An Organizing Framework for Guiding the Design of Just-In-Time Adaptive Interventions to Promote Engagement

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Lay Summary

Digital technologies such as smartphones and wearable devices can support people in everyday life, offering help when it may be most useful. For example, an app might prompt a healthy behavior, suggest a coping strategy during stress, or remind someone to practice a helpful skill. Programs called just-in-time adaptive interventions (JITAIs) adjust what they deliver based on what is happening in the moment. Although JITAIs are promising, people often do not use them enough for them to work well. Two bodies of research address this problem: one focuses on how these programs are built, and the other on what makes people engage with digital health tools generally. However, these areas have not yet been connected. This paper introduces the JITAI Design for Engagement (JDE) framework, which brings these perspectives together. The framework highlights three ideas: that the right conditions must be in place for people to meaningfully engage with support; that each part of an intervention involves a prompt and an action, each requiring different effort; and that designers must balance how important an activity is for health against how likely someone is to do it. Six practical guidelines for building more engaging digital health programs are provided.

Teaser Text

Smartphones and other digital tools can offer help in the exact moments people need it—but many of these programs fail because people do not engage with them. This article introduces a practical guide for designing digital tools that people are more likely to stay engaged with and benefit from in the midst of their daily lives.

Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards: All authors declare that they have no conflict of interest. All procedures, including the informed consent process, were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration.

Abstract

Background: Just-in-time adaptive interventions (JITAIs) leverage digital technologies to deliver support in individuals' daily lives by adapting to changing internal states and contexts. Although JITAIs hold substantial promise for improving health behaviors and outcomes, engagement with these interventions is often suboptimal, limiting their effectiveness. Existing frameworks describe either the structural components of JITAIs or the determinants of engagement with digital interventions, but provide limited guidance on how to design JITAIs that are both engaging and beneficial. **Purpose:** This paper introduces the JITAI Design for Engagement (JDE) framework, which integrates JITAI architecture with mechanisms of engagement to guide the design of JITAIs. **Method:** We integrate two complementary frameworks—one describing core JITAI components and another focused on engagement with digital interventions, and illustrate applications using examples from published studies. **Results:** The JDE framework advances JITAI design by (1) reconceptualizing receptivity as conditions that facilitate effective engagement, (2) decomposing JITAI components into distinct stimuli and tasks, and (3) introducing a design tradeoff between intervention necessity and likelihood of engagement. Building on this framework, we derive six practical guidelines for developing more engaging JITAIs (e.g., specify proximal intervention targets related to both health and engagement, design the adaptation of stimuli/tasks to be based on necessity and facilitators of engagement). **Conclusion:** By explicitly linking JITAI components with mechanisms of engagement, the JDE framework provides a more comprehensive and actionable foundation for intervention design. This approach has the potential to improve engagement, enhance real-world effectiveness, and ultimately increase public health impact of JITAIs.

Keywords: just-in-time adaptive interventions; engagement; receptivity; mobile health (mHealth)

Health behaviors unfold moment by moment. Many behavioral interventions aim to equip individuals with strategies for navigating these moments – for example, regulating emotions (e.g., cognitive reappraisal), coping with urges and cravings (e.g., urge surfing), or increasing values-aligned, goal-directed actions (e.g., values clarification). Yet a persistent challenge remains: what is recommended to individuals is often not implemented in daily life, especially in moments that might matter most [1,2]. Advances in digital health technologies have greatly increased the potential to design behavioral interventions that can support individuals in real time as they go about their daily lives [3].

Just-in-time adaptive interventions (JITAIs [4]) have emerged as a promising approach to designing an intervention that enables rapid adaptation of intervention delivery. Here, an intervention is defined as "a manipulation of the subject or subject's environment for the purpose of modifying one or more health-related biomedical or behavioral processes and/or endpoints" [5]; the term "intervention design" refers to the approach used to deliver an intervention in practice; 'Just-In-Time' refers to an attempt to deliver the right type of intervention, at the right time, while minimizing waste and disruption [2]; and "adaptation" refers to the replicable and evidence-based use of dynamic information about the person to guide decisions about whether and how to intervene [2,3]. JITAIs are explicitly intended to address the rapidly changing needs of individuals in a resource-efficient manner. Thus, they are well positioned to provide support in real world contexts where competing demands on time, effort, and attention are substantial [4].

