Using Digital Technology to Increase Integration of Meditation into Daily Life: The Case for Meditation-Based Ecological Momentary Interventions

Qiang Xie[1,2], Victoria Amo[3], Inbal Nahum-Shani[4], Simon B. Goldberg[1,2]

[1]Department of Counseling Psychology, University of Wisconsin-Madison, Madison, WI, USA

[2]Center for Healthy Minds, University of Wisconsin-Madison, Madison, WI, USA

[3]Max Planck Institute for Intelligent Systems, Tübingen, Baden-Württemberg, Germany

[4]Institute for Social Research, University of Michigan, Ann Arbor, MI, USA

Author Note

Qiang Xie https://orcid.org/0000-0003-3968-9629

Victoria Amo https://orcid.org/0000-0002-3097-8160

Inbal Nahum-Shani https://orcid.org/0000-0001-6138-9089

Simon B. Goldberg https://orcid.org/0000-0002-6888-0126

Correspondence should be addressed to: Simon B. Goldberg, Department of Counseling Psychology, University of Wisconsin-Madison, 335 Education Building, 1000 Bascom Mall, Madison, Wisconsin, 53706, United States, phone: 608-265-8986, fax: 608-265-4174, email: sbgoldberg@wisc.edu

Funding

SBG was supported by the National Center for Complementary & Integrative Health of the National Institutes of Health under Award Number K23AT010879, the National Institute of Mental Health under Award Numbers R24AT012845, and R01MH139512, and the Hope for

Depression Research Foundation Defeating Depression Award. INS was supported by grants P50 DA054039 (NIDA), U01 CA229437 (NCI), and R01 DA039901 (NIDA). The content is solely the responsibility of the author and does not necessarily represent the official views of the National Institutes of Health.

Ethical Approval

Not applicable.

Informed Consent

Not applicable.

Clinical Trial Number

Not applicable.

Author Contributions

QX: Conceptualization, Writing - Original Draft, Writing - Review & Editing. VA: Writing - Original Draft, Writing - Review & Editing. INS: Writing - Review & Editing, Funding Acquisition. SBG: Conceptualization, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding Acquisition.

Data Availability Statement

Not applicable.

Conflict of Interest

The authors declare no conflict of interest with respect to the research, authorship, or publication of this article.

Abstract

Background: Meditation-based interventions (MBIs) hold promise for enhancing health and well-being. However, substantial barriers impede engagement in traditional forms of these interventions. Innovations in mobile health offer an avenue for overcoming barriers associated with traditional MBIs. A particular mobile health innovation – Ecological Momentary Interventions (EMIs) – has the potential to enhance the accessibility, acceptability, and efficacy of MBIs. However, there is limited research on EMIs integrated into MBIs (i.e., meditation-based [MB]-EMIs). This conceptual paper aims to make a theoretical case for MB-EMIs to highlight their potential and to inform future studies on MB-EMIs. **Methods:** We discuss the historical context, conceptual foundations, motivation for adoption, and empirical evidence supporting the potential of EMIs. Additionally, we explore the conceptual intersections between EMIs and both traditional contemplative sources and contemporary secular MBIs. Furthermore, we describe empirical studies on MB-EMIs. **Findings/Results:** Studies have demonstrated diverse approaches to integrating EMIs into MBIs. These studies exhibit variability in key dimensions, including the MBI with which the EMI is integrated and the characteristics of the EMI itself. MB-EMIs have therapeutic potential, but there are many important scientific questions about them that have not yet been answered. **Conclusions:** Future studies should continue to examine the impact and safety of meditation-based EMIs, leverage innovations in passive data collection, explore user experiences, develop these interventions for and with marginalized populations, and emphasize informal meditation practice. As the field matures, systematic reviews or meta-analyses will be essential to map the full landscape of MB-EMIs.

Keywords: mindfulness; meditation; smartphones; ecological momentary intervention; just-in-time adaptive intervention

Using Digital Technology to Increase Integration of Meditation into Daily Life: The Case for Meditation-Based Ecological Momentary Interventions

Meditation has become widespread in the West in the past several decades (Lam et al., 2023; Nahin et al., 2024). Meditation can be defined as a family of practices that provide training in attention and emotion regulation (Lutz et al., 2008), which in the Western biomedical context, are often aimed at cultivating wellbeing. The definition of meditation is inherently broad and context-dependent. Matko and Sedlmeier (2019), in their empirically derived classification system, identified substantial heterogeneity across meditation techniques. Their findings highlight that there is no single agreed-upon definition of meditation, and that classifications often depend on tradition, context, or intended outcomes. Examples of meditation include mindfulness (i.e., cultivating nonjudgmental awareness of present-moment experiences such as bodily sensations or thoughts; Kabat-Zinn, 1990) and loving-kindness and compassion meditation (i.e., generating feelings of kindness and compassion toward oneself and others; Shonin et al., 2015). Meditation has been incorporated into a wide variety of meditation-based interventions (MBIs; Kabat-Zinn, 1990; Neff & Germer, 2013; Segal et al., 2013). In this paper, we conceptualize MBIs as structured interventions that incorporate instruction in formal meditation practices, defined as dedicated and intentional practices conducted outside the context of daily activities, drawn from contemplative traditions which may be adapted for secular contexts to support mental health and well-being. Many MBIs have been widely applied in clinical practice as part of third-wave cognitive behavioral therapies (Kabat-Zinn, 1990; Segal et al., 2013). Standardized MBIs such as Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT) often emphasize mindfulness, defined as the capacity for non-judgmental awareness of present moment experience (Kabat-Zinn, 1990; Segal

et al., 2013). However, many MBIs including MBSR also involve instruction in other styles of meditation practice. Although emphasizing mindfulness, MBSR also includes loving-kindness practices which involve cultivating feelings of care for oneself and others (Kabat-Zinn, 1990). For the purposes of this paper, we follow Crane et al. (2017) and require MBIs to include training in formal meditation practice. However, we broaden Crane et al.'s definition to include meditation practices drawn from the range of contemplative traditions. Thus, MBIs as discussed here are not restricted to the training of mindfulness skills (i.e., attentional and deconstructive families of practice), but also include training in constructive practices such as loving-kindness and compassion (Dahl et al., 2015). This broadened definition allows for a more accurate reflection of the various types of meditation practices incorporated into secularized MBIs and appearing in the scientific literature.

