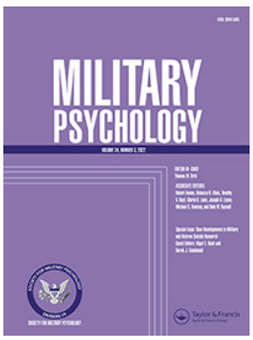

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Feasibility and acceptability of the mobile application for the prevention of suicide (MAPS)

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ABSTRACT

Rates of Veteran suicide continue to be unacceptably high. Suicidal ideation and behavior are contextually and situationally based, limiting the ability of traditional prevention and assessment strategies to prevent acute crises. The Mobile Application for the Prevention of Suicide (MAPS) is a novel, smartphone-based intervention strategy that utilizes ecological momentary assessment to identify suicide risk in the moment and delivers treatment strategies in real-time. The app is personalized to each patient, utilizes empirically intervention strategies, and is delivered adjunctively to Veterans Affairs (VA) treatment as usual. This article outlines the MAPS intervention and presents results of an open trial to assess its feasibility and acceptability. Eight Veterans were recruited from aVeterans Affairs Medical Center (VAMC) psychiatric inpatient unit following hospitalization for either a suicide ideation or attempt. Veterans received MAPS for 2 weeks post-hospitalization. Veterans reported high levels of satisfaction with MAPS and all opted to extend their use of MAPS beyond the 2-week trial period. MAPS may be a useful adjunctive to treatment as usual for high-risk Veterans by allowing patients and their providers to better track suicide risk and deploy intervention strategies when risk is detected.

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Suicide prevention; mobile applications; Veterans

What is the public significance of this article?—Suicide continues to impact the lives of Veterans and reducing suicide rates is a critical public health goal. Mobile technologiescombined with ecological momentary assessment, such as the one described in this manuscript, have the potential to target in the moment risk, reduce suicidebehaviors, and provide highly accessible tools for our high-risk Veterans. The work described in this article represents the first step in a larger goal of developingempirically supported, interventions to reduce suicide.

Suicide is a major public health crisis for Veterans. Veterans account for 14% of all known suicide deaths in the United States, but only comprise 7% of the national population (Department of Veterans Affairs, 2020). Many new prevention programs have been developed and implemented to improve the identification of Veterans who may be at-risk for suicide (i.e., universal screening and the REACH VET algorithm (Matarazzo, Brenner, & Reger, 2019), streamline monitoring and case management of suicidal Veterans (i.e., VA Suicide Prevention Coordinator program and regular risk screening), further training of peers who may come into contact with a suicidal Veteran (i.e., Operation S.A.V.E (King et al., 2012), and facilitate national suicide event tracking (Hoffmire et al., 2016). However, approaches to assist Veterans who are already at high-risk for suicide, especially during suicidal crises, are much more limited. Thus, despite these efforts, rates of suicide among Veterans remain unacceptably high.

The nature of how suicide behavior emerges is inherently challenging for prevention. Though a broad range of risk factors make a person more vulnerable to suicide (Franklin et al., 2017), acute risk remains difficult to predict as suicide behavior emerges from contextual and situational factors. Thus, prevention approaches that employ traditional psychotherapy formats (e.g., weekly sessions in a clinic or hospital) are limited in their ability to reduce suicide behavior because risk is typically identified and treated outside the real-world context in which suicide behavior occurs. Situationally experienced factors such as impulsivity, anger, and other negative emotional states are examples of constructs that have been found to play a role in the emergence of specific episodes of suicidality (Baud, 2005; Brodsky, Malone, Ellis, Dulit, & Mann, 1997; Brown, Comtois,

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

& Linehan, 2002; Conner & Duberstein, 2004; Mann et al., 2009). Similarly, distress associated with relational problems (i.e., a suicide risk factor) frequently emerges from situational experiences (e.g., episodes of interpersonal conflict).

Interventions delivered through mobile technologies are powerful tools for enhancing prevention because they enable the identification of risk in its real-world context. Mobile technologies offer an opportunity to extend care beyond the hospital and clinic settings. An early demonstration that changes in ideation severity are signaled by predictable fluctuations in affective ratings collected via smartphones indicates this approach's promise (Armey, Brick, Schatten, Nugent, & Miller, 2018). These technologies are currently being developed and pilot tested for use in a range of mental health conditions (Armey, 2012; Ranney et al., 2015; Thorsen, Patena, Morrow Guthrie, Spirito, & Ranney, 2016).

