SARA: A Mobile App to Engage Users in Health Data Collection

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UbiComp/ISWC'17 Adjunct, September 11–15, 2017, Maui, HI, USA

ACM ISBN 978-1-4503-5190-4/17/09 $15.00
https://doi.org/10.1145/3123024.3125611

Abstract

Despite the recent progress in sensor technologies, many relevant health data can be only captured with manual input (e.g., food intake, stress appraisal, subjective emotion, substance use). A common problem of manual logging is that users often disengage within a short time because of high burden. In this work, we propose SARA, a novel app to engage users with ongoing tracking using timely rewards thereby reinforcing users for data input. SARA is developed for adolescents and emerging adults at risk for substance abuse. The rewards in SARA are designed to be developmentally and culturally appropriate to the target demographic and are theoretically grounded in the behavioral science literature. In this paper, we describe SARA and its rewards to increase data collection. We also briefly discuss future plans to evaluate SARA and develop just in time adaptive interventions for engagement and behavior change.

Author Keywords

Engagement, Just-in-time-adaptive-interventions, Substance use

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

1. Introduction

A key advantage of mobile health (mHealth) is its capacity for in-situ data collection and intervention, which overcomes several problems of in-clinic assessment and treatment (e.g., recall bias, not in-

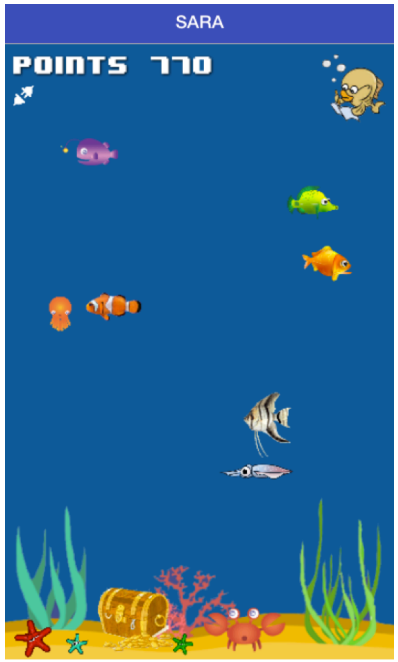


Figure 1: SARA incentivizes its user with a growing aquarium. Above is a screenshot of SARA after a participant logs data for 14 days.

the-moment) [8]. Mobile phones are also pervasive, especially among youth, as the majority of teens (73%) and emerging adults (85%) own a smartphone [30]. However, the promise of mHealth greatly depends on the quality of the collected data. Although sensor technologies have made some health data collection nearly effortless [10], many important health-related data can be only manually captured (e.g., food intake, stress appraisal, mood, substance use) [11]. Unfortunately, sustaining user engagement with manual data collection is a challenge because of high burden. Indeed, previous work has demonstrated that the 30-day retention rate for using health and fitness apps is only 47% where the usage is 2.7 times a week on average. [31]. Financial incentives are one way to engage participants; however, it may not be cost-effective to provide financial incentives for population-scale deployments. New research is required to find scalable solutions that can engage participants with little or no dependence on financial incentives.

Fortunately, engagement is closely related to motivation and persuasion [1]. Skinner's pioneering work on operant conditioning [2] and schedules of reinforcement [3] demonstrate how rewards, and their frequency, can shape behaviors. Cialdini [4] showed how humans are influenced in a social setting. Recent work by BJ Fogg suggests that persuasion involves not only desirability of the incentives, but also the ease and accessibility of the task [5]. Although these theories give general guidelines to engage users, they do not directly translate to the mHealth setting. Furthermore, it is also not clear how these incentives interplay with each other over time and what adjustments are necessary for specific sub-populations in the mHealth setting.