Interest in JITAIs has grown rapidly over the past decade, underscoring their potential to transform behavioral health care and improve population health outcomes [3,6]. For example, in PubMed, only one article indexed with the term "just-in-time adaptive intervention(s)" appeared in 2014, compared to 60 in 2024. A similar trend is evident in the National Institutes of Health (NIH)

Reporter database, where 56 projects across ten NIH institutes were indexed with JITAI-related terms in 2024, compared to just three projects in 2014. However, as is common in a burgeoning area of research, enthusiasm for developing and testing JITAIs has outpaced efforts to deepen theoretical understanding of how and why these approaches work or fail to work. A central challenge is participant engagement. Empirical evidence suggests that engagement with JITAIs is often low or inconsistent [1,7]. Following Nahum-Shani et al. [8], we define engagement as the investment of physical, emotional, and cognitive energy in a focal stimulus or task [8]. Because engagement is a key mechanism driving intervention effectiveness [9,10], even well-designed interventions are unlikely to produce meaningful outcomes if individuals do not engage with them. Improving engagement is therefore essential for realizing the full potential of JITAIs.

Despite this, existing frameworks provide only partial guidance for intervention design. Established JITAI frameworks clearly describe the structural components of these interventions (e.g., interventions options, the variables used to determine which option to deliver) [2], while frameworks of digital intervention engagement describe factors that influence how participants interact with the intervention components (e.g., motivation, affect, burden, habituation) [8]. However, these perspectives remain largely disconnected. This disconnect creates a critical design gap: researchers lack clear guidance on how to design JITAIs that are both engaging and effective.

To address this gap, we introduce the JITAI Design for Engagement (JDE) framework. The JDE framework integrates JITAI architecture with mechanisms of engagement to guide how intervention components should be designed to maximize both engagement and effectiveness. Specifically, the framework (a) operationalizes receptivity in terms of conditions that facilitate effective engagement, (b) decomposes JITAI components into distinct stimuli and tasks, and (c) highlights a fundamental design tradeoff between intervention necessity and likelihood of

engagement. Moreover, the decomposition of stimuli and tasks extends beyond intervention delivery to include the measurement processes needed for adaptation, which also require engagement and may influence JITAI effectiveness. We illustrate the application of the JDE framework using examples from published studies and derive six practical guidelines to support the design of more engaging JITAIs.

Bridging JITAI Structure and Engagement: Two Complementary Perspectives

Designing JITAIs that are both effective and engaging requires integrating two complementary lines of work. One focuses on the structural components of JITAIs, offering foundational principles for their configuration and establishing the empirical and theoretical evidence required for their construction. The other focuses on engagement with digital interventions and provides insight into how participants interact with intervention components in practice. Although each perspective offers important insights, they have largely developed in parallel. Integrating these perspectives is critical for advancing the design of JITAIs that can achieve their intended effects in real-world contexts.

Organizing Framework for JITAI Components

An organizing framework for developing JITAIs highlights four key components that collectively comprise this intervention design [2,4]: (1) decision points: the times at which a decision should be made about whether and how to intervene (e.g., every day in the morning), (2) tailoring variables: information used to make intervention decisions (e.g., self-reported stress), (3) intervention options: the types or intensities of interventions that may be delivered (e.g., a message from the mobile device recommending a stress management strategy, no message from the mobile device), and (4) decision rules: if-then statements that link tailoring variables to intervention options by specifying the conditions in which different intervention options should be delivered, at

each decision point (e.g., IF stress=yes, THEN intervention option= a message recommending a stress management strategy; ELSE, intervention option=no message). The decision rules, which protocolize the adaptation process (i.e., the process of using dynamic information about the individual to decide whether and how to intervene), are aimed at impacting proximal outcomes (e.g., stress reduction in the next two hours, reducing the likelihood of smoking lapse during the day), which serve as relatively short-term mechanisms of change driving long-term improvement in a distal health outcome (e.g., smoking cessation). Importantly, the decision points, tailoring variables, intervention options and decision rules are all part of the JITAI design. These components are employed in practice by digital tools to address the rapidly changing needs of individuals (or any other relevant unit of interest) in a replicable and empirically grounded manner. Conversely, the proximal and distal outcomes are not part of the JITAI and thus are not employed in practice. Instead, they serve as the theoretical and empirical benchmarks used by investigators to motivate and inform the JITAI's configuration [2,4].

The adaptation process in JITAIs serves two purposes: (1) delivering an intervention *when needed* to address states of vulnerability for an adverse proximal outcome or capitalize on windows of opportunity for promoting a positive proximal outcome; and (2) delivering an intervention only when needed and when the person is *receptive* to this intervention [3], thereby minimizing burden or disruption. In this context, receptivity is defined as "the individual's transient ability and/or willingness to receive, process, and utilize just-in-time support" [2] (p. 450).

