Development and Theoretical Approach to an Adaptive Text Message Program to Promote Well-Being and Health Behaviors in Primary Care Patients

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ABSTRACT

A majority of individuals with chronic medical conditions do not fully follow recommendations about health behaviors, and deficits in health education, motivation, support, and well-being all likely play a role. This report describes the theory, programming, development, and implementation process for a machine learning–based, adaptive, once-daily text message intervention to address this public health problem. The intervention aims to promote psychological well-being and provide education and support around health behaviors. The platform allows patients to provide real-time feedback about each message, and the machine learning algorithm then delivers subsequent messages that are increasingly tailored to individuals' preferred message content.

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The majority of the 117 million Americans[1] with chronic medical conditions are unable to adhere to recommended health behaviors, including physical activity, healthy eating, or medications,[2,3] and such nonadherence is linked to disease progression and poor health outcomes.[3,4] Existing in-person health behavior programs have important limitations. These programs are often intensive and time-consuming, are only attended by a minority of patients, and are not personalized to the specific needs of a given patient.[5–8] Such programs could greatly benefit from a more personalized approach, as individualized and patient-centered health programs, customized to the specific needs of each patient, may be needed to optimally improve outcomes.[9,10]

Mobile health (mHealth)–based programs, which utilize wireless devices to deliver health-related information or interventions, may address limitations of existing, in-person health programs. mHealth protocols can deliver intervention content on demand wherever and whenever patients may need them, providing needed flexibility and accessibility. Among mHealth interventions, text message interventions (TMIs) may be particularly useful. Compared to downloading and interfacing with mobile apps, which can be more time-consuming and complex, TMIs are exceedingly simple and present minimal burden for patients.

While prior TMIs for health behavior promotion have had mixed results,[11–13] several enhancements could increase their effectiveness. First, a TMI that concurrently targets psychological well-being and health education and support to take a multipronged approach to promoting health behaviors and optimizing overall function may be useful. Positive psychological well-being has been independently and prospectively linked to greater subsequent health behavior participation in those with chronic medical conditions.[14] Positive psychology interventions,[15] which utilize short tasks to promote well-being, have been effective in medical populations[16–20] and are well-suited to the brief messaging in TMIs.

In addition, TMIs could provide personalized content via an adaptive, machine learning–based platform to deliver messaging that best fits patients' specific situations, preferences, and needs. When a machine learning algorithm is utilized, feedback from participants about the utility of each message can be used to select and send the type of messages that the individual finds most useful in self-managing his or her illness. For example, a patient that finds messages regarding physical activity and stress reduction particularly useful would receive more of those types of messages, whereas a patient that preferred diet-focused messages might receive more messages related to his or her eating habits. Increasing evidence shows that personalized medicine approaches that tailor content of health promotion programs to the needs of individuals are better accepted and more effective than traditional one-size-fits-all approaches.[21–23]

Clinical Points

- Personalized interventions to promote health behaviors appear to be more effective than one-size-fits-all approaches.
- Patients increasingly want to use their mobile devices to obtain health content.
- Utilization of adaptive text message programs that provide specific health information based on patient input might provide a personalized experience and promote health.

In this report, we describe the theoretical underpinnings, programming, logistics, and rollout of a personalized TMI protocol that uses a feedback-based reinforcement algorithm to deliver subsequent messages from a bank of potentially relevant messages; we do not present results. The intervention has been designed specifically for primary care patients in a community health setting with a high proportion of underserved patients. Because primary care physicians serve as the main physician contact for patients with a variety of medical illnesses, implementation of such an intervention in the primary care setting may be particularly powerful.

METHODS

Overview

In preparation for a clinical demonstration project, we conceptualized and developed a machine learning–based TMI to promote psychological well-being and health behavior adherence among English- or Spanish-speaking primary care patients. In this program, patients receive 1 text message each day and offer feedback about the usefulness of each message. This feedback is then used by an algorithm to select the next message sent to the patient. An intensive, iterative development process was followed by logistical preparation for clinical implementation/demonstration in an urban community health primary care clinic.

Intervention Development

Intervention model. We aimed to target health behaviors in the TMI via a 2-pronged approach that included content to promote well-being and direct education and suggestions regarding specific health behaviors. We utilized this combined psychological-behavioral approach because both components may impact health behavior adherence through overlapping, but distinct, pathways (Supplementary Figure 1 provides additional detail).