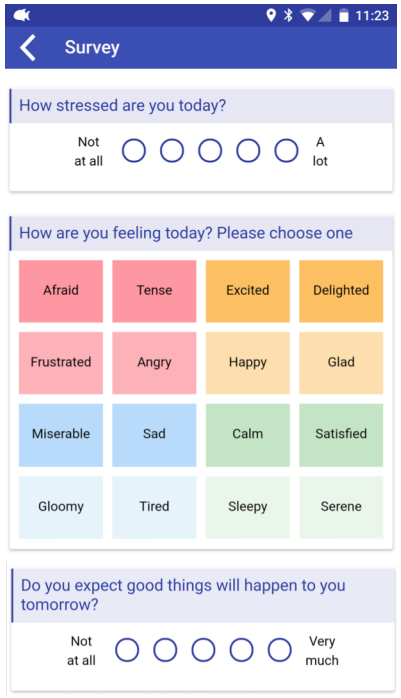
To this end, we introduce SARA, a novel application that integrates various kinds of rewards to incentivize data collection. SARA stands for "Substance Abuse Research Assistant". This first version of SARA is developed for adolescents and emerging adults (14-24 years) who report past-month binge drinking and/or marijuana use. This is a challenging population to engage because the transition from adolescence to adulthood is a developmental period characterized by increased novelty seeking [6], which is reflected in national data showing escalating rates of binge drinking and other drug use, which peak during emerging adulthood [30]. Furthermore, substance use frequently co-occurs with depression and other mental illnesses, which may further reduce motivation to engage [26].

In SARA, participants are asked to complete, every day between 6PM and 12AM, a survey with 7 questions about their emotions (e.g., stress level, mood, loneliness), hopefulness, and daily reflections (e.g., amount of free time, excitement of their day), as well as 2 active tasks [7] which measure their spatial memory and reaction time. SARA incentivizes its users in several different ways. First, SARA has an aquarium theme, and new fishes are awarded as participants complete surveys or active tasks (Figure 1). Sometimes SARA provides rewards in the form of memes and gifs. After participants log their data for a number of days, SARA gives visualizations of past data. SARA also provides some financial incentives, but the total financial incentive is minimal (nine dollars for a 30 day study). The key underlying idea to provide the multitude of different rewards is to provide enough novelty so that participants bear the burden of data collection.

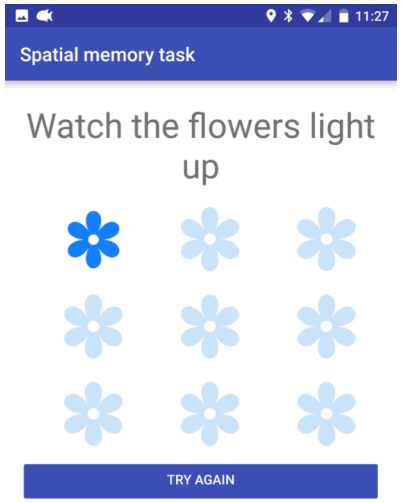
In this paper, we give a detailed description of the SARA application. We then briefly discuss our future plans to conduct user studies with SARA and how the data from these user studies can inform the development of just in time adaptive interventions for engagement [9].

2. The SARA app

SARA is an Android application developed for youth and emerging adults at risk for substance use. The goal is to capture substance use data for extended periods of time in order to inform substance use and addiction science and treatment. The key innovation of SARA is the multitude of different rewards it provides to increase novelty and keep youth engaged in data collection [18].



(a)



(b)

Figure 2.: Screen shots of daily survey (a) and active tasks (b).

These rewards are both culturally relevant and theoretically grounded. Also, to the best of our knowledge, SARA is one of the few systematic investigations of different forms of rewards to incentivize mHealth data collection. Therefore the lessons learned can provide guidance for increasing engagement in mHealth in general.

SARA is comprised of two modules: (1) a data collection module (2) an engagement module. In the following, we first briefly describe the data collection module. Then we discuss the engagement module, which contains different strategies to reward data collection.

2.1 Data collection module

A participant in SARA is asked to complete one survey and two active tasks each day between 6PM and 12am. Typically the survey contains 7 questions about their daily emotions (e.g., stress level, mood, loneliness), hopefulness, and daily reflections (e.g., amount of free time, excitement of their day). On Sundays, an extra set of questions is asked in addition to the 7 questions. These extra questions ask about past-week substance (alcohol, cannabis, smoking) use frequency and motives, perceived risk of regular substance use, impulsivity, violence risk factors, and behavioral intentions to avoid substance use in the following week.

In addition to the surveys, participants complete two active tasks. Active tasks are a way to collect data on reaction time, spatial memory data, gait, problem solving skill etc. and were first introduced in the Apple Research Kit [7]. In the current version of SARA we re-implemented two active tasks on the Android platform. The first active task measures spatial memory. A random sequence of 5 flowers light up in a 2D grid of 9 flowers. Participants are then asked to repeat the sequence. In the second active task, participant tap two buttons alternately for 10 seconds; the number of completed taps provides a measure of reaction time.