Although this framework provides a strong foundation for developing JITAIs by outlining their core components, it offers limited guidance on how to design intervention components that are engaging in practice. While it acknowledges that delivering an intervention during periods of low receptivity may undermine engagement [2], it does not consider the level or the type of energy

investment required to engage with these components, or the factors that influence such energy investment. As a result, this framework offers limited guidance on how JITAI components should be designed to promote engagement that achieves the intended proximal and distal outcomes.

Organizing Framework for Digital Intervention Engagement

A complementary line of work has focused on understanding and promoting engagement with digital interventions generally [8].

This framework conceptualizes digital interventions as collections of interrelated stimuli and tasks, emphasizing the mapping of these elements as a foundation for effective design [11]. This perspective provides a more detailed account of how participants interact with and experience intervention components.

Within this framework, stimuli are external cues that invite interaction to promote behavior change (e.g., text messages, push notifications, emails, in-app alerts). These stimuli often recommend specific tasks, defined as the activities or actions that participants are asked to perform [8]. The universe of potential tasks comprises a wide range of behavioral, cognitive, or emotional actions, such as completing a meditation practice, journaling, taking a walk, eating/not eating a certain food, or reflecting on one's motivation to change.

Distinguishing between stimuli and tasks highlights that engagement is not a single occurrence but rather a sequential process involving multiple steps. Participants must first notice and attend to a stimulus, then decide whether to initiate and complete the associated task. Each step may be influenced by different factors such as motivation, perceived relevance, and the cognitive, affective, or physical energy required. From this perspective, the effectiveness of digital interventions depends not only on the content of intervention components, but also on how it is experienced and enacted in context.

This framework provides a more detailed account of how participants interact with intervention components and highlights the importance of aligning these components with participants' goals, preferences, and contextual constraints to promote sustained engagement. Despite these strengths, the framework does not explicitly acknowledge the architecture of JITAIs, especially the adaptation process. It provides limited guidance on how to tailor stimuli and tasks over time in response to changing individual states and contexts.

Integrated Organizing Framework: JITAI Design for Engagement (JDE)

Together, the two perspectives described above offer complementary strengths: The JITAI components framework provides a clear structure for specifying whether, when and how interventions should be delivered in practice, whereas the engagement framework provides a detailed account of how intervention components may be experienced and enacted by participants. However, these perspectives are not yet conceptually integrated. More specifically, there is limited guidance on how to design JITAI components in ways that balance their potential effectiveness with the likelihood that participants will engage with them in real-world contexts. The JITAI Design for Engagement (JDE) framework addresses this gap by integrating these perspectives into a unified approach to intervention design. This integration yields three key advances.

First, JDE refines the concept of receptivity by linking it explicitly to effective engagement. In prior JITAI frameworks, receptivity is typically defined as the individual's transient ability and willingness to receive, process, and utilize support. While useful, this definition does not specify what it means for support to be "received," "processed," or "utilized" in ways that produce benefits. JDE extends this definition by conceptualizing receptivity as a set of conditions that facilitate effective engagement with a given intervention-related stimulus or task [12]. Within this framework, effective engagement refers to the investment of physical, cognitive, and/or affective

energy in a given stimulus/task [8] that does more good than harm [3]. This reframing shifts the focus from simply delivering interventions at the right time to delivering them under conditions that support clinically meaningful engagement. It also highlights that receptivity may vary across intervention-related stimuli and tasks, depending on the type and amount of energy investment required for effective engagement.

Second, JDE decomposes both the intervention options (i.e., the types/intensities of interventions that may be delivered) and the tailoring variables (i.e., the information used to decide which intervention option to deliver) into stimuli and tasks. Although the intervention options and tailoring variables are often treated as single units in JITAI design, distinguishing between the stimuli and tasks comprising them clarifies that engagement with these core components unfolds as a multi-step process: individuals must first attend to a stimulus (e.g., a message delivered by the mobile device recommending a stress-management strategy) and then initiate and complete the associated task (e.g., practice the recommended stress-management strategy). These steps may require different types and amounts of energy investment and may be influenced by different contextual factors. Importantly, this stimulus-task decomposition extends beyond intervention options to the processes used to assess tailoring variables. Measurement of the tailoring variables often requires its own stimuli (e.g., a notification asking the participant to self-report their stress experiences, or to charge and wear a sensor for stress detection) and a corresponding task (e.g., completing a survey, charging the sensor). As such, stimuli and tasks comprising both the intervention options and tailoring variables should be designed with attention to their distinct roles in shaping engagement.