As these diverse forms of meditation have been integrated into standardized MBIs, growing empirical research has examined their effectiveness and demonstrated how they are typically delivered and practiced. MBIs, such as mindfulness, loving-kindness, and compassion-based interventions, have now been tested in hundreds of randomized controlled trials (RCTs) targeting a range of psychological and physical health conditions, with some evidence for efficacy (Galante et al., 2014; Goldberg, Riordan, et al., 2022). MBIs are traditionally delivered in person by trained instructors and recommend a substantial amount of formal meditation practice (e.g., 30-45 minutes per day of sitting meditation or body scan; Kabat-Zinn, 1990; Segal et al., 2013). MBIs also commonly encourage participants to apply the meditative capacities cultivated during formal meditation to their daily lives, in other words, engaging (i.e., investing physical, affective, and cognitive energies) in informal meditation practice (Kabat-Zinn, 1990; Nahum-Shani et al., 2022; Segal et al., 2013).

Despite some evidence for efficacy, there are substantial barriers associated with accessing and engaging in traditional MBIs. These include logistical barriers (e.g., scheduling, transportation), cost, lack of trained instructors, and the substantial time required to both attend classes and engage in the recommended amount of home practice (Crane et al., 2017; UMass Memorial Medical Center, n.d.). These barriers may be particularly pronounced for high-burden and high-need populations, thus making MBIs inaccessible for many who may benefit (Henshaw & Freedman-Doan, 2009; Nathalie Lyzwinski et al., 2018; Spears et al., 2017).

Mobile health (mHealth) technologies have emerged as a means to expand access to MBIs. mHealth could effectively reduce logistical barriers, as well as those related to cost and reliance on trained instructors (Weisel et al., 2019). There is clear evidence indicating that among mHealth apps, meditation apps are by far the most widely used (Wasil et al., 2020). The rapidly expanding RCT literature suggests that mHealth MBIs can produce small-to-moderate-magnitude reductions in common psychological symptoms (e.g., anxiety, depression, stress; Gál et al., 2021; Goldberg, Lam, et al., 2022) and may reduce physiological indices linked to physical health risk (e.g., inflammation; Dutcher et al., 2022). Of note, meditation practices have a long history of being disseminated through oral, written, and recorded means - efforts that have significantly contributed to their accessibility (Gethin, 1998). However, modern MBIs such as MBSR and MBCT are often delivered in structured, instructor-led group settings. Despite their evidence base, access to these interventions remains limited, particularly for individuals facing logistical, psychological, or financial barriers (Henshaw & Freedman-Doan, 2009; Nathalie Lyzwinski et al., 2018; Spears et al., 2017). In this context, mHealth represents a contemporary extension of past dissemination efforts that may offer new possibilities for expanding access.

Can mHealth also reduce barriers associated with engaging in meditation practice? That is, can mHealth MBIs make it easier for participants to incorporate formal and/or informal practice into their daily lives? In this paper, we explore the potential of a specific mHealth innovation – the ecological momentary intervention (EMI) – as a means of increasing the accessibility, acceptability, and potentially efficacy of MBIs. There has been limited research on EMIs integrated with MBIs (i.e., meditation-based [MB]-EMIs). A recent systematic review of 82 studies on EMIs that included content on nonjudgmental awareness found over half of the studies used cognitive behavioral therapy as their theoretical orientation, and the remainder primarily used mindfulness-informed approaches that do not include meditation as a central component (e.g., Acceptance and Commitment Therapy; Hayes et al., 2006); in contrast, only 4 (4.35%) studies incorporated meditation-based approaches such as MBSR and MBCT (Pavlacic et al., 2024). Moreover, other forms of meditation beyond mindfulness (e.g., lovingkindness, compassion; Dahl et al., 2015) were rarely investigated in MB-EMI studies. We aim to make a conceptual case for MB-EMIs and review a selection of studies to highlight the potential and inform future studies on MB-EMIs. We intentionally choose not to conduct a systematic or scoping review or meta-analysis given the limited literature on MB-EMIs (Pavlacic et al., 2024). Instead, we adopt a conceptual approach to highlight the conceptual foundations and key design features of MB-EMIs. We aim to identify emerging gaps to stimulate future research in this growing area. We pursue the following four specific aims:

1. Describe EMIs including their conceptual underpinnings, motivation for their use, history, and results from meta-analyses and RCTs testing EMIs.
2. Discuss conceptual overlap between EMIs with both traditional contemplative sources as well as modern, secular MBIs.

3. Describe recent empirical studies integrating EMIs into MBIs.
4. Discuss key future directions to address the limitations of previous MB-EMI studies and advance MB-EMIs.

What are Ecological Momentary Interventions and Why Do They Matter

EMIs, often delivered through technology such as mobile devices, have been defined as interventions supporting individuals in improving their psychological or physical health or health behaviors within the context of their daily lives while engaging in daily activities (Heron & Smyth, 2010). This is an admittedly broad definition that can encompass a wide variety of interventions. However, for the purpose of this paper, we focus on EMIs that provide formalized and structured support through mobile devices. The term was first introduced in Heron and Smyth (2010). EMIs grew in parallel with innovations in measurement methods such as ecological momentary assessment (EMA) that recognized the limitations of retrospective self-report assessment (Heron & Smyth, 2010). EMA sought to assess individuals' contextual and internal states in real time and *in situ* – that is, within their natural environments (Shiffman et al., 2008). EMIs seek to move beyond the delivery of momentary *assessment* to the delivery of momentary *interventions* in individuals' natural environment.

EMIs are based on the theoretical rationale that many behavioral interventions such as traditional psychotherapy delivered weekly in 50-minute sessions are limited in their impact due to a lack of penetration into individuals' daily lives (Heron & Smyth, 2010). The advancement of technology including smartphones and wearables dramatically enhanced the capacity to collect internal and contextual information in real time and natural environment (Mohr et al., 2017). Given the dramatic advances in digital technology and the widespread incorporation of these technologies into daily life, there is an untapped potential to deliver interventions *where* and

when individuals need support the most within their natural environment. This has the potential to significantly enhance the effectiveness of treatments (Nahum-Shani et al., 2015; Wang & Miller, 2020).

