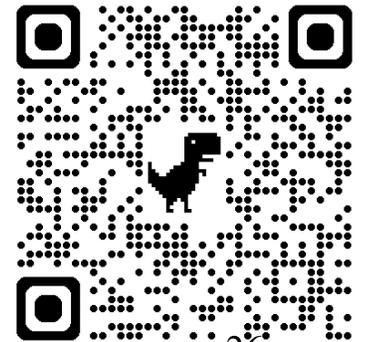
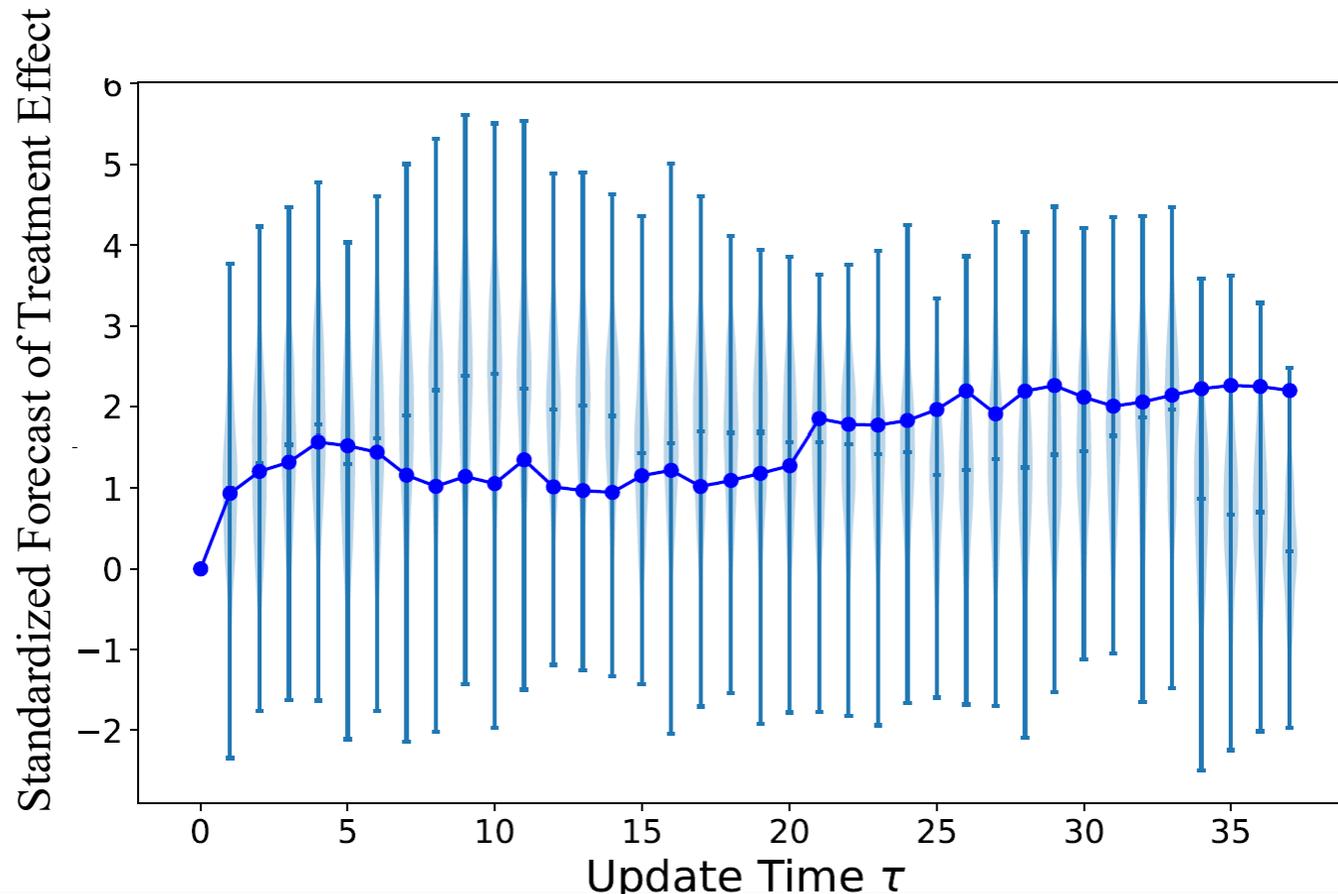# Did the Oralytics RL algorithm Learn?
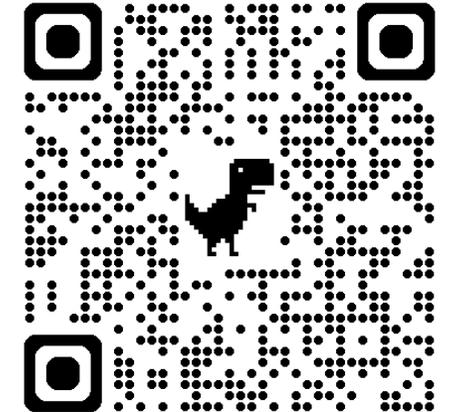