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Just-in-Time Adaptive Interventions for Suicide Prevention: Promise, Challenges, and Future Directions

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Abstract

The suicide rate (currently 14 per 100,000) has barely changed in the United States over the past 100 years. There is a need for new ways of preventing suicide. Further, research has revealed that suicidal thoughts and behaviors and the factors that drive them are dynamic, heterogeneous, and interactive. Most existing interventions for suicidal thoughts and behaviors are infrequent, not accessible when most needed, and not systematically tailored to the person using their own data (e.g., from their own smartphone). Advances in technology offer an opportunity to develop new interventions that may better match the dynamic, heterogeneous, and interactive nature of suicidal thoughts and behaviors. Just-In-Time Adaptive Interventions (JITAIs), which use smartphones and wearables, are designed to provide the right type of support at the right time by adapting to changes in internal states and external contexts, offering a promising pathway towards more effective suicide prevention. In this review, we highlight the potential of JITAIs for suicide prevention, challenges ahead (e.g., measurement, ethics), and possible solutions to these challenges.

Keywords

suicide; self-injury; just-in-time adaptive interventions

Suicide is a leading cause of death for all age groups [1] and in most years the suicide rate has remained unchanged or increased for the year prior.[2] One reason why the suicide rate has

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not yet declined may be that existing suicide prevention interventions are not well-aligned with the dynamic and heterogeneous nature of suicide risk.[3,4] Converging lines of research indicate that suicide risk is a complex and multidetermined phenomenon [5,6] that can change rapidly over a short period of time.[7–9] For example, prior real-time monitoring research has found that more than one quarter of all ratings of suicidal thinking were a standard deviation above or below the previous response from just a few hours earlier.[8] Almost all existing treatments for suicidal thoughts and behaviors (STBs), however, do not deliver content (1) at a frequency that matches these rapid changes, (2) in a way that is highly accessible during periods of elevated risk, and (3) that is tailored to the heterogeneous nature of suicide. Accordingly, this paper has three goals. First, we will detail these potential hindrances to effectiveness of existing, well-established treatment models (i.e., timing, method, and content of treatment delivery). Second, we will explore how a novel intervention design recently used in other areas of intervention science, *Just-In-Time Adaptive Interventions (JITAIs),* may help address these issues and enhance existing treatments for STBs.[10] Finally, we will review the challenges associated with potentially applying a JITAI approach to suicide risk reduction.

Hindrances to treatment effectiveness for suicidal thoughts and behaviors

Timing.

The timing of existing treatments for STBs is not optimally matched to the dynamic nature of suicide risk. Predominant current treatment models tend to consist of people waiting until they are at their most clinically severe to seek help, then providers offering short-term intensive continuous treatment (e.g., inpatient care), followed by either more brief-intensive care (e.g., intensive outpatient programs) or relatively sparse and static treatment (e.g., weekly outpatient models of care with little to no between-session support[11]). This results in a mismatch between the temporal dynamics of suicide risk and the timing of therapeutic approaches. Suicide theories and accumulating empirical findings indicate that the pathway to suicide unfolds quickly over time.[12–15] The final steps on this pathway from suicidal ideation to suicidal behavior typically unfolds over days and hours.[14] Real-time monitoring research, which repeatedly measures individuals over time using mobile technologies such as smartphones, has found that suicidal thinking tends to fluctuate rapidly over just a few hours.[16] Given how rapidly suicide risk changes over time, interventions that are adaptive – ideally providing timely and ecological support when the individual needs it most – are needed.

Accessibility.

Worldwide, more than two thirds of people with STBs receive no treatment.[17] Meta-analytic research shows that the rate of mental health service use for those with past-year suicide ideation, plans, and/or attempts is approximately 29.5%.[18] Traditional forms of treatment, such as one-on-one therapy with a mental health professional, simply cannot meet the needs of individuals with STBs.[19–21] In addition to the immense structural barriers to treatment, including financial costs and availability of providers, attitudinal barriers are commonly endorsed.[18] One of the most frequent reasons people with STBs provide for not seeking treatment is they want to handle it on their own.[17] This finding may be explained by the

phenomena of help-negation, which is the process by which individuals with acute suicidal ideation refuse or reject available treatment or support.[22,23] This help-negation may be due to the nature of existing treatment options. Individuals with STBs report a range of concerns and issues with current mental health care services, especially treatment delivery.[24] Three of the most frequently reported recommendations for improving treatment for STBs pertain to reducing stigma, providing a range of treatment options, and increasing access.[24] Essentially, current treatment approaches require individuals with suicidal thoughts and behaviors (or a loved one, possibly against the individual's wishes) to bring themselves to treatment, rather than bringing a range of interventions to them. Advances in technology offer the opportunity to increase the access to suicide prevention interventions through novel digital formats and delivery.[20]

Personalization.