Specifically, health education and goal-setting messages can lead to greater intention to change, more feelings of control,[24,25] and greater motivation/self-efficacy,[24–27] and these constructs are associated with increased participation in health behaviors.[28–30] Similarly, positive psychology exercises can lead to motivation and self-efficacy. However, they are also directly associated with reduction of depression and improvement in optimism, positive affect, and other markers of well-being,[31–33] which are also associated with health behaviors.[34–37] These combined and complementary effects of positive psychology and health content may be much more powerful in this complex and vulnerable population than either approach alone. Combined health behavior–psychological interventions have been successful in medical patients[38] but thus far have been designed only for the minority of patients with clinical depression. This intervention was designed to be much more widely applicable.

Intervention content. Given that a large number of messages would be needed for an adaptive TMI that could provide a wide variety of intervention content to participants and be applicable to patients with a broad range of conditions, behavior goals, and preferences, we accessed numerous sources for text message content. These sources included publicly available messages and information from (1) prior positive psychology intervention and TMI studies in healthy and medically ill populations,[15,39,40] (2) national health organizations, (3) existing psychotherapeutic interventions (eg, cognitive-behavioral therapy), and (4) our team's previous work delivering positive psychology and health-related content in prior intervention studies.[18,41] These messages were reviewed and adapted for brevity and relevance to this population and resulted in a total of 320 potential messages (Table 1 includes sample messages).

The messages were divided into 5 message types for this initial trial: (1) positive psychology activities performed alone, (2) positive psychology activities performed with others, (3) physical activity messages, (4) healthy eating messages, and (5) stress-reduction messages. We chose these 3 health behaviors (physical activity, healthy eating, and stress reduction) for this initial intervention because they have been associated with improved health outcomes[42–44] and would be relevant to the vast majority of primary care patients.[2]

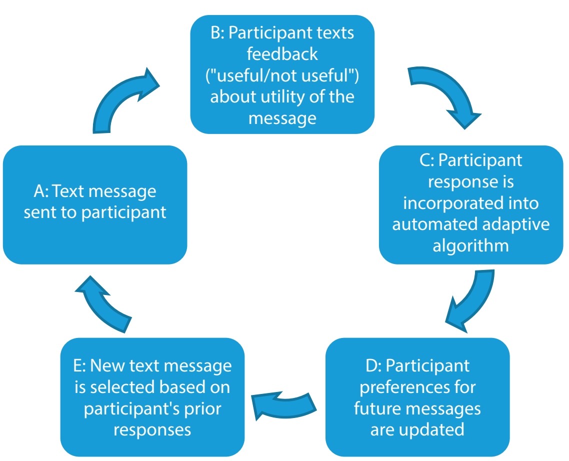
Algorithm creation. In short, we used an algorithm (Figure 1) that recorded the proportion of messages that were liked or disliked for each message type and then began to more frequently provide messages of the favored message types (Supplementary Table 1 provides more detail about algorithm creation). While the 5 message types described previously were used to develop this initial clinical demonstration project, this adaptive system can use a larger number of message types. Furthermore, multiple attributes (eg, positive psychology–based, type of health behavior) can be assigned to a single message, and the algorithm can make decisions on the basis of these attributes instead of a single overall message type (Supplementary Figure 2). For example, a given message might encourage performing physical activity with a friend, which might mean this message is labeled as both prosocial and physical activity related.

Message delivery. To deliver messages, we utilized existing HIPPA-compliant, institutional review board–approved, firewalled servers and services to host the database and the adaptive messaging algorithm and then send automated messages. Utilizing these services, this dynamic messaging system can receive participant feedback about messages in real time, incorporate this feedback into dynamically updated personal preferences, and use those preferences to