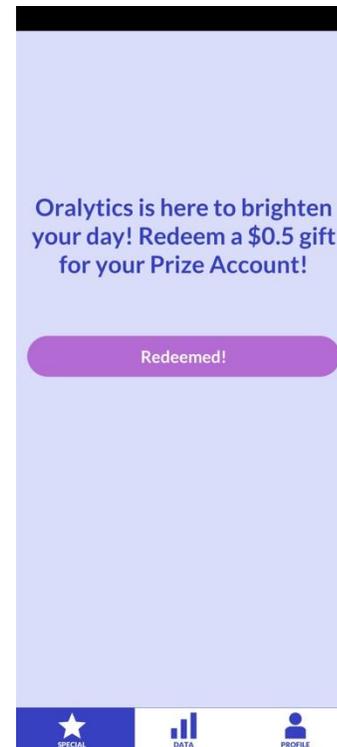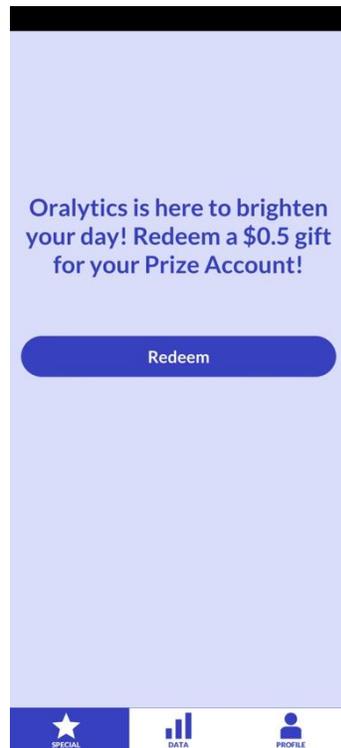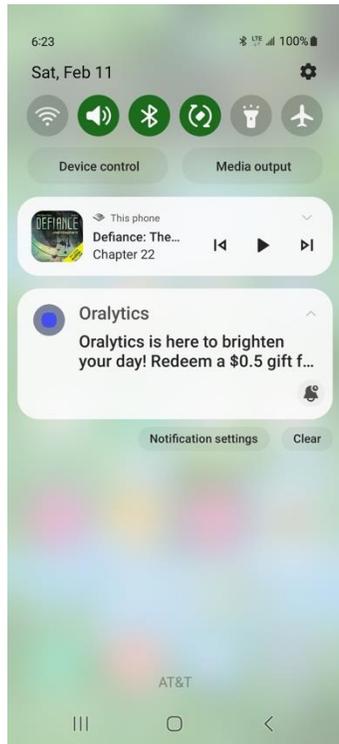
An Oralytics Real-Time Forecast