Suicide risk is complex and heterogeneous,[19,25,26] but there is little guidance on how to personalize the content and format of existing interventions. Regarding content, current "gold-standard" psychosocial interventions for targeting suicide risk consist of some combination of the following elements: caring outreach/promoting social support, cognitive and behavioral skills (e.g., problem solving, distress tolerance), safety planning, and means restriction.[25] Regarding format of interventions includes outreach via phone,[27] multi-session in-person therapies,[28] telehealth video sessions,[29] single session interventions,[30] and preliminary work on smartphone-based apps.[31]

Suicide can be reached via many different pathways.[32] From an intervention perspective, this might translate to different types of content and formats of interventions being more or less effective for different types of patients.[33] For example, consider the following two patients with suicidal thoughts. One is a highly impulsive man with substance use and post-traumatic stress disorder who owns a firearm and becomes extremely suicidal while intoxicated. Another patient is a treatment-resistant, chronically suicidal woman with major depressive disorder who recently had a break-up, has stopped being compliant with her medication, and has been planning over the past weeks a way to end her life. Providing these two individuals with the exact same intervention ignores the unique factors contributing to each patient's suicide risk and results in suboptimal responses. It has been theorized that the product of the gap between the heterogeneous nature of suicide risk and current homogenous treatment approaches is small average treatment effects [25] and likely heterogeneity in these treatment effects.[34] Heterogeneity in suicide risk factors and treatment effects motivates more personalized, tailored interventions. New technologies offer a powerful opportunity to provide more personalized treatments.

JITAIs

JITAIs are a potential solution to these three key hindrances to treatment efficacy. JITAI is "an intervention design that adapts the provision of support (e.g., the type, timing, intensity) over time to an individual's changing status and contexts, with the goal to deliver support at the moment and in the context that the person needs it most and is most likely to be receptive".[10] Thus, JITAIs may be an intervention design well-matched to the dynamic and

heterogeneous nature of suicide risk. JITAIs may be used to enhance existing treatments which have significant but overall small effects.[25,35]

JITAIs are composed of four key components: decision points, intervention options, tailoring variables, and decision rules. Throughout this section, we use a JITAI conceptualized from a recently completed mobile health trial called HeartSteps[36,37], designed to increase physical activity among sedentary individuals, as an example.

Decision points are times at which an intervention may be delivered. Decision points can occur every minute, hour, or day with choice of frequency related to the time-scale at which the delivery of intervention may be useful.[10] In HeartSteps, for example, an activity tracker was used to monitor steps taken each minute. Upon reviewing activity data from a prior study, it was discovered that the highest within-person variability in step count occurred at five time points (morning, mid-day, mid-afternoon, early evening, after dinner) throughout the day with much less variability at other times.[38] This information, combined with the types of treatments being considered, indicated that interventions might be most effective during these five time windows and potentially less effective at other times. Therefore, in a JITAI targeting physical activity, the decision points would align with the five discovered time windows.

Intervention options are the set of treatments that can be provided at any given decision point. This includes type, source, and amount of support provided. Compared to only adaptive interventions, intervention options in a JITAI are designed to be both timely and ecological. In a JITAI targeting physical activity two intervention options would be “Send activity suggestion” and “Do not send activity suggestion.” If the option “Send activity suggestion” is chosen, the content of the suggestion is tailored to the current context of the individual (i.e., only sending suggestions asking the participant to go for a walk when the current weather permits).

Tailoring variables are contextual information that is used in the decision to provide intervention options at decision points. In a physical activity JITAI, decisions could be tailored based on whether a person is at home/work or somewhere else, whether the person is currently walking, and whether the person has an open slot on their calendar right now. For example, activity suggestions related to walking outside would only be sent when it was not currently raining at the current location. This is an example of where the tailoring variable is *passively* collected. Passive data refers to information collected via wearable and smart devices. Alternatively, contextual information can be collected *actively* via ecological momentary assessments (EMAs) in which the user is pinged to self-report important contextual information (e.g., stress, mood) that could then be used as tailoring variables.