Table 1. Sample Messages

Message Type	Sample Message
Positive psychology activities performed alone	People often focus on negative events in their minds, but less often pay attention to good things that happen. Today, try to notice (and maybe write down) 3 good things that happen during the day to give your mood a small boost!
Positive psychology activities performed with others	Hi, XXX! As a mood lifter, try to take a few minutes today to express thanks—by phone or in person—to someone who has done something kind for you (recently or a long time ago). A good mood can help you to live healthy!
Physical activity messages	Hi, XXX! When it comes to activity, every little bit counts. How can you take a few extra walking steps today? Feel good that it will benefit your health! Hi, XXX! Today, try to use easy tricks to increase your activity: park farther away in a parking lot or take the stairs whenever you can! Hi, XXX! People who schedule exercise time on their calendar and treat it as any other important appointment are much more likely to stay active (and feel great!). Can you schedule a time to exercise (even a short walk) today?
Healthy eating messages	Drinking soda or even fruit juice can lead to big spikes in your sugar levels that make you feel more tired. Today, try to think of a healthier replacement if you can: try water, coffee, or tea! The hungrier we are when choosing food, the harder it can be to choose something healthy! If you can, try to plan ahead this morning for a healthy meal tonight! Hi, XXX, it can be helpful to make a list of your favorite healthy foods and to have them easily available at home. Can you make a list of your favorite healthy foods today?
Stress reduction messages	If you can, take 15 to 20 minutes today to sit quietly, relax, breathe deeply, and create a peaceful situation. Importantly, try to notice how you feel afterward.

Figure 1. Text Messaging Algorithm

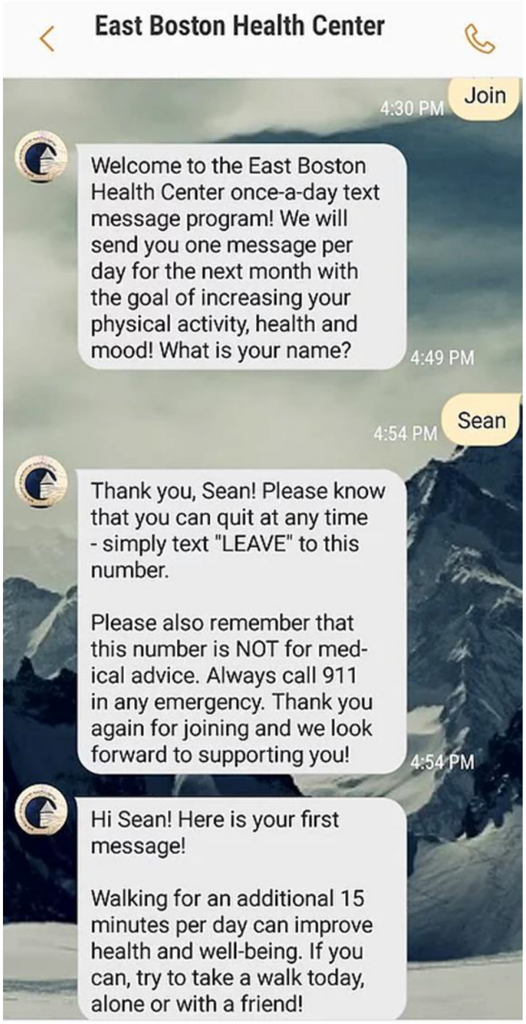


send increasingly personalized messages to the participant (Supplementary Table 1 provides more detail about message delivery).

Pilot Demonstration Project

The adaptive TMI, and an earlier fixed-message TMI, were piloted at an urban community health primary care clinic. This center provides care for a substantial proportion of racial and ethnic minority patients (78.0% of total patients), especially Hispanic/Latino patients (70.8%), with 60.4% of patients identified as being best served in a language other than English (Spanish in nearly all cases).[55] Staff from the TMI development team (S.L.) met with clinical staff to introduce the program and procedures for enrolling participants, and the program was initiated in January 2017.

Figure 2. A Screenshot Showing Initial Enrollment and Delivery of the First Message for Participants



In terms of enrollment criteria, the program was initially open to patients in the health center's chronic disease management program with ≥ 1 chronic medical condition (eg, diabetes, coronary heart disease); after this initial test period, the program was offered to all patients identified by clinicians as in need of assistance or support in integrating health behaviors into their daily lives. Willing patients joined by text messaging the word *join* to the designated phone number to initiate the automated program (Figure 2).