Early work began to explore the effect of EMIs prior to Heron and Smyth (2010). In a randomized clinical trial, Burnett et al. (1985) investigated the efficacy of ambulatory computer-assisted therapy (the EMI) versus paper-and-pencil-assisted therapy for weight loss in 12 women with weight concerns. Both groups engaged in self-monitoring of caloric intake and physical activity, along with brief therapy sessions emphasizing goal setting and feedback. The computer-assisted group, carrying a portable microcomputer system, received real-time feedback and messages (reinforcement, goal adjustment, or instructions on alternative behaviors) contingent on food consumption and exercise. In contrast, the paper-and-pencil group engaged in manual self-reporting using a paper form without automated support. Results showed the computer-assisted group achieved significantly greater short- and long-term weight reductions compared to the control group.

Since this landmark EMI study, a wide variety of EMIs have been developed. EMIs can be classified based on levels of complexity in the interactions between EMIs and users (Carter et al., 2007). Informational EMIs contain static information that individuals can access as they request (e.g., a series of learning modules on mental health; Carter et al., 2007; Schueller et al., 2017). Interactive EMIs can also save and display information such as inspirational quotes. In addition, they can change responses based on users' information (Carter et al., 2007; Schueller et al., 2017). For example, an intervention that prompts EMA of psychological distress several times each day and provides different interventions in response to different distress levels is an interactive EMI. Integrated EMIs go one step further and can interpret users' data with the help

of algorithms. At this level, the intervention system learns from the users' past interactions with the system and intelligently adapt to them. It delivers momentary interventions that have been demonstrated, by previous interactions, to be effective (Carter et al., 2007; Schueller et al., 2017). For example, an EMI with an integrated level of complexity can analyze whether certain interventions it prompts previously are beneficial to help foster engagement in meditation practice. Based on this analysis, only those interventions that are the most likely to increase engagement in meditation practice will be delivered in the future.

A special category of EMIs is just-in-time adaptive interventions (JITAIs; Nahum-Shani et al., 2018; Schueller et al., 2017). JITAIs are intervention designs that adapt the intervention according to individuals' fluctuating internal and contextual states so that individuals can receive appropriate support when they are most in need and receptive (Nahum-Shani et al., 2015). The "just-in-time" part of JITAIs refers to providing the right type or amount of support at the right time (i.e., neither too late nor too early). The "adaptive intervention" part involves the use of moment-by-moment internal (e.g., emotional state) or contextual information (e.g., time, location) to inform the type, amount, or timing of interventions (Nahum-Shani et al., 2018). As adaptive interventions, JITAIs consist of four major components, namely decision points (i.e., time points to make intervention decisions), intervention options (i.e., possible interventions that can be delivered in each decision point), tailoring variables (i.e., internal or contextual information guiding intervention delivery), and decision rules linking tailoring variables with intervention options (Nahum-Shani et al., 2018). Furthermore, JITAIs distinguish between proximal and distal outcomes. Distal outcomes represent the ultimate goals of interventions, such as reducing persistent anxiety and depression, which typically require longer periods to change. Proximal outcomes, on the other hand, are short-term goals of JITAIs. An example of a proximal

outcome might be engagement in meditation practice or momentary anxiety and depression measured 2 hours after delivering a meditation practice reminder. Importantly, proximal outcomes can serve as mediators driving the intervention's effect on distal outcomes or as intermediate measures of distal outcomes (Nahum-Shani et al., 2018; Schueller et al., 2017). JITAIs share similarities with interactive or integrated EMIs. However, compared to other EMIs, JITAIs place greater emphasis on the individuals' receptiveness to interventions (i.e., individuals' willingness or capacity to process or utilize interventions) in enhancing intervention engagement. Moreover, JITAIs are designed with an explicit goal of minimizing unnecessary interventions (i.e., maximizing efficiency; Nahum-Shani et al., 2018).

There is a growing body of evidence supporting the potential of EMIs for improving a range of psychological and behavioral health outcomes, such as anxiety, depression, perceived stress, smoking cessation, and positive psychological well-being (Eghdami et al., 2023; Versluis et al., 2016; Wang & Miller, 2020). Some RCTs (e.g., Depp et al., 2015; Newman et al., 2014) have indicated the potential of EMIs to augment the impact of traditional psychotherapy and self-monitoring. Meta-analytic evidence suggested that EMIs could enhance mental health and foster positive psychological well-being with a small-to-medium effect size ($g = 0.40$) when compared to control groups; moreover, the effect of EMIs tends to be larger when EMIs are supplemented with support from mental health professionals (Versluis et al., 2016).

Seeds of Ecological Momentary Interventions in Traditional and Secular Meditative Traditions

Although EMIs are a relatively recent addition to the scientific literature, the hope that meditative techniques will be applied within the moment-to-moment context of daily life has a long history within both traditional contemplative and secular MBI literature. Many Buddhist

traditions heavily emphasize formal meditation practice (e.g., sitting meditation), particularly for monastic practitioners who have formally committed themselves to the full-time spiritual pursuits (i.e., awakening; Rahula, 1974). Yet even for monastic practitioners, traditional Buddhist sources also place a heavy emphasis on the integration of meditation into daily life. A clear example of this appears in the so-called "mindfulness" or *Satipatthana Sutta* (with *sati* being the word for mindfulness in Pali, the language used in early Buddhist texts; Nanamoli & Bodhi, 2015). Although the sutta (i.e., teaching of the Buddha) begins with instructions for formal meditation (e.g., "gone to the forest, or to the root of a tree, or to an empty hut, [the practitioner] sits down; having folded [their] legs crosswise," Nanamoli & Bodhi, 2015, p. 145), the very next section emphasizes the integration of mindfulness in various activities of daily living (i.e., "when walking, [the practitioner] knows 'I am walking'; when standing, [the practitioner] knows 'I am standing,'" Nanamoli & Bodhi, 2015, p. 146). Indeed, the first of the four foundations of mindfulness outlined in the sutta – mindfulness of the body – explicitly encourages practitioners to maintain body awareness during the most mundane daily activities ("when defecating and urinating," Nanamoli & Bodhi, 2015, p. 147). Similarly, the second foundation of mindfulness – mindfulness of the mind – emphasizes awareness of various mental states that arise during both formal meditation practice and daily life (e.g., anger, lust).