Decision rules are a formal operationalization of which intervention option to offer, for whom, and when. There is a decision rule at each decision point. For example, in a physical activity JITAI, the decision rule would be:

IF the person is at home or work and is not currently walking,

THEN

Send a contextually tailored activity suggestion

ELSE

Do nothing.

There are two types of outcomes related to JITAI design: proximal and distal. The *distal outcomes* are the end goals of the intervention that principally guide intervention development. In a physical activity JITAI, the distal outcome might be average daily step count (i.e., physical activity). *Proximal outcomes* are near-term outcomes that the intervention options are designed to impact. In a physical activity JITAI, the proximal outcome would be step-count in the 30-minutes after a decision time.

Just-In-Time Adaptive Interventions for suicide prevention

JITAIs have been applied to a wide range of behaviors (e.g., smoking, physical activity) and preliminary meta-analytic results show promising effects.[39] Although JITAIs have yet to be applied to suicide prevention, meta-analytic evidence suggests that other mobile- and internet-based psychological interventions generally show positive treatment effects on suicidal ideation.[31] This meta-analysis found a small effect size of interventions, however, this effect was no longer significant in trials with active control conditions. These mobile and internet-based interventions can currently either be used as standalone interventions or to enhance traditional treatments. Furthermore, these finding suggest the potential utility of interventions (such as JITAIs) delivered using similar platforms. Within these technology-based intervention studies for STBs, however, most interventions are either delivered in the same dosage to all patients or patients are expected to access the intervention as much or as little as they wanted. These preliminary studies help address the issues of accessibility to care but have yet to grapple with heterogeneity (i.e., same intervention for all patients), frequency or burden. Furthermore, by requiring patients to initiate usage of the intervention, all studies assume that participants are always in contexts in which they have the cognitive capacity and self-awareness to know when to initiate an intervention. Real-time monitoring data suggest that people often feel overwhelmed when experiencing suicidal thoughts.[9] Therefore, people may be unlikely to initiate interventions when they need them the most. No study to date has systematically varied the timing of delivery and content of interventions for STBs and evaluated the effect of such variation. JITAIs hold promise for suicide prevention because they could increase access to evidence-based interventions during moments of high need, function as a tool for proactive prevention of escalations in suicide risk, and provide personalized interventions that may increase effectiveness and decrease patient burden. JITAIs may be especially useful for people who are unable to access traditional modes of treatment (e.g., people in areas with limited access to traditional treatments).

Example of JITAI for suicide prevention

One critical question for suicide prevention is how to intervene in-the-moment that a person reports having thoughts of killing oneself. A major unknown for scientists and clinicians is: once a person reports that they are seriously considering making a suicide attempt in

the very near future, what brief, evidence-based interventions can be deployed to reduce their risk? We conceptualize suicide risk as a time-varying state measured on an ordinal (i.e., ordered in increases in severity) scale that is influenced by factors such as strength, immediacy, and intent.

Perceived social support is a protective factor for suicidal thoughts [40,41] and behavior [42,43]. From day to day, social support varies considerably. For instance, 45% of daily social support ratings differ by at least one between-person standard deviation from the prior assessment.[40] Prior research has found that within-person changes in social support predict next day severity of suicidal thinking.[40] These results indicate that perceived social support may be an important time-varying protective factor for suicidal thoughts. Connectedness is featured in numerous theories of suicide and empirical research has found social connectedness is protective for suicidal thoughts and behaviors.[44] Brief interventions focused on increasing perceived social support and connectedness have been shown to reduce rates of suicidal behavior.[45,46] These lines of research suggest that brief just-in-time intervention strategies could enhance existing interventions and targeting social support may be promising in reducing proximal suicidal thoughts.

A proposed JITAI to address this pressing issue could therefore target proximal social support as a mechanism to reduce distal risk of death by suicide. The goal of this JITAI would be to provide individuals with social support when they are experiencing suicidal thoughts. Broadly, whenever individuals report that they are experiencing strong of thoughts of suicide via a smartphone survey, they would receive one of three active intervention options associated with social support.

A crucial component of the proposed JITAI is real-time monitoring of suicidal thoughts. Surveys would be sent several times per day. This is useful because suicide risk may vary by time of day, especially at night.[47] Suicidal thoughts would be a crucial component of the JITAI because variation in suicidal thinking predict future suicidal behaviors.[48,49] Therefore, frequent assessments of suicidal thinking currently represent one of the best proxies for suicide risk.