Figure 2 shows two sample screenshots of the survey and active tasks. Screenshots of survey questions can be found in the following link[1]. Finally, SARA continuously tracks physical activity (e.g., stationary, walking etc.) and location in background.

2.2 Engagement module

SARA includes 10 different engagement strategies grounded in theories of motivation and persuasion [1,2,3,4,5]. For this first version of SARA, we chose motivational constructs that were: (1) feasible to implement, (2) consistent with the aquarium theme of SARA, and (3) culturally appropriate for the youth. In the following, we discuss the different engagement strategies in SARA along with their theoretical rationale. Table 1 includes a summary of the engagement strategies in SARA, relevant constructs, and the section number they are described in this paper. The key idea of including many different strategies is to increase novelty and reduce habituation [18].

SARA Engagement Strategies	Theoretical construct	Section
Points	- Extrinsic motivation [2,15]/ - Contingent reward [2]	2.2.1
Fish	- Contingent reward [2] - Fixed ratio reinforcement [3]	2.2.1
Fish trivia	- Sensation seeking [18] - Curiosity [27]	2.2.1

[1] Screenshots of survey and active tasks http://bit.ly/SARA-Survey

Badges	- Contingent reward [2] - Fixed ratio reinforcement [3] - Differential reinforcement for high rate [3]	2.2.2
Monetary rewards	- Contingent reward [2] - Fixed ratio reinforcement [3] - Differential reinforcement for high rate [3]	2.2.2
Inspirational memes/gifs	- Autonomy/competency [29] - Curiosity [27] - Variable ratio of reinforcement [3] - Contingent reward [2]	2.2.3
Funny memes/gifs	- Variable ratio of reinforcement [3] - Positive affect [28] - Contingent reward [2]	2.2.3
Life-insight	- Autonomy/competency [29] - Curiosity [27] - Sensation seeking [18] - Contingent reward [2]	2.2.3
Reminder notification	- Trigger [5] - Effort/motivation [5]	2.2.4
Daily inspirational message	- Reciprocity [4] - Autonomy/competency [29] - Curiosity [27]	2.2.4

Table 1: Summary of different theoretical constructs and engagement strategies in SARA

2.2.1 The aquarium environment

The centerpiece of SARA's engagement strategies is a growing *aquarium*. Each time the participant completes a daily survey or active tasks, the participant earns 30 points for the aquarium. For the longer survey on Sundays, additional 50 points are awarded. When participants reach a certain number of points, different fish are unlocked and become visible in the aquarium. Each time a fish is awarded, SARA also shows a piece of *trivia* about that fish to further spark interest and curiosity. For example, when the goldfish is unlocked, SARA provides the message: "Do you know that goldfish can recognize faces?"

A potential problem might arise that, as more fishes are unlocked over time, the aquarium will get crowded. SARA addresses this problem by incorporating *levels*. SARA currently has two levels for a 30-day study. The first level is a fish tank environment. The fish in the first level resemble fish that can be found in a fish tank. Once a certain number of fish are unlocked (~10), participants graduate to a sea-like environment and the subsequently awarded fish resemble fish from the sea.

Figure 4 shows different stages of the SARA aquarium environment. More information about the fish, the corresponding trivia, and at what point they are unlocked points can be found in this link[2].

Theoretical justification: The mobile persuasion literature has previously used ideas similar to a growing aquarium to increase physical activity or social interaction [12,13,14]. In addition, the point system, awarding of fish, and the multiple levels gamify the data collection process [15,16]. The trivia are expected to spark curiosity [27], which may increase engagement. The fish and accompanying trivia are provided immediately after survey or active task completion. The operant conditioning literature suggests that immediate rewards can influence

[2] Points, fishes, trivia http://bit.ly/SARA-Fish

Figure 3: Badges for completing active tasks, surveys

and shape target behavior, because people connect behavior—in this case, data collection—with rewards that follow [2]. Furthermore, the fish are awarded at a fixed rate of once per day (see[2]). The schedules of reinforcement literature suggest that fixed schedules of reinforcement can produce regular responding in target behavior [3].