Third, JDE introduces a design tradeoff between intervention necessity and likelihood of engagement. It proposes that each stimulus or task should be evaluated along two key

dimensions: (1) necessity, defined as the extent to which the stimulus or task is required to influence the target health outcomes, and (2) likelihood of effective engagement, defined as the probability that, in a given context, an individual will invest sufficient energy in a given stimulus or task to achieve the intended benefits. This dual focus introduces a central design tradeoff. Stimuli/tasks with high potential impact may require substantial energy investment, thereby reducing the likelihood of engagement. Conversely, stimuli/tasks that require only modest energy investment may be more engaging, but their impact on the target health outcomes may be limited. Effective JITAI design requires balancing these competing considerations with respect to the stimuli and tasks comprising the intervention options and tailoring variables.

Taken together, these advances offer a unified framework for designing JITAIs that explicitly account for both intervention effectiveness and participant engagement. By conceptualizing receptivity as a set of conditions that facilitate effective engagement, decomposing intervention components into stimuli and tasks, and introducing a principled tradeoff between necessity and engagement, the JDE framework offers a foundation for designing interventions that are better aligned with the realities of everyday life. Building on this framework, along with a targeted review of the literature, we next derive six practical guidelines to support the development of more engaging JITAIs.

Method

To inform the development of the JITAI Design for Engagement (JDE) framework, we conducted a targeted review of ecological momentary interventions (EMIs; defined as "the delivery of interventions to people as they go about their daily lives" [13], p. 10) and JITAIs. The goal of this review was not to provide a comprehensive synthesis of the literature, but rather to identify

recurring design features and patterns that could inform the development of a conceptually grounded organizing framework.

We searched PubMed for studies published between January 1, 2010, and August 3, 2022, using the terms "ecological momentary intervention," "just in time intervention," and "just in time adaptive intervention." Studies were eligible if they described interventions that delivered support in daily life, including both stand-alone EMIs/JITAIs and those delivered as adjuncts to other treatments. We included quantitative, qualitative, and mixed-methods studies, as well as study protocols (i.e., descriptions of planned but not yet complete studies), to capture a broad range of intervention designs, including recent study designs testing JITAIs. No restrictions were placed on study population, setting, or publication status (i.e., theses/dissertations were eligible). Systematic reviews and conceptual papers were excluded.

The search yielded 190 records, of which 102 met eligibility criteria. Consistent with qualitative approaches to theory development (e.g., content analysis [14]), we randomly selected a subset of 20 studies for in-depth coding (see Supplemental Materials Table 1 for a list of these studies). This approach enabled identification of recurring design elements and themes while maintaining feasibility. This sample size is consistent with approaches aimed at identifying recurring patterns and achieving conceptual saturation rather than statistical representation. Coding focused on characteristics relevant to the JDE framework, including the structure of intervention options, the tailoring variables, the nature of stimuli and tasks, and features related to engagement (e.g., effort, modality). Themes were identified and refined through iterative discussion among the research team, informed by both the empirical literature and the authors' prior experience in conducting systematic reviews and meta-analyses of behavioral interventions, as well as designing and testing JITAIs.

Results: Guidelines for JITAI Development Based on JDE Framework

Guided by the JDE framework (Figure 1), the following six guidelines translate its conceptual advances into actionable design principles. Collectively, these guidelines address theoretical grounding, specification of intervention targets, and the design and adaptation of stimuli/tasks.

Guideline 1: Adopt a Dual-Process Conceptual Model Including Both Health-Related Mechanisms and Engagement-Related Mechanisms

As with all behavioral interventions [15], JITAI development should be grounded in a clear conceptual model informed by behavioral theory and empirical evidence [16]. This model should specify whether and how desired change in targeted distal outcome is expected to occur, including identification of key mechanisms of change (i.e., causal pathways).

Consistent with the JDE framework, conceptual models should include both health-related mechanisms (e.g., craving, stress, self-efficacy) and engagement-related mechanisms (e.g., motivation, intervention adherence, perceived burden, mental fatigue, habituation), as well as the relationship between them. For example, suppose that an investigator would like to develop a JITAI for smoking cessation with 3-month abstinence as the distal outcome. The next step is to identify malleable health-related mechanisms, and the investigator might choose to focus on stress reduction as a key mechanism. The investigator could then outline an intervention option that can influence each key mechanism (one intervention option often influences multiple mechanisms). Suppose that the investigator outlines an intervention option that includes the delivery of a mobile-based recommendation to practice a stress management strategy. Once the core health-related intervention options are identified, the investigator would identify the engagement-related mechanisms, answering the question – what level and form of engagement is

needed for individuals to benefit (i.e., experience improvement in their distal outcomes) from the selected intervention options? In the current example, the key engagement-related mechanism selected by the investigator might be daily engagement with the recommended stress management strategies. Critically, the model should articulate whether and how health-related and engagement-related mechanisms interact; for example, the investigator may expect, based on existing evidence, that engagement with stress management strategies on a given day will reduce daily stress, while elevated stress may simultaneously hinder engagement with stress-management strategies. Explicitly considering these bidirectional relationships and their temporal dynamics (i.e., how these processes unfold and influence one another over time) can help investigators balance necessity and engagement in designing the JITAI.