Ecological momentary assessment (EMA) encompasses a set of intensive longitudinal methodologies employed to identify and describe the interplay of situational or contextual factors on participants' thoughts, emotions, and behavior (Bolger, Davis, & Rafaeli, 2003). Because EMA data is collected frequently throughout the day, it is possible to obtain minimally reactive (Hufford, Shields, Shiffman, Paty, & Balabanis, 2002; Shiffman, 2009) data regarding participant thoughts, feelings, and behavior that is relatively free of social desirability and recall bias. Moreover, many constructs such as suicide risk and suicidal ideation, longitudinal, or even daily assessments may be insufficiently frequent to capture relevant *variability* in affect. Recently, EMA studies have demonstrated clear affective precipitants to increases in suicidal ideation and self-harm behavior (Armey, 2012; Armey, Crowther, & Miller, 2011; Armey, Nugent, & Crowther, 2012; Nock, Prinstein, & Sterba, 2009). And, EMA lends itself to pairing with mobile technologies (see (Peters et al., 2020; Porras-Segovia et al., 2020) for examples). Leveraging this technology as part of an intervention (i.e., ecological momentary intervention or EMI) allows interventions, such as coping skills delivery, to be tailored to patients' answers to EMI items that confer risk for suicide (e.g., suicidal intent and elevated negative affect).

Mobile technologies have many potential advantages for the treatment of psychological problems in military personnel and Veterans. They can: (a) be incorporated into standard care; (b) be widely disseminated; (c) be personalized to individual patients; and (d) minimize stigma associated with traditional forms of therapy. As a delivery system, mobile technologies can be linked with highly sensitive assessment methods such as EMI to target situationally experienced cognitive and behavioral reactions. These methods are particularly important in the assessment and treatment of high-risk behaviors, such as suicide, targeting, and treating behavior in the time and context in which they occur.

Our research team has partnered with a software company to develop the Mobile Application for the Prevention of Suicide (MAPS). The app utilizes empirically supported intervention strategies to target suicide risk as identified by EMA; as such, we consider MAPS an EMI. While there are other mobile applications available for suicide prevention, such as ReliefLink (NCT02691221, NCT03463980; trial results pending), The Virtual Hope Box (Bush et al., 2015), and the Safety Plan application, MAPS' combination of personalized contact, EMA, and intervention strategies provides something unique and more interactive to patients and their providers. Other applications like ReliefLink and the Virtual toolbox provide patients with useful resources, including safety plans and coping strategies, but rely primarily on patient initiative to track mood and make decisions about their care – a task that can be difficult for patients in acute crises. In contrast, MAPS sends assessments and content to the patients at random intervals daily and uses clinical algorithms to suggest intervention strategies appropriate to the identified level of risk. This EMI is the core feature that makes MAPS different from other apps in the market. Content pushed through MAPS is supportive, orienting the user toward coping strategies identified during safety plan creation with the provider, a design choice intended to promote acceptability, build the therapeutic alliance, and reduce stigma. Some have contended that, though effective, other app-based interventions incorporating more challenging content (e.g., Therapeutic Evaluative Conditioning (Franklin et al., 2016)) may unintentionally reduce help-seeking (Nielsen, Kirtley, & Townsend, 2017).

The goal of this paper is to provide a detailed overview of the MAPS intervention, to highlight initial feasibility and acceptability data, and to underscore the clinical and research benefits of this type of intervention for our high-risk Veterans. This paper represents the initial step in a program of research and intervention development, and future developments will be discussed along with limitations of the current iteration of MAPS.

Design and methods

The intervention

Although many smartphone apps for suicide do exist, they have concerning limitations. Few offer evidence-based support, some include potentially harmful

content, such as facilitating access to lethal means (Larsen, Nicholas, & Christensen, 2016) and incorrect crisis contact information (Martinengo et al., 2019). Others lack privacy and/or connectivity to crisis hotlines (Aguirre, McCoy, & Roan, 2013). A recent systematic assessment based on six suicide prevention strategy domains (i.e., tracking of mood and suicidal thoughts, development of a safety plan, recommendation of activities, information and education, access to support networks, and access to emergency counseling) revealed that fewer than 7% of the apps offered all six strategies and most offered only up to three (Martinengo et al., 2019).

The MAPS was created to address the aforementioned gaps in suicide prevention efforts, particularly in the high-risk time period following psychiatric hospitalization, by targeting the contextual nature of suicidal ideation and behavior in the moment with frequent, daily, smartphone-based assessments. Developed in collaboration with JourneyLabs, a third-party software developer, and researchers affiliated with Brown University, MAPS uses a combination of randomly delivered daily assessments and event-cued assessments to detect acute suicide risk and, in the presence of such risk, deploys intervention strategies from individuals' safety plans via the mobile app. While the safety plan guides the framework for the intervention strategy, MAPS also includes other recommended coping strategies derived from the literature (e.g., deep breathing, progressive muscle relaxation, and emotional regulation strategies) to supplement the veteran's own most commonly used coping tools. What makes MAPS unique from other suicide prevention apps is its ability to address suicide risk in real time, without relying on individuals to know when their psychological state may necessitate intervention – which can be challenging for individuals to do when distressed. The app is intended to be an adjunct to therapy rather than a stand-alone treatment.