The contemporary Buddhist tradition contains a wide variety of techniques for supporting the integration of meditation within daily life. Again, while formal meditation is often viewed as the cornerstone for this, many techniques are intended to be implemented within daily life as well. An example of this is the noting technique emphasized in Mahasi Sayadaw's (2016) *Manual of Insight*. Mahasi Sayadaw was a Burmese Vipassana teacher who was an influential teacher for many prominent Western meditation teachers who contributed to the rise in

popularity of meditation in the West (e.g., Joseph Goldstein, Sharon Salzberg; Goldstein, 2013). This technique involves the continual use of mental notes as a means of maintaining mindful awareness during both formal meditation as well as daily life (e.g., noting physical sensations, thoughts, emotions, etc.). Walking meditation, during which a practitioner attends to the physical sensations of walking, is commonly taught as a means of encouraging mindful awareness during daily activities (Sayadaw, 2016). Mahasi-style noting is an example of a traditional technique that may be amenable to support through technology. For example, one could easily imagine a digital prompt that users receive at multiple random points during the day. Initially, participants could be asked to select among a variety of candidate notes for what they were aware of when they received the prompt (e.g., "hearing," "seeing," "thinking," "walking"). Over time, the need to select a specific note could be omitted, with the prompt merely reminding users to attend to their moment-to-moment experience. Alternatively, a user could receive random prompts encouraging them to notice particular aspects of experience (e.g., impermanence, unsatisfactoriness).

Parallel training in formal meditation practice as well as the integration of meditative techniques into daily life is clearly evident in common secularized MBIs like MBSR and MBCT. Both MBSR and MBCT include instruction in walking meditation and both highlight the importance of meditation being something that one carries into daily activities as much as possible (Kabat-Zinn, 1994; Segal et al., 2013). Many contemporary secular MBIs including those delivered through mHealth emphasize this application of meditative techniques outside of periods of formal meditation practice (e.g., Healthy Minds Program; Goldberg et al., 2020).

In summary, there is a long tradition of encouraging practitioners to bring their meditation practice "off the cushion" and into their daily life, in both Buddhist and secularized

meditation traditions. However, practitioners may encounter various potential barriers (e.g., busy schedules, lack of proficiency, forgetfulness) to integrating meditation practices into daily life (Dyer et al., 2025; Xie, Dyer, et al., 2024). The subsequent sections will explore the possibility that recent technological advances that are already deeply woven into our daily lives may serve as a valuable means for further supporting and addressing barriers to this integration.

Meditation-Based Ecological Momentary Interventions

So, what qualifies as a meditation-based EMI (MB-EMI)? Is a smartphone app that sends a reminder to engage in formal meditation practice an MB-EMI? What about a post-it note on your bathroom mirror that says "Kindness" reminding you to be kind to yourself and others? What about a text message from a friend asking how you are doing?

Drawing conceptual boundaries in the era of digital technology, with its rapid rate of change and deep integration into our daily lives, can be difficult. Nonetheless, definitional boundaries can be important, particularly for supporting communication and replication within scientific endeavors. Thus, we define MB-EMIs as EMIs that are designed to promote the integration of meditation practice in individuals' daily lives within the framework of an MBI. These EMIs may induce changes in behaviors (e.g., practicing meditation), cognition (e.g., attending to one's breath, bringing an attitude of kindness to one's next interpersonal interaction), and/or affect (e.g., appreciating important individuals in one's life). This is an admittedly broad definition that would include components intervention developers may not consider MB-EMIs (e.g., reminders to engage in formal practice in widely used meditation apps). It also has fuzzy boundaries; it excludes interventions that share similarities with MB-EMIs but are not a part of structured interventions (e.g., the post-it note and the text message from a friend). It also includes only EMIs occurring within the context of an MBI, but in theory

one could encourage the attitudes of MBIs (e.g., non-judgmental awareness of moment-to-moment experience, an attitude of kindness towards oneself and others) outside the context of an MBI. Nonetheless, for our purposes here, we restrict our examination to EMIs that are combined with some instruction in formal meditation practice. However, given mHealth interventions often include a wide range of techniques (Camacho et al., 2022), we loosen the requirement in Crane et al.'s (2017) definition of MBIs as having a central emphasis on formal meditation practice and instead define MB-EMIs as interventions that include any amount of formal meditation instruction. This formal meditation instruction can be prompted in people's daily lives (e.g., a text message containing a link to guided meditation practice recordings) and/or retrieved (e.g., guided meditation practice stored within an app) by participants.

Parallel to rising interest in EMIs within the broader scientific literature, a growing number of empirical studies have incorporated EMIs into MBIs. An early example of this includes Zautra et al. (2012). In this study, 73 middle-aged adults with depressive symptoms were randomly assigned to mindfulness, personal mastery, or an attention control condition. All conditions received an in-person orientation, supplemented by 27 days of daily prerecorded phone messages delivered each morning. The mindfulness group focused on providing guided formal mindfulness practice and encouraging engagement in informal practice, while the personal mastery group emphasized identifying controllable events and engaging in behavioral activation. The attention control group received health behavior tips. Results showed improved emotional health in both treatment groups compared to the control. The mindfulness group also exhibited greater improvements in physical health than the other two groups.

Since Zautra et al. (2012), an increasing number of MB-EMI studies have appeared illustrating the wide variety of ways in which EMIs can be integrated within MBIs. These studies

vary in several key features, including the MBI with which the EMI is integrated and the EMI itself. Below we discuss examples of MB-EMIs. We select the following MB-EMI studies to ensure that MBIs representing varying levels of accessibility are included in the discussion. Specifically, MBIs can encompass traditional formats (i.e., MBIs delivered by meditation teachers or other mental health professionals), those primarily designed for self-help but with some guidance from meditation teachers or other mental health professionals, and self-help MBIs without any human support. These variations in MBIs represent different levels of accessibility, with self-help MBIs without human support being the most readily accessible. It is important to acknowledge that the examples we explore below are not intended to be an exhaustive list of studies in the literature. As mentioned earlier, research on MB-EMIs is still an emerging field. The purpose of discussing these studies is to demonstrate how existing studies integrated EMIs within different types of MBIs. Future systematic reviews and ultimately meta-analyses will be helpful for mapping the landscape of studies in this field. See Table 1 for the features of each MB-EMI study. In Table 1, we use the components of JITAIs (i.e., decision points, intervention options, tailoring variables, decision rules, proximal and distal outcomes) to describe the EMI features of MB-EMIs. Even though not all MB-EMIs are JITAIs, these features highlight relevant intervention characteristics that vary across MBI-EMIs. Indeed, some MB-EMIs did not incorporate certain JITAI components, such as tailoring variables and decision rules (Spears, Abroms, et al., 2019; Zainal & Newman, 2023).