Given the use of frequent assessments of suicidal thinking in the proposed JITAI, an important first question is whether participants use the surveys on suicidal thoughts to self-monitor and therefore these surveys should be conceptualized as an intervention component that alters risk. Multiple studies on the effects of frequently assessing suicidal thoughts and behaviors have found no effect of the assessment on suicidal thoughts and behaviors.[50,51] Two meta-analyses support the notion that the assessment of suicidal thoughts does not change suicidal thoughts or behaviors.[52,53] The current evidence suggests self-monitoring should not be considered an intervention component. Emerging research also suggests that frequent assessments of suicidal thoughts are feasible and acceptable.[54] Therefore, we next describe a JITAI that provides support beyond purely potential self-monitoring effects of survey completion.

Decision times would occur directly after the six times at which self-report of suicidal thoughts would be recorded. Consider four intervention options. First, a phone call by a

trained clinician that provides initial support and encourages the participant to seek further help through their social network or formal mental health services; brief clinical phone check-ins and clinical support have been found to have small protective effects.[55] Second, an automated intervention encouraging the participant to seek support through their social network or a hotline; such an automated intervention (i.e. a chatbot) has been found to reduce attitudinal barriers to seeking support and increased the use of crisis services by 23%.[56] Third, an automated pop-up message that provides a list of crisis services and emergency contacts when an individual reports suicidal thoughts. These types of resources are frequently provided to individuals at risk as part of standard care, such as in the emergency department and at the point of inpatient discharge.[57]

The fourth option would be no message (i.e., doing nothing). Doing nothing might be optimal at times for limiting participant burden and may allow the participant to practice self-awareness so that they self-initiate access to social support if needed. All three active intervention options are associated with social support and have shown some form of clinical efficacy for suicidal thoughts and/or behaviors. It is currently unknown, however when, where, and for whom they work best. Not all intervention options, for example, are likely to be appropriate at every level of momentary risk and for every person. This issue can be addressed with tailoring variables.

The *tailoring variable* would be a risk score, from 0 to 10, that would be constructed from self-reported suicidal thinking and stratified into no (0/10), low (1–3/10), medium (4–9/10), and high (10/10) risk strata. Once again, suicidal thinking would be the tailoring variable because of the relationship between momentary measures of suicidal thinking and future suicidal behavior.[49,58] Risk stratification is important as certain intervention options may be unethical to provide at various strata.[59] This JITAI would be based on a stepped care approach, as risk increases the strength of the intervention increases.

The *decision rules for the proposed JITAI would be:*

If “No Risk” (0/10):

Do “No message”,

Else if “Low risk” (1–3/10):

Do “Pop-up message”,

Else if “Medium risk” (4–9/10):

Do “Automated message”,

Else if “High risk” (10/10):

Do “Clinician call”

The *proximal outcome* would be reaching out to hotlines or other social contacts. This would be measured through call and text logs on participants’ phones. Phone numbers would be hashed (i.e., anonymized) to protect privacy. To identify hotlines in the logs, at the start of the study, we would build into the hashing algorithm a universal way to hash the standard hotline numbers, so that they would be able to be identified by the research team.

To identify social contacts, at the start of the study, participants would provide a list of the phone numbers of three close contacts. We then would also build into the hashing algorithm a universal way to hash and later identify close contacts. The *distal outcome* would be the severity of suicidal thoughts and likelihood of suicide attempt.

In order to consider these or other potential decision rules, we introduce a data efficient experimental design, the micro-randomized trial (MRT). This experimental design allows suicide researchers to answer these critical scientific questions regarding effective JITAIs for suicide prevention.

Micro-randomized trials for suicide prevention

The JITAI is an intervention design, not an experimental method to test that design. Given the potential decision points, intervention options, and tailoring variables defined above, suicide researchers still have many questions when designing a JITAI such as "Which intervention option should be delivered when the individual is at high risk based on suicidal thinking responses?" and "Does the relative effectiveness of the intervention options depend on other variables beside risk?" The *micro-randomized trial* (MRT) is an experimental design that allows scientists to collect data to address these types of scientific questions. The MRT consists of randomly assigning one of the intervention options at each decision point.[60] Data collection in an MRT allows for the optimization of JITAIs.[60] Within an MRT each participant may be randomized hundreds or thousands of times to different interventions.[61] In HeartSteps, an MRT for physical activity, for example an activity suggestion was provided at each available decision point with probability 60%. This micro-randomization allows the scientist to assess the time-varying effectiveness of the intervention options and how their effectiveness may be moderated by internal states and external context.