MAPS, although still in the development stage, can be installed on both iOS and Android devices. Users download the app onto their personal phones using a QR code or unique one-time passcode. The app icon is non-descript (i.e., masking the nature of the program for privacy reasons) and, once downloaded, it requires a 4-digit pin code chosen by the user to access. The current iteration of MAPS consists of a home screen (see Figure 1) with a running ticker that is personalized to each participant's reasons for living and tabs for a calendar, and resources titled "help now." The ticker content also includes contact information for the study and daily tips or suggestions pulled from a larger bank of messages.

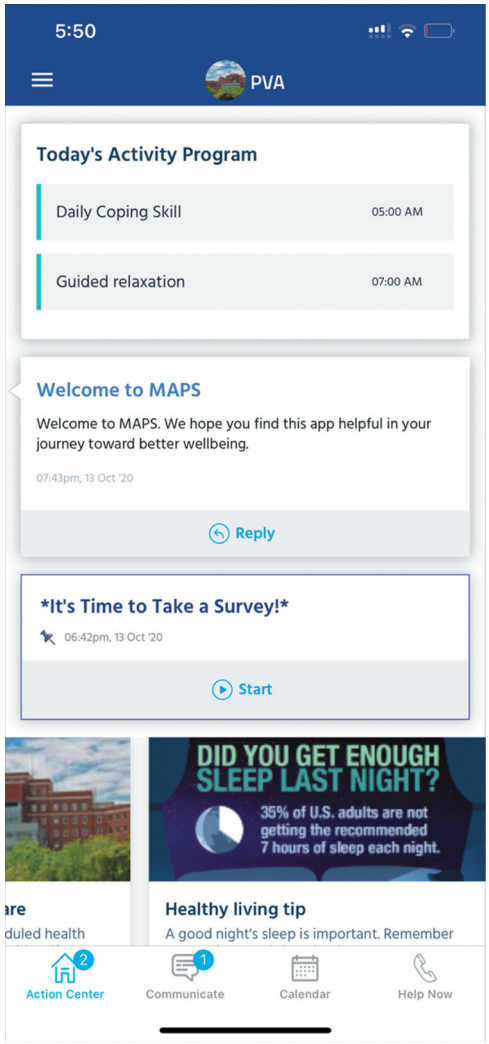

Figure 1. MAPS home screen.

Upon download, participants receive a welcome survey that includes a brief overview on how to use the app and a safety plan survey where the users input their coping strategies, distraction tools, contact information of people who can provide support, and professional services. This information is then used to: (a) personalize the daily surveys by including questions such as whether or not the participant has experienced any of their suicide warning signs, (b) populate the recommended coping strategies that will be used as intervention strategies when prompted by responses on daily surveys, (c) personalize the ticker content, which appears on the home screen, with relevant photos, quotes, and reasons for living, and (d) generate a PDF safety plan that is saved in the resources section of the app. Examples of reasons for living, distraction tools, and coping strategies are provided in table X. Thus, MAPS is designed to be personalized for each user and the initial setup is intended to be a collaborative process between the user and his/her provider. MAPS utilizes a safety plan to guide the algorithm used to respond to survey items;

however, it is not a safety planning intervention, but rather an EMI that draws from the basic suicide prevention plan framework developed by experts (Stanley & Brown, 2012) and utilized clinically within the VA.

At the core of MAPS is a daily assessment protocol that includes both randomly delivered surveys (i.e., surveys that are presented randomly within individuals' wake and sleep times) and event-cued surveys (i.e., participants are instructed to open and complete a survey whenever they feel stressed or are having suicidal thoughts). Each survey takes approximately 5–15 minutes to complete. For this open trial, surveys were programmed to be delivered at random intervals three times daily during a time range indicated by the participant. Surveys assess warning signs, current suicidal thoughts, intent, plan, and emotional state. Recent suicide behavior and life stressors are also assessed. Items from the random survey include items from the Columbia Suicide Severity Rating Scale (C-SSRS) and the MSSI (Miller, Norman, Bishop, & Dow, 1986), the Positive and Negative Affective Scale (PANAS) (Watson & Clark, 1994; Watson, Clark, & Tellegen, 1988), and individual items about daily stressors, and alcohol/drug use. Users receive a notification on their phones when a survey is delivered, and they have 30 minutes to start the survey before it disappears from the home screen.