EMIs Integrated into Traditional MBIs

In a pilot RCT, Spears, Abroms, et al. (2019) investigated the feasibility and efficacy of an EMI designed to promote mindfulness practice as a complement to in-person mindfulness group treatment. Current smokers (n = 71), motivated to quit, underwent an eight-week

Mindfulness-Based Addiction Treatment. Among them, 38 participants additionally received two to six daily text messages, serving as reminders for both formal (e.g., body scan and sitting meditation) and informal mindfulness practice (e.g., mindful breathing throughout the day) between treatment sessions. Although participants exhibited high engagement with the messages and perceived them as helpful, the cessation rates for those receiving the additional EMI were not significantly better than those undergoing only Mindfulness-Based Addiction Treatment.

In a recent RCT, Garland et al. (2023) explored the efficacy of combining Zoom-based Mindfulness-Oriented Recovery Enhancement (MORE) with EMI prompts triggered by wearable sensors in opioid-treated chronic pain patients. The study randomized participants (n = 63) into either MORE + EMI or a Zoom-based supportive group psychotherapy control. In the MORE + EMI group, participants received eight-week MORE training. Moreover, audio-guided mindfulness practices were triggered by physiological stress detected via heart rate variability changes. The use of heart rate variability changes as a tailoring variable is aligned with evidence that mindfulness can enhance interoceptive awareness and support modulation of autonomic nervous system activity, including heart rate variability (Christodoulou et al., 2020; Fissler et al., 2016). Results reveal that MORE + EMI led to greater improvements in momentary craving, pain, stress, and positive affect over time compared to the support group. Moreover, EMI-initiated mindfulness practice demonstrated associations with improved momentary outcomes and increased heart rate variability observed from before to after the practices.

EMIs Integrated into Self-help MBIs with Some Human Support

In Rauschenberg et al. (2021), help-seeking youth experiencing psychotic symptoms, depression, and/or anxiety (n = 10) underwent a three-week compassion-based EMI alongside treatment-as-usual. The EMI comprised weekly enhancing, daily consolidating, and momentary

interactive components delivered through an mHealth app, alongside psychologist-delivered human support elements. Enhancing components involved learning new compassion-focused practices, while consolidating components focused on reinforcing learned practices. The interactive component delivered EMA of negative emotions and thoughts seven times daily and prompted compassion-focused practices during heightened cognitive or emotional negativity. The use of momentary stress, negative affect, or threat anticipation as a tailoring variable is in line with the idea that delivering compassion-based practices in these moments can generate affiliative emotions and counteract negative self-referential processing, thus facilitating emotional regulation (Gilbert, 2009; Liu et al., 2023). Human support included 3-session, face-to-face psychoeducation and training on compassion-focused practices, guidance on app use, and addressing participant queries. Results indicated significant improvements in momentary negative emotions, thoughts, and overall psychological symptoms from baseline to post-intervention and at four-week follow-up.

In an RCT, Zainal and Newman (2023) examined the impact of a 14-day mindfulness-based EMI on generalized anxiety disorder. Participants (n = 110) were randomly assigned to either the EMI or a matched self-monitoring condition. In the EMI group, participants watched a video where a therapist provided psychoeducation and training on mindfulness practices. They also received prompts (i.e., text instructions) to support formal mindfulness practice and encourage informal mindfulness practice five times per day at pre-specified times over the 14-day period. The self-monitoring group watched a video where a therapist provided psychoeducation on monitoring thoughts and emotions, without emphasis on present-moment awareness and acceptance. They were prompted to engage in self-monitoring five times per day for 14 days. Results indicated significant improvements in generalized anxiety disorder symptom

severity, perseverative cognition, cognitive inhibition, and trait mindfulness in the EMI compared to the self-monitoring group from baseline to one-month follow-up. Additionally, the EMI group showed greater improvements in state anxiety, depression, and mindfulness immediately after receiving the prompts compared to the self-monitoring group.

EMIs Integrated into Self-help MBIs without Human Support

In an RCT (Everitt et al., 2021) involving adults wanting to improve their depressive symptoms (n = 235), participants were randomly assigned to three intervention groups (ImproveYourMood+, ImproveYourMood, MoodTracker) and a waitlist control. Over three weeks, intervention group participants filled out EMA of mood and contextual factors four times daily via an app. ImproveYourMood+ and ImproveYourMood offered in-app audio files with guided mindfulness and gratitude exercises for two weeks. ImproveYourMood+ additionally prompted reminders to use the audio files when EMA indicated elevated depression. These exercises were chosen based on the authors' pilot testing showing strongest immediate mood benefits. While the tailoring variable (i.e., elevated depression) was selected pragmatically, it aligns with the idea that mindfulness and gratitude practices may help disrupt negative thought patterns and support emotional regulation and mood improvement (Guendelman et al., 2017). ImproveYourMood+ and ImproveYourMood, except for MoodTracker, were found to significantly improve automatic negative thoughts compared to the waitlist control. Nevertheless, there were no significant differences in the effects among the three intervention groups. This study illustrated that the MB-EMI outperformed the waitlist control; however, the EMI component did not enhance the efficacy of self-monitoring plus on-demand, app-based mindfulness support.

Pavlacic et al. (2022) examined the efficacy of a low-dose mindfulness-based EMI. Undergraduate students (*n* = 161) were randomly assigned to either the EMI or a mood monitoring condition. Participants in the mood monitoring condition received a text message prompting them to complete measures of positive and negative affect, emotion dysregulation, and mindfulness at 5 pm each day over a period of 21 days. Participants in the EMI group received the same mood monitoring surveys daily, along with additional prompts. Specifically, they were instructed to read mindfulness psychoeducation texts on three days and to listen to or read body scan instructions on six days following completion of the daily surveys during the 21-day period. Results indicated that participants perceived the EMI as helpful for enhancing emotional awareness. However, the EMI group did not demonstrate greater improvements in daily positive and negative affect, emotion dysregulation, or mindfulness compared to the mood monitoring condition.