The MRT design provides data that can be leveraged to build an effective JITAI targeting suicidal thoughts and behaviors. Consider the example designed to increase proximal social support. There may be some desire to do *something* instead of nothing at ANY level of endorsed suicide risk (given concerns about participant safety); however, (i) we do not currently know if automated pop-up messages or interactive interventions are effective for imminent suicide risk and as so, need to test them, and (ii) it may be that presenting pop-ups or interactive interventions at low levels of risk actually makes them less potent later on and makes people less likely to use them when surfaced during higher levels of risk (e.g., due to habituation). For "moderate'' risk, we realize that there may be a desire to avoid automated interventions in all such cases; however, (i) we do not currently know if there is any difference between these conditions, including whether human contact is more effective, and (ii) it is possible that the automated interventions are more effective because they can potentially be deployed - and reach the person - more quickly than getting the person on the phone with a human. This would be important to know for future monitoring and prevention efforts. For "high'' risk, we would likely view a pop-up as insufficiently strong and thus want to offer at least one of the two more potent interventions.

In each instance, we would randomize participants to the conditions noted above, and test the proximal outcomes of whether one versus the other(s) conditions are associated with a higher rate of reaching out to hotlines or other social contacts and how this difference varies with time-in-study and other variables such as gender and day of week. This hypothetical MRT is presented in Figure 1. Here, we would randomize the participant at each decision time to one of potentially several intervention options depending on the reported suicidal thinking strata.

Current challenges of JITAIs for suicide prevention

Although JITAIs overcome many of the challenges of traditional treatment approaches for STBs, this intervention design comes with a unique set of challenges when applied to suicide risk.

Measurement of Real-Time Suicide Risk.

Within the context of JITAIs, real-time assessments of suicidal thoughts would be key observations of risk which would inform intervention decisions and could also serve as proximal outcomes to judge the effectiveness of the interventions. Reviews of the real-time assessments of suicidal thoughts [16,62,63], however, notes there is inconsistency across studies in constructs assessed, type of scales used, and the frequency of sampling. There is an overall dearth of evidence on the psychometrics properties of any (non-STB specific) real-time self-report assessments.[64–66] To justify the real-time assessments as intervention outcomes, there needs to be more work on the reliability and validity. Another challenge of only relying on self-reported suicidal ideation for decision times within a JITAI is the self-report measures of suicide risk have numerous threats to validity.[67] These include stigma and a fear of loss of autonomy, which can lead to underreporting.[68] It is also possible that suicidal ideation changes on a rapid timescale (e.g., of minutes or even seconds), but the sampling of self-reported ideation is unable to match this fast timescale.[69,70]

Beyond self-reported measures of risk, passive measures of risk via wearables and smartphones have immense potential, but also pose numerous measurement questions. Passive streams of data are valuable for JITAIs because they provide continuous data with minimal burden to the participants. The use of wearable devices for measurement of physical health outcomes is relatively straightforward (e.g., use of an accelerometer to measure physical activity). The validity of passive streams of data (e.g., wearables) as markers of psychological constructs (e.g. suicidal thoughts) is far more complicated [71]. It is currently unknown if we can identify suicidal thoughts with wearable devices given heterogeneity in suicidal thinking [72]. Therefore, a crucial area of future research is to combine gold-standard laboratory measures of physiology and ambulatory measures of physiology to test for physiological signatures of suicidal thinking [73]. Given that these data could inform intervention decisions, establishing the reliability and validity of passive streams of data is essential for the development of effective interventions.

Balancing Risk and Receptivity.