We first utilized a fixed text message program (all patients got the same messages) to test the logistics of enrolling participants in the clinical demonstration program and deploying the text messages. Then, we began utilizing the adaptive TMI. In both the fixed-message and adaptive TMIs, participants received 1 text message per day. Text messages were translated into Spanish, and participants could receive messages in English or Spanish according to their preference. Participants, if desired, also recorded a first name or nickname, and messages used this salutation for further personalization. Text messages were sent each day beginning at the time of enrollment. In the adaptive text messaging model, following each text message, participants were asked whether the message was helpful or not. Their response to this question was then recorded and utilized by the algorithm to choose a message for subsequent days.

Seventy-four patients enrolled in the initial fixed-message program, and enrollment for the adaptive text message program is ongoing as of July 2018. All participants in both phases thus far have successfully initiated the program on their cell phone and received text messages. The demonstration project team is collecting data on rates of enrollment, text message reception, and message feedback (for the adaptive program) to assess the feasibility and acceptability of the program.

DISCUSSION

We successfully conceptualized and created an adaptive, machine learning–based TMI that combines psychological and health education content for an underserved primary care population in English and Spanish using existing mHealth technology.

TMIs have been used in health promotion, with mixed but promising effects on cardiovascular health promotion.[11–13] Such interventions should be applicable to a very wide range of patients, given that 95% of American adults own a cellular phone,[45] and as opposed to mobile apps, TMIs work well with less-expensive phones (eg, nonsmartphones) or data plans, making them accessible to underserved populations. Our protocol expands on prior work by being the first health behavior TMI, to our knowledge, that includes both English and Spanish content and the first to combine health-related messaging with content specifically designed to promote facets of psychological well-being that are linked to cardiac health behaviors.[46,47]

Perhaps most importantly, this is the first TMI, to our knowledge, to utilize an adaptive, personalized approach to messaging using a machine learning approach based on content type. This approach can match messaging with participants' needs and preferences and can provide a precision medicine approach to health promotion. Other programs, such as cardiac rehabilitation, have used participant preferences at intervals to tailor programming, but this is the first to provide ongoing, daily tailoring throughout such a program to dynamically meet participants' needs.

This intervention is early in development, and many questions remain. First, it will be important to obtain results from this clinical project to determine total rates of successful message delivery and rates of feedback to the daily messages to assess feasibility and acceptability in greater depth. In addition, interviews with a representative sample of participants can provide additional data on patient experience. Even if it does appear that this intervention is feasible and well accepted in this real-world primary care setting, more work is needed to assess its effects on well-being, health behavior change, and specific metrics of health (eg, lipid levels).

Future development and evaluations of adaptive TMI projects should determine an optimal duration of the intervention, assess effects of the intervention on health-related outcomes, and study the program in a broad cohort of patients from numerous sites to assess whether it is feasible and effective in the widest group of real-world populations.

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Supplementary material: See accompanying pages.

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Supplementary material follows this article.

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Supplementary Material

Article Title: Development and Theoretical Approach to an Adaptive Text Message Program to Promote Well-Being and Health Behaviors in Primary Care Patients

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List of Supplementary Material for the article

Disclaimer

This Supplementary Material has been provided by the author(s) as an enhancement to the published article. It has been approved by peer review; however, it has undergone neither editing nor formatting by in-house editorial staff. The material is presented in the manner supplied by the author.

Supplementary Table 1. Additional Information About Algorithm Creation and Message Delivery in This Project

Algorithm creation. Algorithms of various complexity can be used to create a customized TMI. We chose a simple reinforcement algorithm for this demonstration project. This simple algorithm utilizes the percentage "liked" of each type of message, which is calculated from the total actual number of messages "liked" and "disliked" of that type based on ratings (liked/disliked) from participants via text after each message. The algorithm then combines this information with the number of times the participant has provided feedback and with a weighting multiplier that determines how quickly the model adapts to patient feedback. By combining these three variables, the algorithm generates the probability of selecting future messages of that specific type. In this way, all message types have an identical probability of being chosen at the start of the program. However, over time a message type can become more or less likely to be chosen based on the participant's reaction to similar messages in the past, allowing the TMI content to become curated over time to the specific preferences and needs of patients.