When risk is detected via the participants' responses to survey items, an intervention recommendation is deployed. Elevated risk was defined as endorsement of any suicide ideation causing distress to the participant. These elevated risk categories were created using "yes/no" responses to items 1–5 from the Columbia Suicide Severity Rating Scale and an additional item added to assess in-the-moment intent (e.g., *Do you intend to act on suicidal thoughts now or in the near future*?). Three levels of risk were created: (a) mild risk defined as endorsement of distress or high negative emotions but no current suicidal intent, method, or plan; (b) moderate risk, defined as endorsement of suicidal ideation with intent at some point since last assessment but no current intent or plan (Yes response to "*since you last completed a questionnaire, when you had thoughts of suicide or wishing you were dead, did you have any intention of acting on them*" and a "NO response to "*Do you intend to act on suicidal thoughts now or in the near future*"); and (c) high risk, defined as endorsement of current suicidal ideation with intent OR any suicide attempt made during the time frame. These three risk levels corresponded to three intervention pathways.

At the beginning of every survey, participants are told that surveys are not monitored in real time and that if they are in any current crisis, they should call 911 or emergency services. MAPS contains three primary pathways of intervention. The lowest risk pathway is triggered by participants' endorsement of stress and or/negative emotions in combination with a lack of endorsement of current or recent suicide intent or plan. This pathway pushes a secondary survey with recommended coping strategies that include strategies taken from the safety plan and additional empirically supported coping strategies such as diaphragmatic breathing, progressive muscle relaxation, mindfulness techniques, and emotional regulation exercises and distraction ideas for reducing stress levels. Participants are given the opportunity to pick whether they would like to try a coping skill or a distraction strategy and the system will recommend a few tools based on their preferences. The second pathway (triggered by current or recent suicidal ideation but no acute intent) suggests the participant contacts a support person or professional service and provides the contact information from their safety plan. These individuals and/or agencies are pulled from both the participant's safety plan and our database of local support agencies. The third pathway, triggered by acute suicide risk (i.e., endorsement of current intent at the time of the survey) leads to a "pop up" which allows direct dial to an emergency number. For most, this number is the Veterans Crisis Line but, on initial survey, the Veteran may decide to input a different crisis number, such as 911 or their local hospital crisis service. A red screen pops up with a dial indicator and the app will directly dial this once the participant clicks on it. If any of the pathways are triggered, participants will receive a follow-up survey an hour later to assess if (a) they tried the recommended strategy and (b) if it was helpful. If the strategy is reported to be unhelpful or the participant did not engage in any strategy, new suggestions will be offered.

Participants also receive a morning check-in survey which asks about sleep and current mood and an end-of-day survey that asks the user about their experiences over the entire day (emotions, suicide, treatment adherence, alcohol use, drug use, and stressors). This end-of-day survey can be used to track mood and ideation across each day and is a general indicator of well-being. Participants also have the ability to access all their resources and coping strategies at any time using the resource tab. Communication features are also built in to the program that allows the user to send a message (image or text) to their provider. This feature was disabled for this pilot study but is being developed for future iterations of the intervention.

On the back end, the delivery platform comes with a flexible provider dashboard that allows providers, researchers, and/or administrators to set risk indicators and track symptom endorsement and engagement with the app (see Figure 2), set risk indicators, or compute customized measures of risk using any data collected by the platform. While default risk levels are set according to CSSRS responses (as described earlier), clinicians

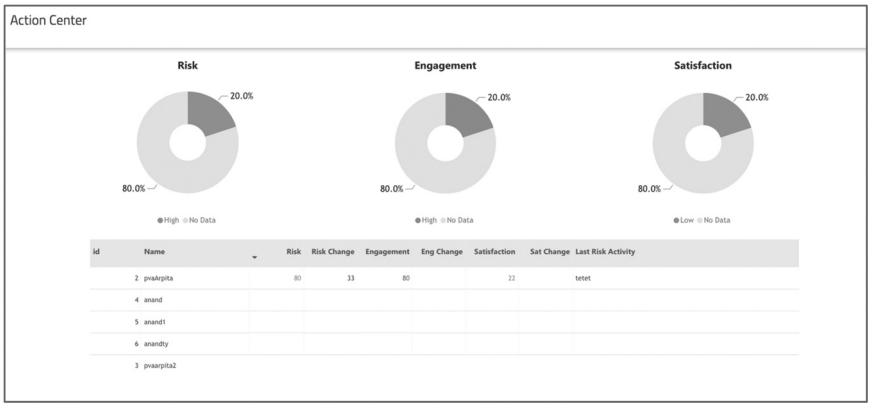

Figure 2. Provider dashboard for MAPS. This dashboard is to illustrate and does not represent real participants nor their data.