Summary of Characteristics and Findings of Example Studies

Existing MB-EMI studies exhibit variability in key dimensions, including the MBI with which the EMI is integrated and the characteristics of the EMI itself. MBIs included interventions delivered by meditation teachers or other mental health professionals (Garland et al., 2023; Spears, Abroms, et al., 2019), those primarily designed for self-help but with some guidance from meditation teachers or other mental health professionals (Rauschenberg et al., 2021; Zainal & Newman, 2023), and self-help MBIs without human support (Everitt et al., 2021; Pavlacic et al., 2022). Studies mainly focused on mindfulness-based interventions, with less research investigating compassion-based interventions (Rauschenberg et al., 2021).

Regarding the characteristics of EMIs, decision points were typically random or prespecified time points throughout the day and week (Everitt et al., 2021; Pavlacic et al., 2022;

Rauschenberg et al., 2021; Zainal & Newman, 2023). Intervention options included reminders (Everitt et al., 2021; Spears, Abroms, et al., 2019), text or audio instructions for meditation practice (Garland et al., 2023; Pavlacic et al., 2022; Zainal & Newman, 2023), and no interventions (Everitt et al., 2021; Garland et al., 2023; Rauschenberg et al., 2021). Some EMIs did not incorporate tailoring variables and decision rules (Pavlacic et al., 2022; Spears, Abroms, et al., 2019; Zainal & Newman, 2023), while others utilized momentary affective state or physiological indices to guide the delivery of interventions (Everitt et al., 2021; Garland et al., 2023; Rauschenberg et al., 2021). In terms of proximal outcomes, some EMIs focused on enhancing engagement in meditation practices (Garland et al., 2023; Pavlacic et al., 2022; Spears, Abroms, et al., 2019), while others emphasized improving momentary distress and mindfulness (Everitt et al., 2021; Rauschenberg et al., 2021; Zainal & Newman, 2023). EMIs aimed to improve a variety of distal outcomes, including negative outcomes such as smoking cessation, opioid craving, pain, and psychological distress (Everitt et al., 2021; Garland et al., 2023; Pavlacic et al., 2022; Spears, Abroms, et al., 2019; Zainal & Newman, 2023), and positive outcomes including emotional resilience, positive affect, and mindfulness (Garland et al., 2023; Pavlacic et al., 2022; Rauschenberg et al., 2021; Zainal & Newman, 2023).

Of note, despite the promise of EMIs to support informal practice that can be integrated seamlessly into daily activities, the EMIs we reviewed primarily aimed to support formal practice. That is, participants received prompts to engage in guided meditation, often accompanied by text or audio instructions. Among the six studies we reviewed, only Spears, Abroms, et al. (2019) and Zainal and Newman (2023) explicitly promoted informal practice. While strategies supporting formal practice may help increase its use, they do not fully capitalize on the opportunities for intervention in real-world contexts. Indeed, informal practice (e.g.,

pausing to notice bodily sensations right before a stressful meeting without formal guidance) can be particularly feasible and well-suited for supporting individuals in coping with stressors in daily life. Promoting informal practice in a context-sensitive way is critical for optimizing the accessibility and impact of MB-EMIs.

Some studies indicated participants' high engagement with and perceived usefulness of EMIs (Pavlacic et al., 2022; Spears, Abroms, et al., 2019). Moreover, MB-EMIs were found to improve momentary outcomes compared to control conditions, such as momentary craving, pain, psychological distress, positive affect, and mindfulness (Garland et al., 2023; Zainal & Newman, 2023). Nonetheless, evidence for the efficacy of MB-EMIs on pre-post and/or follow-up outcomes was mixed across different studies and control conditions. MB-EMIs were found to outperform waitlist control, self-monitoring, and supportive group psychotherapy in improving pre-post and/or follow-up outcomes (Everitt et al., 2021; Garland et al., 2023; Zainal & Newman, 2023). However, EMIs did not augment the effectiveness of self-monitoring plus on-demand, app-based mindfulness support and traditional MBIs on pre-post and/or follow-up outcomes (Everitt et al., 2021; Spears, Abroms, et al., 2019).

In summary, MB-EMIs have exhibited diverse features, representing varying degrees of accessibility and adaptation. Overall, participants have found these interventions to be engaging and useful. However, evidence for the efficacy of MB-EMIs has been mixed. It is important to highlight that most studies had small to moderate sample sizes, and several lacked a control condition. This can limit the capacity to draw conclusions about the overall efficacy of MB-EMIs.

The Moment is Now: Future Directions for MB-EMIs

MBIs have been widely applied in clinical practice as part of the third-wave cognitive behavioral therapy family. We think it is very likely that MB-EMIs will become increasingly common in the coming years and have the potential to positively impact mental health practice. Just as digital technology has incredible potential to produce negative momentary effects (e.g., increasing distraction, negative affect; Bennett et al., 2020; Siebers et al., 2022), these same technologies have the potential to produce positive momentary effects (e.g., increasing health promoting behaviors; Fiedler et al., 2023). We believe the positive momentary effects of digital technology can be harnessed to support MBIs. Here we discuss several specific future directions for addressing the limitations of previous MB-EMI studies and further advancing work in this area. In Table 2, we provide a summary of the key future research directions for MB-EMIs.

A key scientific question that in our view has not been definitively answered by previous studies is whether or not EMI components indeed make MBIs more accessible, acceptable, and efficacious. Answering this will require RCTs that directly compare MBIs with and without an EMI component on measures of accessibility, acceptability, and efficacy. The studies reviewed showed that EMIs did not augment the effectiveness of self-monitoring plus on-demand, app-based mindfulness support or traditional meditation-based interventions on pre-post and/or follow-up outcomes (Everitt et al., 2021; Spears, Abroms, et al., 2019). However, these studies did not investigate accessibility and acceptability specifically and were characterized by small sample sizes per study arm (Everitt et al., 2021; Spears, Abroms, et al., 2019). Future studies will ideally include larger sample sizes and assess the impact of EMI features on the accessibility and acceptability of MBIs. Ultimately, a key test of MB-EMIs will be comparisons between MB-EMIs that do not rely on human support with traditional MBIs (e.g., in non-inferiority trials).