More specifically, though algorithms of various complexity can be used, the simple reinforcement algorithm for this project utilizes the percentage "liked" of each type of message (P), calculated from the total actual number of messages "liked" of that type (L) and the total number disliked (D). We then chose an arbitrary weighting multiplier (W) that can change how fast the model adapts, such that with a larger W there is more rapid favoring of messages with previously "liked" attributes. These values are combined to produce a modifier (B), which changes the calculated probability of selecting future messages of that specific type. In this demonstration project, for a given attribute we chose the following formula:

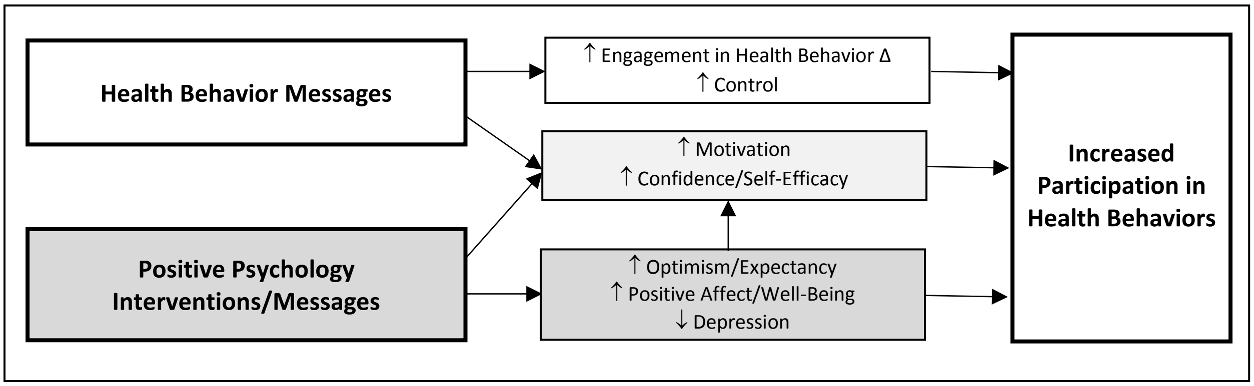
$B = 1 + (W \times (L/(L+D)) \times L)$. Or, simplified: $B = 1 + (W \times P \times L)$

We selected 1.5 as the arbitrary weight modifier (W) to have a moderate level of evolution of the model. Thus, in practice, this means that if a participant "likes" 4 physical activity education messages (L=4) and dislikes one (D=1), they would have liked 80% (P=0.80) of messages of this type. Using the weight modifier of 1.5 (W), they will then be 5.8 times more likely (B) to receive an activity education message in the future. In this way, all messages start with an identical probability of being chosen, but over time can become more likely to be chosen if the participant likes the attributes of that particular message. Likelihood of message selection becomes stronger with the more total previous 'likes' of that type of message. For instance, if a participant likes 10 PP messages in the program, over time, PP messages will be more heavily favored for the next message compared to a newer participant who has only liked two PP messages. Given that messages are selected probabilistically, messages of disliked attributes can be chosen randomly, but will be selected at a lower frequency.

While only five message types were used for this initial clinical demonstration project, the adaptive system can use a larger number of message types to be deployed based on participant feedback. Furthermore, multiple attributes (e.g., PP-based, type of health behavior) can be assigned to a single message, and the algorithm can make decisions based on these attributes instead of a single overall message type (see Figure 3). For example, a given message might encourage performing physical activity with a friend, which might mean this message is labeled as both pro-social and physical activity-related. Depending on the needs of a particular patient population, any set of message characteristics can be used with the system designed for this project.

Message delivery. For the creation of the dynamic message system, messages, message attributes, and user responses were stored in separate tables in a NoSQL database. In the initial trials we used the MongoDB service (https://www.mongodb.com/), which is widely used in industry and healthcare applications. Both the database and the adaptive messaging algorithm were hosted on Amazon Web Services (AWS)—another commonly utilized service in the healthcare and health insurance industry (https://aws.amazon.com/health/)—while the messages themselves were sent via Twilio (https://www.twilio.com/). Utilizing these three web services, this dynamic messaging system can receive participant feedback about messages in real time, incorporate this feedback into dynamically updated personal preferences, and utilize those preferences to send increasingly personalized messages to the participant.

Supplementary Figure 1. Conceptual Model Outlining Potential Mechanisms by Which the Combined TMI May Promote Health Behaviors[32-45]



Supplementary Figure 2. A Screenshot Showing How the Internal Program Is Designed to Set Up an Algorithmic Messaging System