2.2.2 Badges and financial incentives

In addition to the fish and points, SARA awards *badges* if surveys or active tasks are completed a certain number of consecutive days. Each badge also has a *financial incentive* associated with it. For example, if daily surveys are completed for 3 consecutive days, then a badge is awarded and 25 cents are earned. For longer *streaks*, participants earn different badges and a higher monetary incentive. SARA can reward 3, 6, 12, 18, 30-day streaks and for these streaks 0.25, 0.50, 1, 2, and 3 dollars are awarded respectively. If we assume 90% adherence, then there is less than 5% chance that participants will earn more than 9 dollars in a 30-day study.

Finally in SARA, the streaks for active tasks and surveys are counted separately due to potential differences in how participants view the level of burden for each task. Also, extra badges and monetary incentive are rewarded when participants complete a longer survey on Sundays. Figure 3 shows the different badges awarded in SARA. Participants can access their earned badges and monetary rewards any time by clicking a treasure chest in the aquarium.

Theoretical justification: Badges are commonly used in gamified interfaces [16]. Foursquare, a popular gamified location-sharing app uses badges to increase engagement [17]. Furthermore, the concept of a streak is an example of differential reinforcement of high rates (DRH), where reinforcement is provided only if the number of target behaviors is equal to or higher than a predefined level [3]. In earlier work, DRH has shown to reduce the slow-down of target behavior (in our case, engagement in data

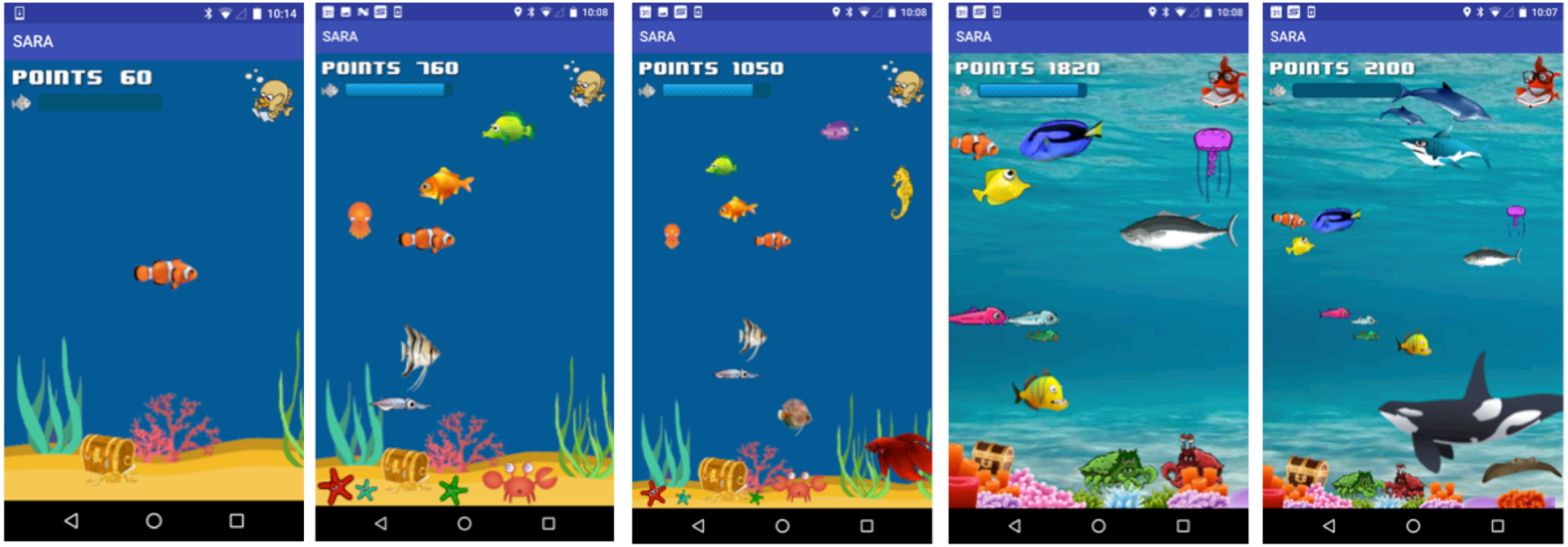
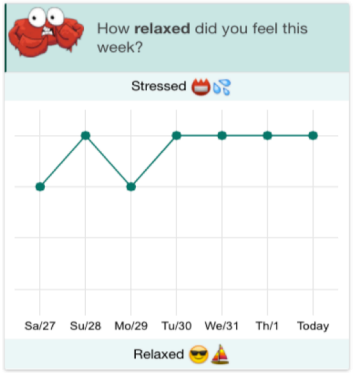


Figure 4: Different stages for the growing aquarium of SARA. a,b,c,d,e respectively shows the state of aquarium if a participant logs for 1,7, 14, 24, 30 days.