have the opportunity to create additional risk indicators based on their work with these patients to allow them to sort patients into those who may need more support/intervention. MAPS will continue to send intervention strategies based on survey responses, but clinicians can increase risk indicator on the back end in order to better track and highlight patients who may need extra services. The designated administrator can set the length of survey administration (how many days/weeks participants will receive surveys), the number and timing of surveys (random, fixed intervals), and the details of a variety of parameters, such as how long the surveys stay on the home screen and which days of the week to push surveys. This back-end also allows designated administrators or providers to push additional surveys or brief messages as needed. The system allows providers or administrators to tailor unique "journeys" for each user. For example, pushing more content after psychiatric hospitalization or an acute crisis period and phasing out surveys with periods of sustained improvement. This can be done on the back-end by setting participant "attributes" which can be modified or updated based on survey responses and may lead a participant to a different set of surveys, a different frequency of surveys, and so forth. The dashboard was not heavily used for this study but is under development for future iterations. Likewise, future development will focus on the development of risk prediction models based on data collected by the platform.

Overview

MAPS development involves a multi-stage approach with ongoing content development and feedback from Veterans, providers, local hospital administrators, and VA central office personnel. The first stage of development was centered on acceptability and feasibility from the first round of Veteran participants. The target questions for this phase of the study were: (a) Will high-risk Veterans use MAPS? (b) Do Veterans like MAPS? (c) What features will be seen as most useful? and (d) What are the areas for improvement?

Procedures

Veterans recently hospitalized for suicidal ideation or behavior were recruited from a psychiatric inpatient unit at a VA Medical Center in the northeastern United States. Inclusion criteria were: (a) suicide attempt or suicidal ideation with intent to make a suicide attempt within 48 hours of hospitalization and confirmed by the administration of the Columbia Suicide Severity Rating Scale (C-SSRS) (Posner et al., 2011); (b) access to a personal Android or iOS smartphone; and (c) ability to speak, read, and understand spoken English sufficiently well to complete the procedures of the study. *Exclusion criteria* included: (a) current psychotic or manic symptoms severe enough to interfere with the completion of study procedures and (b) cognitive impairment that would interfere with adequate participation in the project (as indicated by a score of less than 20 on the Mini Mental Status Examination) and (c) medical record diagnosis of severe substance use disorder. Participants provided informed consent prior to any study involvement. All procedures were approved by the local IRB.

Study participation included a baseline assessment, 2–6 weeks of app use, and a 6-week follow-up assessment. Participants were given a QR code to download MAPS. All participants met with study staff in order to complete a safety plan and learn how to use the app. Research staff used the information from each safety plan to personalize the app for each participant on the back end, a step that will be eliminated in future versions of the platform. Veterans were asked to use the app for 2 weeks. At the 2-week point, participants were contacted by study staff and given the option to either

disable the app or to continue using it for an additional 4 weeks. After the 6 weeks were complete, Veterans were brought back in to complete self-report measures and to discuss their experiences with the app.

Participants

Participants were eight Veterans. Most were male (75%) and white (87.5%), with a mean age of 45 (SD = 15.41). Most (75%) had been hospitalized for suicidal ideation, but a sizable portion (25%) had been hospitalized for a suicide attempt.

Measures

Feasibility

Feasibility was assessed by the following indicators: (a) percentage of Veterans approached who consented to participate, (b) drop-out rates from download of MAPS to the 2-week follow-up, (c) number of surveys completed, and (d) percentage of participants who requested to extend app use to 6-weeks.

Acceptability

Satisfaction with the app was assessed using The Session Evaluation Form (SEF) modified for this study (Harper, Contreras, Bangi, & Pedraza, 2003), the Client Satisfaction Questionnaire (CSQ)(Attkisson & Zwick, 1982), and qualitative interviews. The SEF is a 10-item self-report questionnaire used to assess patient ratings of therapy sessions. Responses are rated on a 4-point response scale ranging from 1 = strongly disagree to 4 = strongly agree. It is aimed at eliciting information about the participant's experience with an intervention or therapy session. Total scores range from 10 to 40 with higher scores reflecting more positive program ratings. For this study, the SEF was modified to reflect the use of the app rather than a therapy session (i.e., "I learned a lot from this intervention" rather than "I learned a lot from this session."). The CSQ is an 8-item self-report measure used to assess patient satisfaction with services received. Items are rated on a 4-point Likert scale ranging from 1 to 4 with higher items reflecting greater satisfaction. Total scores range from 8 to 32 with higher scores reflecting greater satisfaction. Sample items from the CSQ include "To what extent has our program met your needs," "How satisfied are you with the service you received," and "have the services you received helped you to deal more effectively with your problems." Both measures have established reliability and validity (Attkisson & Zwick, 1982; Harper et al., 2003).