Findings from our review suggest this dual-process approach is not yet widely implemented. Among the 20 studies examined, only half ($k = 10$) referenced a theoretical basis, and even fewer ($k = 3$) explicitly incorporated mechanisms of engagement. Moreover, even when a theoretical basis was provided, intervention options were not mapped onto these mechanisms. For example, Morgiève et al. [17] implemented a variety of strategies to mitigate suicide risk (e.g., breathing practices, distracting activities, social support), consistent with established treatments such as dialectical behavior therapy [18]. However, the intervention was not explicitly grounded in a coherent conceptual model linking these components to distal outcomes. The absence of a clearly articulated dual-process model limits interpretability of findings and constrains the ability to inform future JITAIs.

Guideline 2: Specify Proximal Intervention Targets Related to Both Health and Engagement

An intervention target is a specific, measurable, and modifiable mechanism through which an intervention exerts its effects. Because JITAIs are designed to address conditions that fluctuate

over relatively short time frames (e.g., minutes, hours, or days), their primary intervention targets are typically proximal (i.e., relatively close in time to intervention delivery). Informed by the dual-process conceptual model, these proximal targets should incorporate both health-related processes (e.g., momentary stress) and engagement-related processes (e.g., engagement with a coping strategy within a defined time window). Explicitly specifying both health-related and engagement-related proximal targets clarifies what level and form of engagement is required for an intervention option to be effective.

Across the studies reviewed, all interventions specified at least one specific health-related intervention target. These generally fell into two categories: the modification of health behaviors (e.g., smoking cessation, physical activity; [19,20]) or the reduction of clinical symptoms (e.g., those related to mental health [21]). In contrast, engagement-related processes were rarely specified as explicit intervention targets [3]. Only three of the 20 studies incorporated intervention targets related to engagement. For example, Rabbi et al. [22] tested a variety of strategies to increase proximal adherence to self-monitoring of substance use among adolescents and emerging adults (e.g., delivering a reminder, delivering funny or inspirational content as a reward for completing assessments). However, this study focused on proximal adherence (i.e., task completion) rather than engagement per se (i.e., degree of physical, affective and cognitive energy invested in the task). This distinction is important, as completing a task does not necessarily imply meaningful engagement with its content, although it could be a proxy that is more feasible to measure. Indeed, the limited emphasis on engagement as a target likely reflects methodological challenges in measuring affective and cognitive investment of energy in real time [8]. However, advancing the field will require explicit specification, and improved measurement, of engagement-related targets.

Guideline 3: Design Stimuli/Notifications to Balance Influence on Both Health- and Engagement-Related Proximal Targets

In JITAIs, stimuli serve as the entry point to intervention engagement. The intervention options in JITAIs typically involve notifications to prompt engagement with a particular therapeutic task (e.g., practice a stress-management activity). The tailoring variables in JITAIs often rely on notifications to prompt engagement with self-reporting or sensor-based assessments required to adapt the delivery of intervention options. In both cases, the design of these notifications should balance their potential to influence both health-related proximal targets (e.g., stress, craving, smoking) and engagement-related proximal targets (e.g., stimulus/task interaction, reduced burden, and minimized habituation). Two key features are central to notification design: modality and content.

Notification Modality. Modality refers to the channel and sensory format through which a stimulus is delivered (e.g., push notifications, SMS/text messages, emails, in-app messages, wearable device alerts; visual, auditory, multimodal formats). For example, Cerrada et al. [19] used push notifications from the mobile app to remind each participant about their plan to respond to risky situations related to smoking cessation. Wright et al. [23] focused on SMS text messages reminding participants of their intentions to reduce their drinking. Although many JITAIs rely on text-based stimuli, other modalities are possible. For example, Huang et al. [24] used a light-emitting diode (LED) linked to an activity tracker to remind participants to take a physical activity break following a sedentary period. Modality influences both the salience of the stimulus and the burden it imposes. More information-rich modalities (e.g., text-based messages) may better support complex cognitive or behavioral shifts, whereas lower-burden modalities (e.g., passive LED) may be easier to engage with but less potent.