(a)

(b)



(c)

Figure 5: Example of memes/gifs and life-insights. (a) and (b) respectively shows an inspiration meme and a funny meme. (c) shows a life insight of stress levels from the past 7 days.

collection for SARA), but DRH cannot completely eliminate the slowing down.

2.2.3 Memes/gifs and life-insights

The fish, badges and monetary incentives described above might become repetitive and users can habituate to them. Therefore SARA periodically provides additional incentives when participants complete a survey or active task.

The first kind of reward is *memes* and *gifs*. Memes and gifs are popular among SARA's initial target population of youth and emerging adults.[3]. SARA contains two types of memes and gifs: funny and inspirational. SARA contains 60 memes and 60 gifs that were created by undergraduate RAs to increase their relevance to younger adults. When participants complete a survey, 50% of the time they receive a meme/gif and the remaining 50% of the time, participants receive nothing. Participants who receive memes and gifs there can either receive an inspirational meme, funny meme, inspirational gif or a funny gif.

In addition to the memes and gifs, participants may also receive a visualization of their tracked data from the past week. We refer to these visualizations as *life-insights*. SARA contains seven life-insights: (i) stress levels, (ii) loneliness, (iii) level of fun, (iv) how new and exciting were their days, (v) free hours each day, (vi) daily step count, and (vii) most frequent location. When participants complete their active tasks, they receive a life-insight 50% of time and the remaining 50% of time they receive nothing.

Theoretical justification: We selected funny and inspirational memes/gifs, because they can generate positive emotion [2]. The further division of inspirational and funny memes and gifs is motivated by earlier work of several authors of this paper, where it was found that exclusively using funny items is not always preferred. A possible explanation is that funny memes and gifs generate positive emotions but are more extrinsic in nature whereas inspirational memes/gifs are more intrinsic motivators that increase autonomy and competence [15]. The life-insights may spark curiosity and reflection, which is grounded in curiosity-drive theory and intrinsic motivation theories [17, 27]. Earlier work also concluded that participants want to see their data after they log for a period of time [20]. Finally, the randomization of receiving or not receiving memes, gifs and life-insights is rooted in the schedules of reinforcements" literature, where it was found that variable rate of reinforcements can generate higher rates of target behavior (data collection in SARA) [3].

2.2.4 Notifications

Notifications are the final type of SARA's engagement strategies. SARA has two kinds of notifications. First, SARA sends *reminder notifications* every day after 6PM to remind participants to complete the surveys. The reminder notification shows information on how close the participant is to completing a streak, or what fish will be unlocked next. If participants do not complete their surveys by 10 PM, then a vibration is generated to remind users to complete the survey and active tasks.

The second type of notification is a *daily inspirational quote*. These notifications are randomized every day with 50% probability; if provided, the notification occurs between 10AM-6PM. Several undergraduate RAs in the research team selected these messages so that they resonate with the SARA's target population of younger adults. SARA now contains 60 of these quotes and they come from a mix of popular contemporary celebrities (singers, actors/actresses, sports figures, etc.). Finally, the delivery of these daily inspirational quotes does not depend on whether participants complete a survey or active task. Therefore, the daily inspirational quotes provide a way to give something to the participants and remind them about SARA even when they are disengaged.

[3] All inspirational memes in SARA: http://bit.ly/SARA-InM
All funny memes in SARA: http://bit.ly/SARA-FunM
All inspirational gifs in SARA: http://bit.ly/SARA-InG
All funny gifs in SARA: http://bit.ly/SARA-FunG