A post-treatment semi-structured interview was conducted to gain participants' feedback about intervention components and research procedures. The interview was designed to be a collaborative process between participants and interviewers. Participants were asked open-ended process evaluation questions regarding their views on: (a) app structure; (b) response format; (c) content; and (d) overall impressions. Each aspect of the program (e.g., ease of access, content, format, appearance, relevance, and potential problems in use) was discussed. Participants' impressions of the app, and the extent to which the program was viewed as helpful and relevant to their ability to manage their negative moods and suicidality were assessed. Broad questions were followed by probes and unstructured questions based on areas raised by participants to encourage elaboration and clarification.

Interest in additional features was assessed by a 10-item measure listing each of the features (e.g., an expanded bank of coping skills, calendar, and photo bank). Participants were asked to rate how interested they would be in each of the 10 features using a Likert scale ranging from 0 = not at all interested to 4 = very interested.

Safety

Safety was determined by the number of adverse events and by an examination of changes in suicidal ideation from baseline to 6-week follow-up. Adverse events were defined according to VA IRB reporting requirements and included suicide attempt, death, and medical or psychiatric hospitalization.

Results

Feasibility

Ten participants were approached while in the inpatient psychiatric unit and eight (80%) consented to participate. One Veteran denied that he had any suicidal thoughts and another stated he was not interested in participating. Of the eight participants who consented, two were lost to contact between the baseline assessment and the individual app session. These two participants, both women, did not download the app prior to loss of contact. The remaining 6 participants completed the final 6-week assessment. At the 2-week timepoint, all 6 participants who downloaded the app requested to extend their use of the app for another 4 weeks. Half the participants asked if they could continue using the app after their study participation was over during their 6-week interview. Participants completed an average of 26 (SD = 9.6) random surveys over the 2 weeks following

their hospital discharge (3 random surveys were delivered each day), an average of 12.83 (SD = 2.40) morning surveys, and an average of 8 (SD = 4.80) end of day check-in surveys. All participants were scheduled to receive 14 full days of surveys. Therefore, on average, participants completed 62% of random surveys, 86% of morning check-in surveys, and 57% of end of day check-in surveys. Only one participant completed an event triggered survey. Ten follow-up surveys were completed representing a 100% completion rate with all participants reporting they completed the recommended coping strategy and responding "yes" to it helped them feel better. No crisis calls were initiated since no participant reported current intent at the time of survey completion.

Acceptability

Ratings on both the CSQ and the SEF were overwhelmingly positive (see Table 1). Overall, participants reported that they were satisfied with the app and all stated that they would use it again and would recommend it to a friend.

Areas of strength

Several themes emerged from semi-structured interviews. Common areas of strength mentioned by multiple participants included: increased self-awareness, decreased feelings of isolation, facilitation of coping skills, and personalization of questions and coping strategy recommendations. We consider the central themes briefly below.

All participants mentioned that a central reason for why they liked MAPS was because it allowed them to better understand themselves and their emotions.

> I like it because it reminds you to think about like, what you are feeling? You know, the early feelings . . . and so it kind of like reminds you to check in with your brain.

> It slowed things down. When my thoughts were bad and going a mile a minute, the questions helped me focus on one thing, the here and now. It helped me see how angry I was.

> It was a distraction from all the things going on around me. I think it made [me] more aware of what was going on inside instead of all the stuff around me.

Participants mentioned that while the surveys were repetitive, the routine of answering questions about their current emotional and mental state gives them the opportunity to understand triggers and become more self-aware. One participant stated that as a result of the surveys, he decided to start journaling again in order to understand the antecedents of his emotions and suicidal thoughts.

Several participants also stated that MAPS made them feel less isolated.

> I'm alone a lot, you know, for most of the time or at work . . . but it kind of like if you're thinking something and you start getting these like racing thoughts or whatever, and then all of a sudden you get a "bing" and then it's time for afternoon check in. And it's just like, it feels like you're talking to somebody.

> I know it was just a computer program but it felt like someone was worried about. like you all were there giving me support.

Participants also reported that having their support people listed in the application and getting push notifications to contact their support people during moments of crisis (e.g., after risk was indicated on survey), made them think more about reaching out to others on a regular basis.

Areas for improvement

The repetitive nature of the surveys was mentioned as a recurring theme by a few participants, although others reported finding the repetition to be helpful.

> It's kinda like, it's usually like the same questions over and over and over and over, and that gets kind of tiring.

> After I did them a few times, it became easy to rush through, you know? Because it was the same questions each time.

> I sometimes answered them like on autopilot.

Several participants stated they would have liked the opportunity to answer different variations of the survey questions or to be able to add more detail to the questions, so they could track events that impacted their mood.