RCTs testing MB-EMIs should examine effects on both proximal outcomes (e.g., momentary psychological distress or meditation practice) as well as distal outcomes (e.g., pre-post changes in psychological distress). Both types of assessment provide important and complementary information. In theory, an EMI may fail to impact a proximal outcome (e.g., show no effect on the likelihood of engagement in formal meditation practice) but may still impact a distal outcome (e.g., produce larger pre-post reductions in psychological distress) in a way that would still recommend its use. This scenario may be plausible whenever the proximal outcome being measured is not capturing the underlying mechanism through which an EMI impacts a distal outcome. Extending the example above, it may be that an MB-EMI produces larger pre-post reductions in psychological distress (the distal outcome) relative to a comparison MBI that does not include an EMI component, even if the MB-EMI does not produce greater engagement in formal meditation practice (the proximal outcome). It may be that it is actually informal practice (i.e., integrating meditative techniques in daily activities; Kabat-Zinn, 1994; Segal et al., 2013) that is differentially impacted by the MB-EMI and that accounts for pre-post reductions in psychological distress.

Similarly, an EMI may impact a meaningful proximal outcome (e.g., state loneliness) but not a distal outcome (e.g., pre-post reductions in loneliness; Lindsay et al., 2019). Indeed, the studies we reviewed showed that MB-EMIs improved momentary outcomes such as momentary craving, pain, psychological distress, positive affect, and mindfulness compared to control conditions (Garland et al., 2023; Zainal & Newman, 2023). However, evidence for the efficacy of MB-EMIs on pre-post and/or follow-up outcomes was mixed across different studies and control conditions. Given momentary and retrospective assessments may assess somewhat different constructs (Shiffman et al., 2008) and interventions can impact one but not the other

(e.g., Lindsay et al., 2019), an MB-EMI may still be recommended even if it does not differ from a non-EMI MBI on distal outcomes. Ideally, future RCTs testing MB-EMIs are adequately powered to detect not only small between-group differences but also to allow evaluation of between-person factors that may predict response to either the traditional MBI or the MB-EMI (i.e., determine for whom MB-EMIs may be more or less effective; Webb et al., 2022).

Innovations in passive data collection may result in highly customized, low-burden MB-EMIs. One non-MBI example is the Addiction-Comprehensive Health Enhancement Support System (A-CHESS) smartphone app (Gustafson et al., 2014). The A-CHESS app uses passive collection of geolocations to determine if a user is near a high-risk location (e.g., a bar they previously frequented). When the risk is determined to be high, the app delivers an EMI, initiating an alert asking whether the user wants to be there. There is a wide variety of data streams that MB-EMIs could use as inputs to guide intervention delivery. This could include wearable sensors, along with various digital inputs captured through smartphones and other devices, such as audio and visual data, text from email and other messaging platforms. Among the studies we reviewed, Garland et al. (2023) exemplified this approach by leveraging heart rate variability measured via wearable sensors to tailor the delivery of mindfulness practices. However, all other studies we reviewed either relied exclusively on subjective self-report data or did not use momentary data to guide intervention delivery, highlighting the need for incorporating passive data collection into future MB-EMIs. In addition to heart rate variability used by Garland et al. (2023), other potential approaches future studies may explore include prompting individuals to engage in mindful walking when walking is detected through the Global Positioning System (GPS), or encouraging intentional feelings of loving-kindness and compassion when their use of social media to interact with others is identified. Incorporating

passive data collection into MB-EMIs enables real-time, context-driven personalization of interventions without increasing user burden, potentially enhancing both engagement and effectiveness.

As intervention development continues, it will likely be increasingly important to gather information from target users regarding their experience of the MB-EMIs to determine whether the features are in fact desirable to users. Among the studies we reviewed, Spears, Abroms, et al. (2019) evaluated participants' engagement with the EMI messages according to the percentage of participants reading messages and responding to interactive messages. While EMIs may sound attractive in theory, some EMI features such as repetitive reminders lacking variability and overly frequent reminders may diminish responsiveness to reminders (Almourad et al., 2021; Muench & Baumel, 2017). This may ultimately lead to reduced engagement in and discontinuation of interventions.

If MB-EMIs are indeed going to achieve their potential to increase the accessibility of MBIs, it will be important to continue developing them for and with members of underserved populations. Rigorous work at this intersection has already begun. For example, among the studies reviewed, Spears, Bell, et al. (2019) designed and tested an EMI focused on mindfulness for smoking cessation for African Americans with low socioeconomic status, guided by input from the target population. Nonetheless, many other underserved populations (e.g., individuals with high caregiving burden, gender and sexual minorities) were not specifically investigated in the MB-EMI studies we reviewed. Given their heightened burden and/or minority stress, these populations may especially benefit from the in-the-moment support that tailored MB-EMIs can offer in daily life. Continuous efforts like Spears, Bell, et al. (2019) are crucial for maximizing the accessibility and equity of MBIs. Community-based participatory approaches involve

community members throughout the whole research process such as research design and intervention development and implementation (Wallerstein & Duran, 2010). Community-based participatory approaches are characterized by centering the voices of community members and an equal partnership between researchers and participants (Wallerstein & Duran, 2010). However, no studies we reviewed incorporated community-based participatory approaches into the design and study of MB-EMIs. Future studies utilizing such approaches have the potential to enhance the cultural sensitivity, feasibility, acceptability, and sustainability of MB-EMIs.

It will also be essential to continually evaluate the safety of MB-EMIs and take seriously concerns regarding the unauthorized access to health information and potential breaches and misuse of passively collected health data (Bhuyan et al., 2017; Tangari et al., 2021). As technology becomes increasingly embedded into society and algorithms for harnessing passive data become increasingly powerful (OpenAI, 2024), the risk for misuse will only grow. Moreover, few of the studies we reviewed have evaluated the potential adverse effects of MB-EMIs (see exception; Rauschenberg et al., 2021). This is in line with the observation of a recent meta-analysis, which found that only one in three clinical trials on mental health apps reported adverse events (Linardon et al., 2024). Therefore, it will be important for MB-EMI developers to be transparent about what data are being collected, how and why these data are being used, and the potential adverse effects of interventions (Linardon et al., 2024; Xie & Chen, 2025). It is also important for MB-EMIs to have strong security measures in place to protect the privacy of users. This may include measures such as encryption (i.e., encoding data into a format that is unreadable without the proper decryption key), access control (i.e., only allowing authorized individuals or systems to access specific data), secure login, and user authentication (Martínez-Pérez et al., 2014).