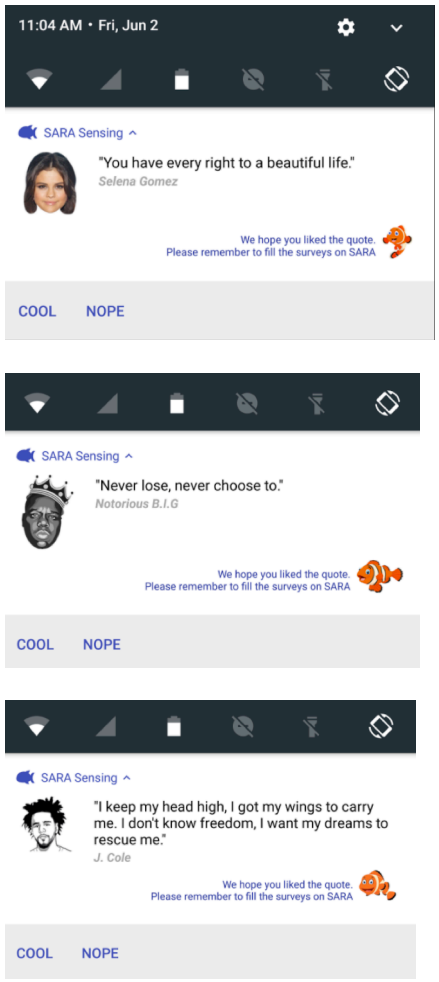


Figure 6: Examples of daily inspirational messages.

Figure 6 shows several examples of the daily inspirational quotes.

Theoritical justification: The reminder notification is grounded in the *trigger* construct from BJ Fogg's persuasion theory [5]. Fogg suggests a trigger is necessary to engage in target behavior even when target behavior is easy to do and incentivized. The daily inspirational quote is grounded in intrinsic motivation theories similar to inspirational gifs/memes [16]. Furthermore, the daily inspirational quotes are given irrespective of whether participants are engaged or disengaged. The hope is participants will like the quote and will return the favor (i.e., reciprocate) by completing the survey/active tasks. Ciadini often refers this kind of behavioral influence as *reciprocity* in the social influence literature [4].

3 Implementation

SARA is implanted on the Android platform. The aquarium animations, badges, and other non-notification related reinforcement are implemented with a combination of Ionic and Phaser frameworks [32,33]. The location and activity sensing are implemented in native android codes. Finally, all the data stored in Amazon S3. The communication between Amazon S3 is encrypted with RSA 2048 and AES-256 in order to be HIPAA compliant.

4 Future work

We have already implemented an initial prototype of SARA and will be conducting a focus group and a field test of SARA in the summer of 2017. The goals of these studies are several folds:

The focus group study will be conducted before the field trial. The purpose of this focus group is to investigate the acceptance of SARA and gather feedback to improve SARA before the field trial. We will recruit undergraduate students between the ages of 18-24 old. 32% of the undergraduate students use alcohol or marijuana according to our data from past studies. We will recruit 25 students and divide the students up into 4 separate focus groups. Focus groups will be audiotaped, transcribed and analyzed for emerging themes by trained undergraduate RAs.

Following the focus group, we will improve SARA and then deploy SARA on a cohort of 60 adolescents and emerging adults. Participants will be recruited from the University of Michigan Health System's Emergency Department and enrolled in the study if they meet the following criteria: are 14-24 years old, report past-month binge drinking (4/5 drinks in a day, tailored by gender) or recreational cannabis use, can download the app, and provide written consent/assent. Enrolled participants will use SARA for one month and complete a follow-up interview to provide user feedback.

This field trial data will provide early evidence of the efficacy of SARA. In addition, several engagement strategies (i.e., memes/gifs, life-insights, notifications) in SARA are randomized and we can thus analyze these data to measure their causal effects on increasing engagement. In other words, the analysis can inform the development of *science* for just-in-time engagement interventions. Also, the size of the subject pool is sized to detect small-standardized intervention effects (<0.2). We refer readers to the work on "micro-randomization" for details on this trial design and the analysis methods [21, 22].

Furthermore, the collected data can be used to train algorithms that provide engagement when they are based on the data. In other words, the dataset can be used to train policies. Policies are data-based decision rules that can dictate which engagement strategy to use in each context (such as stress level, mood etc.). Policy learning is a topic from the reinforcement learning literature and a full discussion is outside the scope of the paper. But, we refer readers to [23, 24, 25] for preliminary work on the application of reinforcement learning algorithms to adapt interventions in mHealth.

Acknowledgements

This work has been supported by the Michigan Institute for Data Science (PI S. Murphy), the University of Michigan Injury Center (PI M. Walton), NIDA P50 DA039838 (PI Linda Collins), NIAAA R01 AA023187 (PI S. Murphy), CDC R49 CE002099 (PI: M. Walton). We thank Katharine Li, Joshua Song, Steven Zheng and the members of Statistical Reinforcement Learning group at University of Michigan for their input throughout the SARA development.

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