Providing just-in-time support requires identifying the right times to intervene. Key tailoring variables for JITAIs are predictors of states of vulnerability to adverse health events, and states of receptivity - times at which the individual is willing to receive just-in-time support [10]. If the individual is vulnerable but not receptive, then support is needed but the intervention may be ignored. If the individual is receptive but not vulnerable, then the intervention will be received and processed but will have limited impact on reducing their proximal risk. Vulnerability has different implications for treatment versus prevention. If the goal is treatment (i.e., to lower risk of an adverse event in the moment), then the individual should be in a state of vulnerability when considering this intervention option. If the goal is prevention, then the intervention option might be considered when the individual is receptive but not in a state of vulnerability. In the example JITAI focused on suicide described in this paper, the intervention option is designed as treatment for vulnerable moments. However, future exploration of intervention options focused on prevention would also be valuable. This balance between risk and receptivity is especially relevant to suicide prevention because research suggests that as an individual's suicidal thinking increases in severity, they become less receptive to interventions.[22] Therefore, one of the greatest challenges for JITAIs for suicide prevention is balancing risk and receptivity in decision points, an issue we elaborate upon in the "future directions" below.

Ethics of Real-Time Interventions.

Monitoring people at high risk for suicide in real-time comes with ethical challenges.[59,74,75] The challenges include informed consent, privacy, confidentiality, balancing risk and benefit, and knowing how and when to intervene. Therefore, experimenting with different interventions in real-time when participants are at heightened risk for suicide poses a series of ethical questions. For example, at what level of suicide risk should researchers be allowed to experiment with different interventions? Is a human supported intervention required at a certain level of risk? What obligation do researchers have to actively monitor risk and intervene during an MRT?

A consensus statement (generated from a panel of 24 experts) on the ethical and safety practices for conducting real-time monitoring studies of individuals at risk for suicide and related behaviors was recently released.[59] There was a strong (about 94%) agreement that when participants provide a "high-risk" response, the study team should reach out to them directly to conduct a suicide risk assessment as soon as possible (within 12–24 hours for responses indicating "imminent" risk). A systematic review of practices in 59 previous or ongoing digital monitoring studies of STBs,[74] however, indicates a gap between this apparent consensus and reality, as just over half (58%) reported monitoring and intervening upon incoming responses during the study. Thus, there remains a notable departure between expert consensus and real-world practices for responding to incoming data.

Therefore, implementing JITAIs for suicide prevention will require discussions with ethics boards, individuals with lived experiences, and clinicians. We argue that fear of real-time suicide risk and potential consequences, should not lead to completely avoiding a potentially

powerful intervention tool. Rather ethical concerns should result in proceeding cautiously and rigorously towards trials where participant safety is the top priority.

Future directions for suicide prevention

Identifying States of Risk and Receptivity.

States of risk and receptivity are crucial variables in JITAIs, but we have little idea of what these states look like for suicidal individuals. Statistical modeling frameworks that account for the non-linear nature of suicide risk over time allow for the identification of suicide risk states within an individual. Describing features of suicidal states, such as their frequency and duration, will aid in design decisions for JITAIs. Along similar lines, time is intertwined into nearly all aspects of JITAIs including tailoring variables (e.g., time of day), decision points (e.g., the number per day), and proximal outcome (e.g., over what time window to look for change). Therefore, describing the temporal dynamics of suicide risk states could aid in informing more effective JITAIs for suicide prevention. A program of research is also required for identifying states of receptivity [10] for individuals at risk for suicide. Preliminary research suggests that smartphone sensor data (e.g. location, phone battery) can be especially useful for understanding receptivity.[76] Preliminary research suggests that context based on the combination of participant-specific information (e.g. personality) and context-specific information (e.g. location) can be used to predict in-the moment receptivity.[77] Receptivity appears closely linked to treatment efficacy.[77] It remains unclear, however, how these receptivity models operate in clinical populations, such as individuals with STBs. Therefore, leveraging sensor data to identify when individuals with STBs are most receptive to interventions could improve the engagement and efficacy of JITAIs for suicide prevention.

Matching Mechanisms, Outcomes, and Interventions.

Whereas it is now known that suicide risk fluctuates over time, it remains unclear when and why it fluctuates. Identifying dynamic mechanisms will aid in the development of real-time interventions.[78] To identify such mechanisms, one may conduct real-time monitoring studies with predictors and suicidal outcomes. One then can test how within-person changes in the potential mechanism are associated with changes in the suicidal outcome.[15] Preliminary real-time research on social, affective, and arousal mechanisms has shown promise for the prediction of suicidal thinking. [16,40,62,79,80] Building out a suite of real-time predictors of suicide risk, to accommodate the heterogeneity of risk, is an important step towards transitioning from real-time prediction towards real-time intervention.