Standardized forecast of effect of "send an engagement message" versus "no message" on oral self-care behavior quality


Tailoring Variables: Morning, recent oral self-care behavior is poor, recent dose of engagement messages is about one per day, poor self-monitoring

500 replays of the Oralytics RL algorithm under NO effect in this state.

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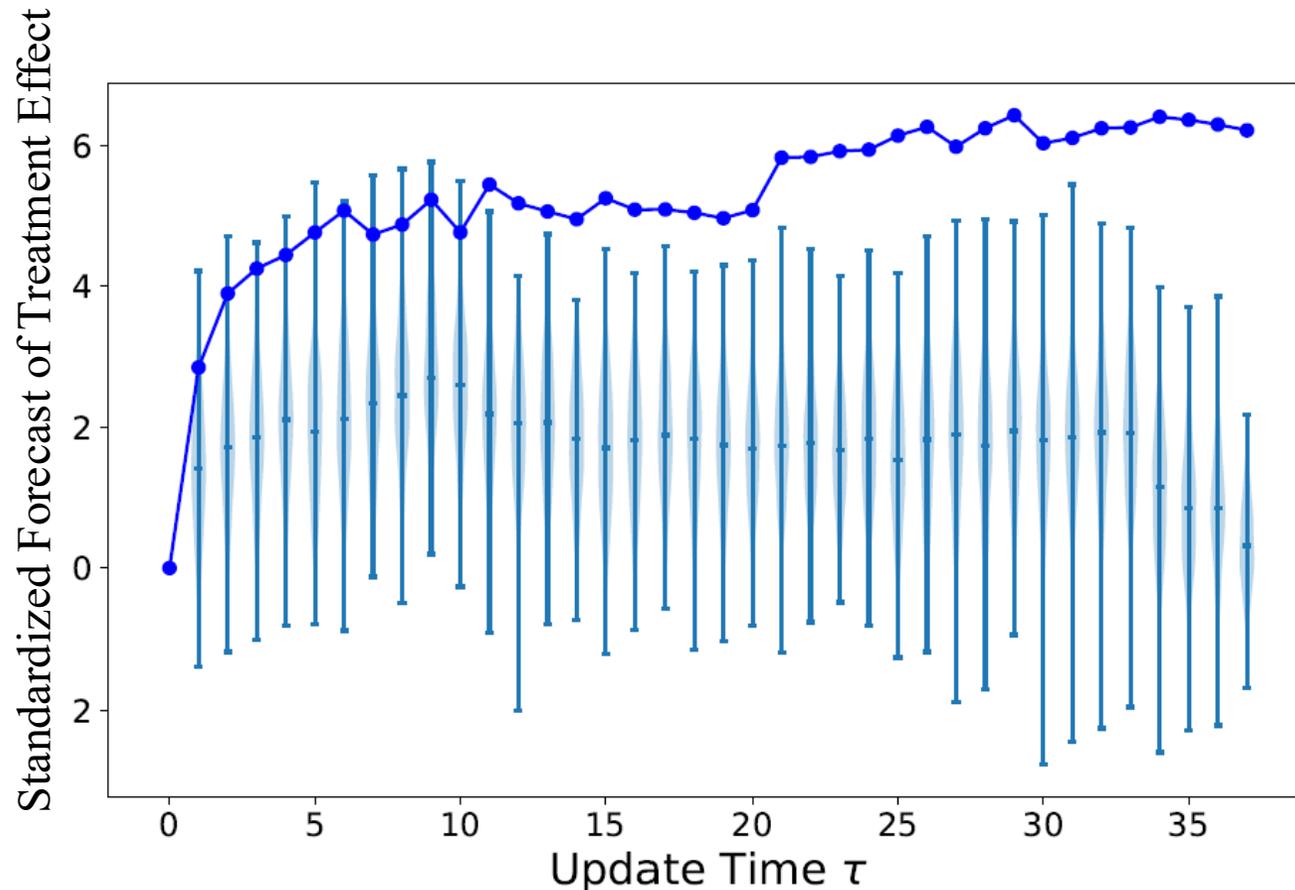
State: *Evening*, recent oral self-care behavior is poor, received around an average of one engagement message *per 5 days* in prior week, poor self-monitoring
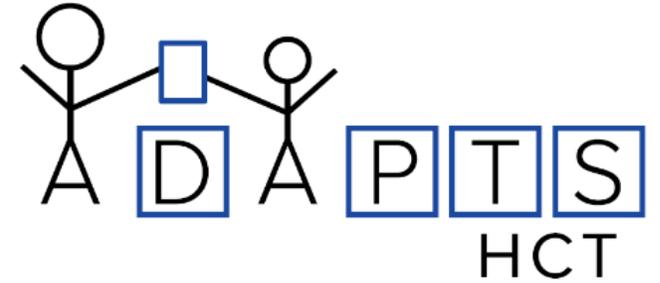
OralyticsTeam!

Billie Nahum-Shani

Anna Trella

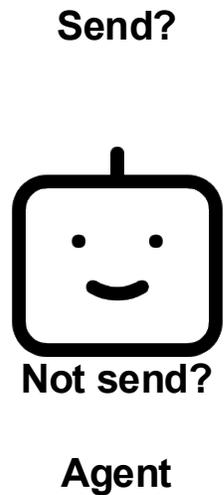Kelly Zhang

Vivek Shetty

+ the software engineering team!

New pJITAI!

- Dyadic Digital Health pJITAI
  - for adolescents and young adults following a blood and marrow transplant

- Goal: enhance medication adherence (to prevent/reduce severity of GVHD)

Dyadic Interventions!

Send?

Not send?

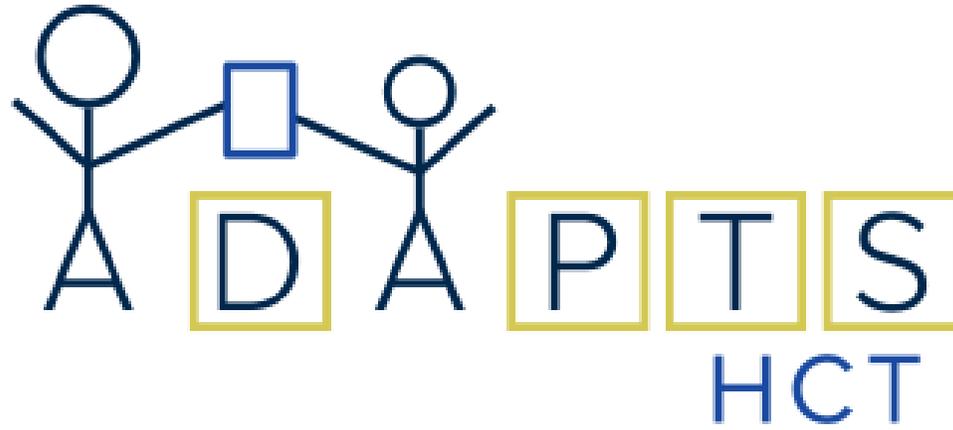**Agent**

AYA

Positive emotions

Relationship quality

Self-care strategies

Care partner

Ziping Xu

DAPTS HCT

The Team