> I would like to add that, you know, my morning went great at work, or this guy pissed me off at work. And this is why I'm feeling it ruined my whole day. You know, like 'he was feeling good this morning, but why is he

Table 1. Means and standard deviations of baseline and outcome metrics.

	M (SD)
CSSRS difference score: baseline to 6-week	1.17 (0.75)
SES total	36 (3.41)
CSQ total	28.33 (2.42)
Interest in Message bank of Inspirational quotes	4 (0)
Interest in expanded coping strategies back	4 (0)
Interest in ability to edit or change items within the app	3.3 (0.52)
Interest in links to music and/or videos	3.17 (0.98)
Interested in deep breathing, relaxation, and mindfulness	3 (0.89)
Interest in a weekly progress report of thought and feelings	4 (0)
Interest in a photo bank	3.67 (0.51)
Interest in Journey	4 (0)
Interest in calendar feature	3.67 (0.51)

feeling like this this evening?' It says, have you had any problem with relatives, friends, uh, coworkers and you hit a box, but yeah. **What** was the problem?

Veterans also expressed interest in the features under consideration for future development of MAPS. Ratings of additional potential features were all positive with all participants rating some interest in all of the additional features. See Table 1 for ratings of each feature. Participants were most interested in the following features: inspirational quotes, broad bank of coping strategies, a weekly progress report to track symptoms and mood, and the concept of a journey with surveys and content shifting according to current suicide risk (i.e., increased surveys during days/weeks of acute risk and minimal surveys during sustained periods of low endorsement of suicidal ideation and behavior).

In general, while the participants rated the application very highly, they all expressed an interest for more features and expanded surveys.

Safety

There were no adverse events reported during the 6-week app-use period. None of the participants reported any suicide attempts and none were re-hospitalized. While efficacy was not assessed for this pilot study, all participants reported an average decrease of 1.17 (SD = 0.75) in suicidal ideation from baseline to 6-weeks.

Discussion

This manuscript describes MAPS, a novel suicide prevention mobile application that leverages an EMA approach in concert with a patient's preexisting safety plan to facilitate in-the-moment intervention strategies during periods of varying risk. Open trial results from the first development stage of MAPS provide preliminary support for the acceptability and feasibility of the program. All participants who downloaded the application rated it highly and used it at least once a day. Participants provided feedback about recommendations for additional features to improve program utilization and usefulness. Strengths included greater insight/self-awareness, reduced isolation, assistance in selecting coping strategy – factors that could contribute to patient's ability to engage in therapy and to develop self-efficacy to manage distressing situations, although additional research is needed to examine these possible benefits of the app in additional detail.

One consideration of EMA-based approaches is the potential burdensomeness on patients. However, patients did not identify this as a concern. In fact, all participants who downloaded MAPS requested to extend the program and on average completed 61% of all random surveys. While 61% may seem low, it is important to note that high-risk Veterans are typically only assessed weekly or less frequently in traditional therapy. With MAPS, all participants completed at least one daily assessment, yielding rich data. Although some Veterans stated that the surveys were repetitive, others stated they liked the repetition of questions, especially on days of high stress. In fact, future directions for MAPS development will include the creation of the journey concept to front load assessments during periods of high risk and reduce repetitive assessments during periods of greater stability and low risk. Furthermore, most participants did not take any event cued surveys, relying instead on random and fixed surveys. It remains unclear whether this was due to the overall burden of EMA or simply due to the low need for additional surveys for these specific Veterans. More research is required to assess the utility of event-cued surveys and to enhance motivation if need is detected.

Our team is currently working on developing additional features based on the feedback. Subsequent iterations of MAPS will build features such as an expanded bank of coping strategies, increased personalization, and the creation of algorithms in order to create transition journeys as patients move from various levels of risk and stability. Areas for improvement were largely to be expected in the early stages of developing an application but will be driven by pilot acceptability data. Weaknesses highlighted by participants included inability to change content or material, repetitive nature of the surveys, and need for more content to increase engagement. Although patients appreciated the initial iteration of the application, their feedback generally suggested a desire for the application to be more individually tailored in ways that could facilitate better coping during distress as well as improved insight into their progress.

