Modeling Habit as Information States for Adaptive Intervention Optimization

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Is Intervention Disengagement Always Harmful?

Just-in-time adaptive interventions (JITAIs) provide timely, personalized mHealth support.[1] While sustained engagement remains challenging,[2]

intervention engagement $\neq$ behavioral engagement

As behaviors are repeated in stable contexts, regulation may shift from external support to internal, cue-driven automaticity.[3]

In this case, continued intervention may become unnecessary.

How can adaptive interventions distinguish maladaptive disengagement from successful independence?

A JITAI-Twin for Latent Habit States[4]

We propose a framework that represents automaticity and context cues as latent information states for adaptive intervention and assessment.

Rather than treating intervention disengagement as direct evidence of success or failure, we model a state-estimation problem:

Can reduced intervention engagement reflect habit formation of the target behavior?

This requires solving two linked measurement problems:

1. **Context cue discovery**: linking passive sensing and EMA responses to recurring context-behavior patterns.
2. **Adaptive assessment**: using adaptive and micro-EMAs,[5–7] combined with self-monitoring, to increase information gain and reduce burden.

Habit as Context-Dependent Behavioral Probability

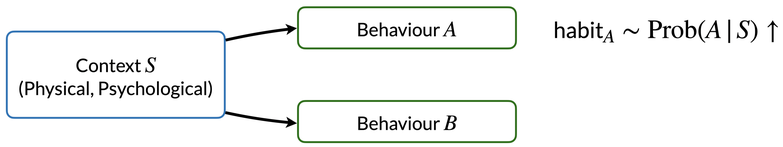


Figure 1. Repeated behavior in stable contexts can result in automaticity.

Habit Cue Configurations Are Latent

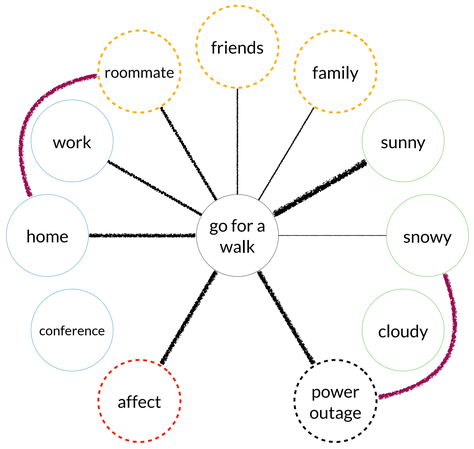


Figure 2. Toy network of potential cues associated with walking. Dotted nodes are not passively observable; thicker edges indicate stronger cue-behavior associations. The network shows only main effects and first-order cue interactions.

Updating Habit States for Intervention/Assessment

Goal: estimate latent habit states with passive sensing, adaptive EMAs, and self-monitoring. Passive data capture behavior and physical context; non-passive reports capture psychological cues.

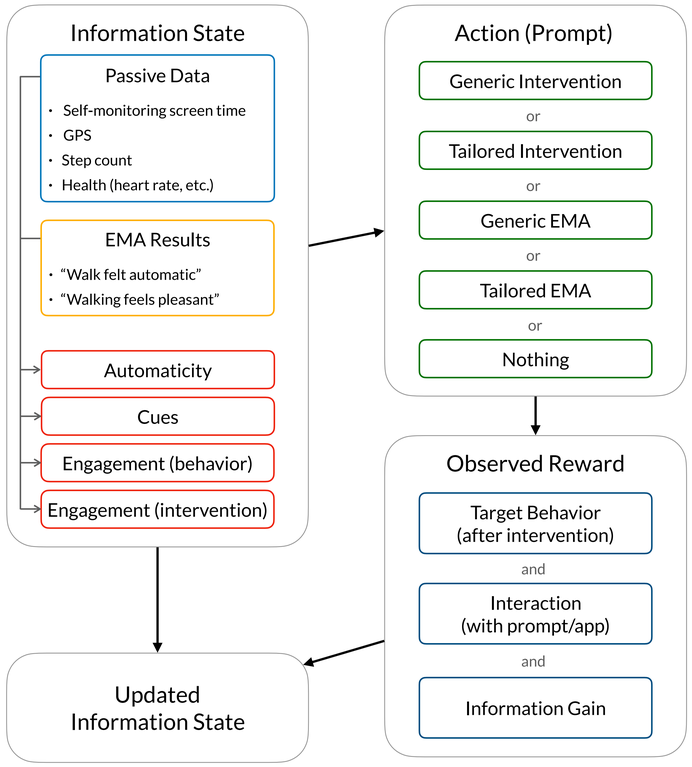


Figure 3. A directed acyclic graph representing the iterative steps used to update information states (red) for intervention and assessment.

Information States: Action Under Uncertainty

Information states support action optimization. Updating beliefs about latent states can guide whether to send an intervention or assessment.

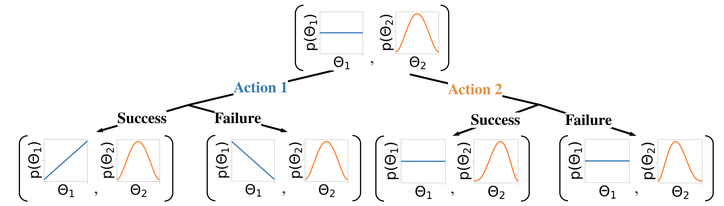
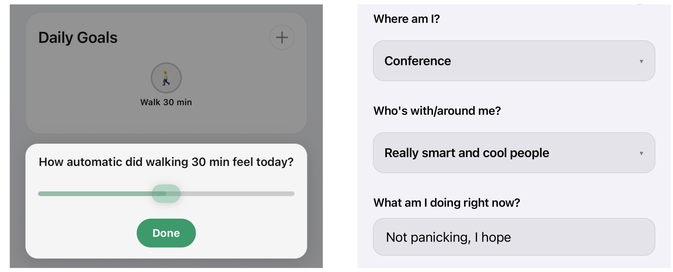


Figure 4. Toy diagram from *Probabilistic Machine Learning* to illustrate sequential information updating for a two-action decision system.[8] The uncertainty about each action's outcome probability is updated sequentially as new information becomes available.

Adaptive EMA Prompts: Ask Less, Learn More[5,6]

Adaptive EMAs can prioritize questions expected to provide the greatest information gain and reduce unnecessary prompts.



(a) Micro-EMA for measuring automaticity.[7] (b) EMA for probing context.

Figure 5. EMA examples from our pilot app.

Self-Monitoring: Behavior Change + Data

Self-monitoring is both an effective behavior change technique and an efficient data source.[9] It may increase awareness of low-salience behaviors while generating user-initiated reports that update habit-state estimates.

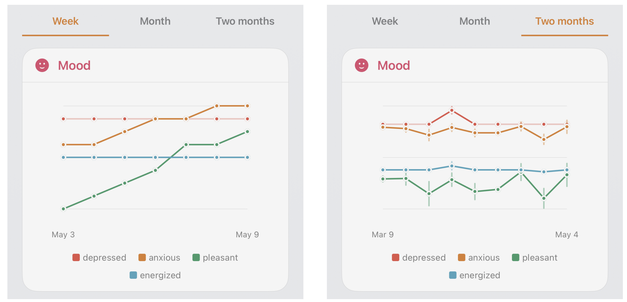


Figure 6. Synthetic self-report data visualized in our pilot app.

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