Notification Content. Content refers to the information conveyed by the stimulus. Across the reviewed studies, common content types included: (1) goal assignment and feedback (e.g., information about progress on one's goals [where a goal is defined as a state that carries a reward value, motivating the individual to pursue it] [25], assigning a new goal), (2) motivational messages (i.e., communication designed to drive, energize, or sustain goal-directed behavior), (3) psychoeducation (i.e., evidence-based didactic information on the health condition and its management [26]); (4) reminders (i.e., cues designed to evoke a behavior the participant has already learned [27,28] such as self-monitoring their current state and context, chewing a nicotine lozenge when experiencing intense craving), and (5) recommendations (e.g., advice suggesting what the individual should do in a particular situation, such as specific self-regulatory activities [e.g., distraction, deep breathing, noting] when experiencing stress). These categories are not necessarily mutually exclusive; a single message may combine multiple functions (e.g., a notification with a motivational statement paired with a reminder to self-monitor one's stress level). Content type influences both health-related and engagement-related targets. For example, reminders may effectively prompt previously learned behaviors [27,28], whereas recommendations may be necessary when introducing new strategies or responding to novel situations. More complex or personalized content (i.e., self-relevant—perceived as aligned with one's values, meaning, needs and personal goals [29]) is expected to be more therapeutic [30] and engaging [31], but can also increase cognitive burden [1], creating a trade-off between potential effectiveness and engagement. Designing stimulus content therefore requires balancing personalization and therapeutic potency with simplicity and ease of processing.

Guideline 4: Design the Adaptation of Stimuli/Notifications to be Based on Necessity and Facilitators of Engagement

According to the JDE framework, receptivity is conceptualized as conditions that facilitate effective engagement with the specific stimulus/task. Thus, this framework calls for adapting the delivery, modality and type of notification not only based on conditions indicating need for intervention, but also conditions that support effective engagement with the notification. In the context of the smoking cessation example described above, evidence may suggest that when smokers attempting to quit experience stress, they likely need a strategy recommendation to regulate stress and thus prevent a smoking lapse [1]. Thus, the investigator may be motivated to design the adaptation such that the notification is delivered only when the participant experiences stress. However, empirical evidence also suggests that individuals may not be receptive to digital prompting when experiencing stress in daily life (e.g., due to cognitive load [32]). Thus, the adaptation should be designed in a way that balances necessity and likelihood of effective engagement. Further, suppose the investigator plans to use self-reported stress to adapt the delivery of a strategy recommendation. They might deliver a notification prompting a self-report only when necessary (e.g., during expected periods of meaningful stress fluctuations) and when participants are likely to effectively engage with these notifications (e.g., when they are not driving a car [1]).

To date, most JITAIs focus on adapting notification delivery based on conditions that signal need for an intervention (e.g., delivering a notification only when craving is expected in order to prevent gambling [33]), with limited attention given to conditions that facilitate effective engagement with the notification. Further, in theory, different conditions can be used to adapt the notification's modality and type, though empirical research in this area remains nascent. Some emerging work demonstrates the potential of this approach. For instance, Businelle et al. [34] used information about the level of imminent smoking lapse risk determined via EMA to decide which type of notification to deliver. When risk was low, the notification included motivational or

psychoeducational content. When risk was elevated, the notification included suggestions for how to cope with current lapse triggers. Extending this approach to include adaptation of notification modality and using facilitators of effective engagement as tailoring variables represent important opportunities for improving JITAI effectiveness.

Guideline 5: Design Tasks to Balance Influence on Both Health- and Engagement-Related Proximal Targets

Tasks are the behavioral, cognitive, or emotional activities through which JITAIs exert their effects on proximal outcomes. These may include strategies aimed at modulating thoughts (e.g., cognitive reappraisal), emotions (e.g., mindfulness), or behaviors (e.g., physical activity). Compared to stimuli, tasks typically require greater investment of physical, cognitive, or affective energy to yield benefits. As with stimuli, the modality and type of the task are two critical design features that shape its impact on both health- and engagement-related proximal targets.

Task Modality. Task modality refers to the means by which the recommended task is designed to be carried out, including digitally supported formats (e.g., guided exercises delivered via an app, self-reporting momentary experiences via the app) and non-digital activities (e.g., taking a walk, practicing a breathing exercise independently [20]), as well as combinations of both (e.g., guided meditation with audio prompts [35]).