To match this suite of risk factors, one could build out a suite of intervention components that target different proximal outcomes. These different intervention components can be combined together to reduce distal suicide risk. For example, emotion dysregulation, sleep, and social connectedness are dynamic, modifiable constructs that have been associated with STB risk.[43,81,82] JITAIs could include content targeting each of these, perhaps drawing from existing evidence-based psychotherapies. For example Dialectical Behavior Therapy[28] or the Unified Protocol [83] to target emotion dysregulation, cognitive behavioral therapy for insomnia (CBT-I)[84] to target sleep, and caring contacts, a text message based intervention,

to target social support.[27] One promise of JITAIs is that you could combine these three separate intervention components which each uniquely target emotion dysregulation, sleep, and social connectedness (all of which have been associated with suicidal behaviors) into an intervention package that seek to reduce suicide risk. JITAIs provide an opportunity to match the complexity and heterogeneity of suicide risk with a diverse set of existing evidence-based interventions.

Integrating into Clinical Care.

As JITAIs for suicide prevention are developed, a crucial future area of research is how best to use JITAIs to complement existing, traditional models of clinical care. For example, JITAIs may be useful for patients on the waitlist for traditional forms of psychotherapy. They may also serve as a helpful tool to promote use of skills learned during therapy in between sessions during moments of elevated distress. They could help ease the transition between inpatient and outpatient treatment, a period of elevated risk.[85] Finally, as noted above, they may serve as a useful treatment tool for patients who are unable to access traditional models of care.[20]

Conclusions

JITAIs for suicide prevention hold immense potential to increase access to care and reduce suffering. The great potential of JITAIs is reflected in its ability to match the dynamic and heterogeneous nature of suicide risk. The journey towards realizing the potential of JITAIs, however, remains long and challenging. We advocate that focusing on the measurement and description of suicide risk and receptivity, the identification of dynamic mechanisms, and the translation of evidence-base treatments into mobile platforms as promising pathway towards this goal.

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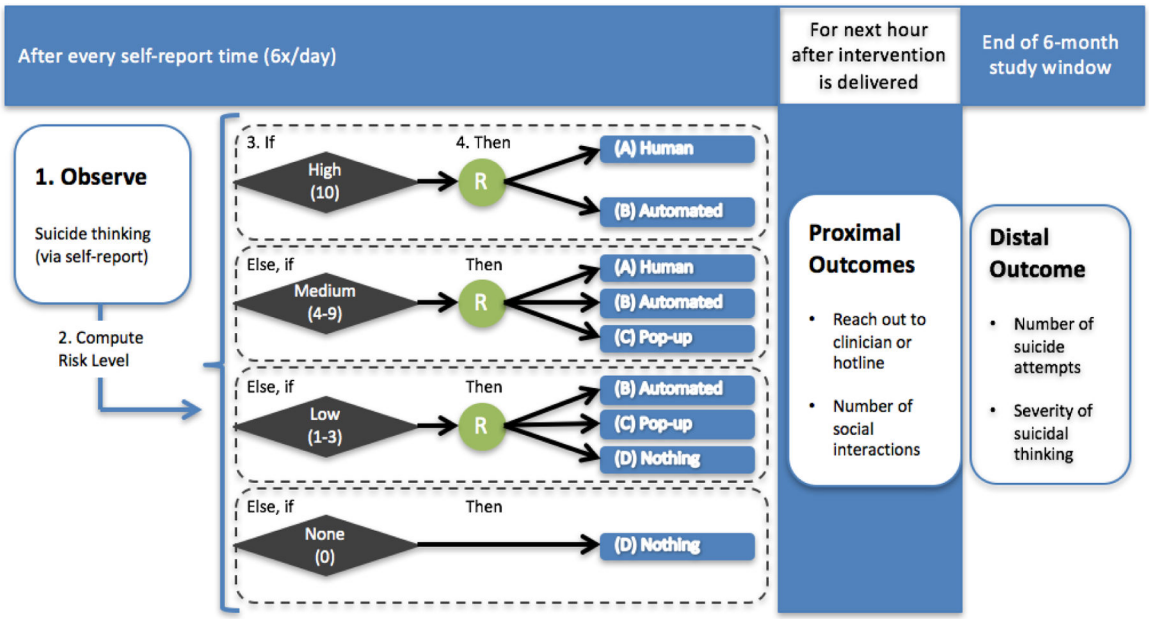

Figure 1.
Hypothetical Micro-Randomized Trial for Suicide Prevention