MAPS represents a highly innovative approach to suicide prevention, leveraging well-established prevention strategies from the field (i.e., safety planning and coping skills) with ecologically valid momentary assessment of suicide risk to deliver personally tailored interventions in moments of heightened risk. Clinically, it offers both patients and providers with additional support, monitoring, and intervention. Importantly, suicide risk fluctuates significantly throughout the course of one day and MAPS is developed to address this fluctuation. While it is important

to note that MAPS assessment schedule of three random surveys and two fixed surveys per day will not capture every moment of suicide risk, participants may choose to take additional surveys when in crisis and with continued development, the algorithm could allow researchers to tailor intervention strategies to be delivered before moments of crisis based on what the system learns about their patterns of suicide risk. For example, if patient A reports elevated ideation following a period of anger and patient B shows elevated ideation in reaction to sadness, then interventions could be pushed out to those patients upon detection of elevated anger or sadness, respectively. Subsequent efficacy testing will also allow us to better explore whether the current assessment schedule is sufficient to detect all episodes of risk throughout the day or whether additional surveys would be beneficial or whether effort to enhance motivation to take event-cued surveys would be a better approach to capturing all risk episodes.

Although these initial clinical findings are important, EMA methods have substantial scientific and research potential as well. First, there is great interest in the development of *proximal* models of suicide risk. Traditionally, models of suicide risk have been developed using self-report, interview, or chart review data. These models, while an important first step, were able to create general categories of risk, with prediction of suicide behavior being only slightly better than chance and single predictors rarely yielding odds ratios greater than 1.5 (Franklin et al., 2017). However, as EMA data are more representative of how patients are thinking, feeling, and behaving in the present moment, EMA data have great potential to improve prediction of suicide risk *states* that immediately precede suicidal behavior and attempts. For example, our team has found that in the days immediately following discharge from a psychiatric hospital, negative affect, and suicidal ideation were strongly coupled, with odds ratios ranging from 2.5 for between-subjects models comparing individuals to other at-risk patients to greater than 4.5 for within-subjects models comparing patients to themselves (Armey et al., 2018). Indeed, this finding suggests that perhaps the most effective approach to the prediction of suicide risk might be the development of personalized suicide risk models consistent with the push toward personalized medicine. This is not to say that general risk factors are unimportant, but that they can be integrated into algorithms used to predict acute suicidal crises. Clinical algorithms developed from EMA/EMI can be developed that integrate both existing risk factors (causal risk factors) and newly discovered factors derived from algorithms in the service of reducing risk for those patients with identified risk factors. MAPS and other EMA/EMI programs can harness knowledge from both risk factors and in-the-moment risk to provide a more complete risk profile with real clinical implications.

Second, the data generated by MAPS and related applications can be readily used in digital phenotyping studies. In digital phenotyping, non-self-report sensor data collected by a patient's cell phone are used to infer patterns of behavior and, potentially, predict mental health risk states (Insel, 2017). For example, studies have demonstrated a correlation between time spent using a smartphone device and the severity of psychotic symptoms (Torous et al., 2017) as well as self-report and accelerometer-inferred sleep quality (Staples et al., 2017). However, this remains an area of potential innovation for suicide research and will likely inform the development of personalized models of suicide risk.

Limitations

Results from the pilot study lend support to MAPS as a potential tool for Veteran suicide prevention. However, there are some limitations that must be considered. First, the sample used, while yielding extensive amounts of data, is small and may not be generalizable to either non-Veteran service members or other Veteran samples. In addition, the sample was relatively homogeneous in terms of racial/ethnic diversity and sex. Both women who enrolled dropped out of the program prior to downloading that application. Veterans are a heterogenous group representing a wide diversity of people with respect to gender, racial/ethnic identity, age, and with varying levels of health comorbidities, and MAPS will require large-scale testing to determine both efficacy and acceptability in this diverse group. Second, mobile technology is constantly developing, and applications may become obsolete unless frequently updated. Related to this, our knowledge of proximal risk factors for suicide is limited. As both the technology and scientific knowledge increases, updates will be required to maintain the usefulness of MAPS. Third, MAPS efficacy has not yet been established. While the program relies on empirically supported strategies and all participants in this study reported reduced suicidal ideation at follow-up, efficacy data is needed prior to implementation. Finally, while programs like these are highly needed, implementation can come with a myriad of challenges. VHA has highlighted the need for more technology-based interventions in suicide prevention, but regulations around information security, privacy, contracting, and integration within VHA may pose significant implementation challenges.

Future directions

In spite of the challenges, MAPS has the potential to contribute to Veteran suicide prevention efforts in that it supplements work done inside the therapy room, provides additional data for both the patient and the provider, allows for monitoring and support at the Veteran's fingertips, and has the potential for expansion as we learn more about individual suicide risk and treatment. Continued development efforts will build on the existing framework with a focus on understanding mechanisms of change and expanding the most effective intervention strategies. The next stages will involve efficacy testing and will allow us to track, which types of intervention strategies are most useful and why. Additional development work will focus on developing a participant feedback loop to allow Veterans to track their own progress through their journey to reduce suicide risk. Large-scale testing will also allow us to use data collected in EMA to predict acute risk and improve MAPS algorithms.

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