Modality can influence both health-related and engagement-related proximal targets. For example, non-digital tasks may be necessary for certain health-related targets (e.g., seeking social support to cope with craving [36]), whereas digital guidance may reduce burden and thus support engagement by scaffolding task execution. At the same time, sustained reliance on digital support may limit habit formation [37]. Thus, JITAIs may benefit from strategically

transitioning over time from digitally guided to independent task performance to promote long-term behavior change. This approach gradually fades the digital 'scaffolding,' preventing long-term dependency and encouraging the sustainable integration of the behavior into daily life.

Task Type. Task type refers to the nature of the activity a participant is asked to complete, reflecting the behavioral, cognitive, or emotional process it is intended to elicit. Across the reviewed studies, tasks included a range of strategies commonly derived from cognitive-behavioral approaches that can shape both health-related and engagement-related targets. While a comprehensive review of all possible task types is beyond the scope of this paper, they include urge surfing (i.e., observing an urge as it rises and falls without acting on it), progressive muscle relaxation (i.e., sequential tensing and relaxing muscles in the body [33]), and various forms of distraction (e.g., eating). Physical activity was a task recommended in multiple studies (e.g., [24]). Further, self-reporting is a common task used to gather information about tailoring variables [38], as well as to serve as a self-monitoring tool that facilitates self-reflection (i.e., "the introspection and evaluation of one's thoughts, feelings, and behavior" [39], p. 821).

Tasks that require substantial investment in cognitive or emotional energy may be more effective but harder to initiate or sustain, whereas simpler tasks may be easier to engage with but less potent. Engagement may also be enhanced when tasks align with individuals' value and preferences (i.e., drive to perform certain behaviors out of interest or personal importance [40]). For example, Cerrada et al. [19] provided interventions incorporating participant-generated tasks, which may increase autonomous motivation and relevance (e.g., self-developed coping plans for high-risk situations such as giving cigarettes to a non-smoking friend when going to a bar [19]).

Guideline 6: Design the Adaptation of Tasks to be Based on Necessity and Facilitators of Engagement

As with stimuli, task recommendations should be adapted based on both necessity and the likelihood of effective engagement. Existing JITAIs commonly adapt task delivery and type based on need (e.g., delivering more intensive coping strategies during high-risk moments). For example, Businelle et al. [34] implemented four levels of messages to promote smoking cessation. The first level (Level 0) was delivered during the period prior to the quit attempt and post-quit attempt when a participant indicated they were no longer interested in quitting. These messages did not recommend specific cessation strategies, but instead focused on increasing motivation (e.g., providing information on the benefits of quitting). Levels 1–3 were delivered based on lapse risk: when risk was low (Level 1), imminent (Level 2), or after a lapse had occurred (Level 3). Similarly, Castilla et al. [41] used emotional intensity to adapt task type in emotion regulation training. During moments of low or moderate emotional intensity, participants were encouraged to engage with strategies like cognitive reappraisal (i.e., changing how one is thinking) and learning (i.e., psychoeducation about sleep). During high emotional intensity, participants were encouraged to engage with strategies focused on deploying attention in specific ways (e.g., using distraction or mindfulness). Studies also adapted whether or not a task was recommended to begin with based on contextual cues (e.g., using location data coupled with information on prior cigarette use [42]). However, relatively little attention has been given to adapting tasks based on conditions that facilitate effective engagement with the task.

Within the JDE framework, the participant's likelihood of effectively engaging with a specific task depends on the extent and nature of energy the task requires. For example, brief, low-effort tasks (e.g., a short activity break of 2-3 minutes) may be appropriate during periods of high demand (e.g., work hours), whereas more intensive tasks may be feasible during periods with fewer constraints. Importantly, tasks also differ on whether they require primarily physical,

cognitive, or affective energy investment. For instance, Hollis-Hansen et al. [43] provided participants with recordings of themselves describing short personal narrative (e.g., 3-5 sentences) about the future (i.e., episodic future thinking). These narratives were designed to inspire their adherence to an anti-hypertensive diet. Although listening to a short recording may require low-to-moderate physical energy, for this task to be maximally effective, individuals may need to invest sustained cognitive and affective energy in envisioning this potential future and reflecting on how their current behavior aligns with it.

Designing adaptation strategies that align the cognitive, affective, or physical energy investment requirements of a task with the conditions most conducive to such investment represents a key opportunity to improve both engagement and intervention effectiveness. Although this area remains underexplored, emerging work suggests that the amount and type of energy a task requires may play a crucial role in the success of the JITAIs [44].

Limitations and Future Directions

While these guidelines offer a structured approach for designing engaging JITAIs, several limitations and open opportunities for future research remain. First, the proposed framework is based on the integration of two conceptual perspectives and a targeted review of a subset of the literature. Although this approach allowed for in-depth analysis of recurring design features, it was not intended to be a comprehensive or systematic synthesis. As such, additional refinements may emerge from broader reviews or meta-analyses of empirical studies.

Second, advancing JITAIs will require more dynamic and comprehensive theories of engagement. In particular, there is a need for theory that explains how engagement fluctuates over time, how it can be sustained, how it impacts proximal and distal health outcomes, and how interventions can promote engagement while supporting independence and habit formation. Such

theory is essential for specifying the relationships between engagement-related and health-related mechanisms with dual-process models.

Third, effective engagement remains difficult to define and measure despite its central role in the JDE framework. While engagement is conceptualized here as the investment of physical, cognitive, and affective energy in intervention components, most existing studies rely on behavioral proxies (e.g., task completion, app usage) that capture only a subset of this construct. Developing reliable and feasible methods to assess the multidimensional nature of engagement, particularly its cognitive and affective components, is an important priority. Potential approaches include self-report measures or qualitative interviews, behavioral indicators of effort (e.g., the number of times an individual completes a given task before giving up, the financial compensation required to get an individual to complete a task a given number of times [45]), and emerging physiological or neurobiological assessments [46].

Fourth, although the framework emphasizes balancing health-related and engagement-related proximal targets, relatively little empirical work has examined how these targets are linked. Intervention components likely vary in both their potential impact on health outcomes and the amount and type of energy required for effective engagement. Future research should identify the minimum effective "dose" of engagement required for different types of stimuli and tasks and examine how these requirements vary across individuals and contexts. Examining how momentary engagement with stimuli and tasks accumulates over time to influence longer-term outcomes [30,47] may help clarify how repeated moment-to-moment interactions with stimuli/tasks translate into sustained behavior change. Early meta-analytic evidence focusing on investment of physical energy (i.e., app usage) suggests a modest association (r = .16) between engagement and outcomes

for mental health apps generally [10]. However, more work is needed to characterize the temporal dynamics of engagement and its role as a mechanism of behavior change.

Fifth, several design features identified in this framework, such as stimulus modality, content, task type, and adaptation strategies are strong candidates for optimization. By intervention optimization, we mean the process of achieving a desired balance between intervention effectiveness, affordability, scalability, and efficiency [48]. The Multiphase Optimization Strategy (MOST [49]) provides a useful framework for this work, with methods such as micro-randomized trials and factorial experiments well suited to evaluating JITAI components and their interactions. These approaches can support the development of optimized JITAI prior to large-scale evaluation.

Finally, an important extension of the JDE framework is that the distinction between stimuli and tasks applies not only to intervention options, but also to the measurement processes used to assess tailoring variables. These processes often involve their own stimuli and tasks, which impose energy investment demands and may influence receptivity to subsequent elements. Future research should examine how timing, frequency, and burden of measurement interact with intervention delivery to shape engagement and effectiveness. Overall, advancing JITAIs will require a stronger empirical and theoretical integration between health-related and engagement-related processes, as well as more systematic approaches to optimizing intervention design.

Conclusions

Just-in-time adaptive interventions (JITAIs) offer a powerful approach for delivering support in daily life, but their effectiveness depends critically on whether individuals meaningfully engage with intervention components as they are delivered. In this paper, we addressed a key gap in existing frameworks by integrating principles of JITAI architecture with insights from the science of digital intervention engagement. This integration yielded the JITAI Design for

Engagement (JDE) framework and six corresponding guidelines for intervention design. The framework emphasizes the importance of specifying both health-related and engagement-related mechanisms, distinguishing between stimuli and tasks comprising the intervention options and tailoring variables, and explicitly considering the tradeoff between necessity and likelihood of engagement with each stimuli/task.

As digital technologies continue to expand the possibilities for delivering JITAIs, frameworks that explicitly incorporate engagement into intervention design will become increasingly important. Emerging technologies highlight the potential to deliver highly engaging and scalable support in real-world contexts. However, theoretical and empirical work has not yet kept pace with these advances. The JDE framework provides a foundation for addressing this gap by guiding the design of JITAIs that are not only theoretically grounded, but also more engaging. By doing so, it establishes the necessary groundwork for harnessing technological innovations in a manner that transcends mere user retention to meaningfully improve public health.

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Figure 1. The Just-In-Time Adaptive Intervention (JITAI) Design for Engagement (JDE) framework.

Supplemental Materials Table 1. Coded Studies

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