MB-EMIs may emphasize informal meditation practice given its potential to enhance the accessibility of MBIs and impact on individuals' day-to-day coping. Informal meditation practice can be seamlessly incorporated into daily life without formal guidance (Kabat-Zinn, 1990; Segal et al., 2013). Compared to formal meditation practice, informal meditation practice may be less time-intensive and more readily applicable in daily life. Notably, the MB-EMIs we reviewed were primarily designed to enhance formal practice rather than cultivating informal practice during individuals' daily activities. This may limit the accessibility and impact of MB-EMIs and represents a key limitation of the current literature. Promoting context-sensitive informal practice has the potential to be a paradigm-shifting innovation in the field. Although far less frequently studied than formal practice, existing research has underscored the positive outcomes associated with informal meditation practice within MBIs (Xie, Riordan, et al., 2024). Qualitative research suggests that EMIs (e.g., reminders) hold the potential to boost engagement in informal meditation practice (Xie, Dyer, et al., 2024). Future studies on MB-EMIs may investigate different strategies for promoting engagement in informal meditation practice to bolster the accessibility and impact of MBIs. Of note, in this paper, we intentionally excluded EMIs solely promoting informal meditation practice without formal instruction in meditation to avoid an overly broad definition of MB-EMIs. However, considering the high accessibility and low burden associated with informal meditation practice, it may be worthwhile to explore EMIs focusing exclusively on informal meditation practice even without formal meditation instruction.

Conclusion

There is no doubt that digital technology has and will continue to impact modern society in profound and previously unimaginable ways. We believe the contemplative traditions provide a nuanced understanding of the human mind and a rich set of techniques for training capacities

that have the potential to promote individual and human wellbeing and shape mental health practice. MB-EMIs that integrate momentary interventions into MBIs may therefore harness the benefits of MBIs and play an important role in increasing the accessibility and impact of MBIs. While this paper does not follow a systematic or scoping review format, which we acknowledge as a limitation that may affect the breadth of included studies, our intention is to make a conceptual contribution in a nascent area of research. As the literature on MB-EMIs expands, future reviews and meta-analyses examining their efficacy and potential moderators will be essential to map the full landscape of interventions and related outcomes.

References

Almourad, M. B., Alrobai, A., Skinner, T., Hussain, M., & Ali, R. (2021). Digital wellbeing tools through users lens. *Technology in Society*, *67*, 101778. https://doi.org/10.1016/j.techsoc.2021.101778

Bennett, B. L., Whisenhunt, B. L., Hudson, D. L., Wagner, A. F., Latner, J. D., Stefano, E. C., & Beauchamp, M. T. (2020). Examining the impact of social media on mood and body dissatisfaction using ecological momentary assessment. *Journal of American College Health*, *68*(5), 502–508. https://doi.org/10.1080/07448481.2019.1583236

Bhuyan, S. S., Kim, H., Isehunwa, O. O., Kumar, N., Bhatt, J., Wyant, D. K., Kedia, S., Chang, C. F., & Dasgupta, D. (2017). Privacy and security issues in mobile health: Current research and future directions. *Health Policy and Technology*, *6*(2), 188–191. https://doi.org/10.1016/j.hlpt.2017.01.004

Burnett, K. F., Taylor, C. B., & Agras, W. S. (1985). Ambulatory computer-assisted therapy for obesity: A new frontier for behavior therapy. *Journal of Consulting and Clinical Psychology*, *53*(5), 698–703. https://doi.org/10.1037/0022-006X.53.5.698

Camacho, E., Cohen, A., & Torous, J. (2022). Assessment of Mental Health Services Available Through Smartphone Apps. *JAMA Network Open*, *5*(12), e2248784. https://doi.org/10.1001/jamanetworkopen.2022.48784

Carter, B. L., Day, S. X., Cinciripini, P. M., & Wetter, D. W. (2007). Momentary health interventions: Where are we and where are we going. In *The Science of Real-Time Data Capture: Self-Reports in Health Reasearch* (pp. 289–307). Oxford University Press.

Christodoulou, G., Salami, N., & Black, D. S. (2020). The Utility of Heart Rate Variability in Mindfulness Research. *Mindfulness*, *11*(3), 554–570. https://doi.org/10.1007/s12671-019-01296-3

Crane, R. S., Brewer, J., Feldman, C., Kabat-Zinn, J., Santorelli, S., Williams, J. M. G., & Kuyken, W. (2017). What defines mindfulness-based programs? The warp and the weft. *Psychological Medicine*, *47*(6), 990–999. https://doi.org/10.1017/S0033291716003317

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences*, *19*(9), 515–523. https://doi.org/10.1016/j.tics.2015.07.001

Depp, C. A., Ceglowski, J., Wang, V. C., Yaghouti, F., Mausbach, B. T., Thompson, W. K., & Granholm, E. L. (2015). Augmenting psychoeducation with a mobile intervention for bipolar disorder: A randomized controlled trial. *Journal of Affective Disorders*, *174*, 23–30. https://doi.org/10.1016/j.jad.2014.10.053

Dutcher, J. M., Cole, S. W., Williams, A. C., & Creswell, J. D. (2022). Smartphone mindfulness meditation training reduces Pro-inflammatory gene expression in stressed adults: A randomized controlled trial. *Brain, Behavior, and Immunity*, *103*, 171–177. https://doi.org/10.1016/j.bbi.2022.04.003

Dyer, R. L., Zimmerman, K. M., Zhao, X., Xie, Q., Dahl, C. J., Quanbeck, A., & Goldberg, S. B. (2025). Developing meditation practice in individuals with elevated psychological distress via a meditation app intervention: An implementation science–informed qualitative investigation of barriers and facilitators. *Psychological Services*. https://doi.org/10.1037/ser0000980

Eghdami, S., Ahmadkhaniha, H. R., Baradaran, H. R., & Hirbod-Mobarakeh, A. (2023). Ecological momentary interventions for smoking cessation: A systematic review and meta-analysis. *Social Psychiatry and Psychiatric Epidemiology*. https://doi.org/10.1007/s00127-023-02503-2

Everitt, N., Broadbent, J., Richardson, B., Smyth, J. M., Heron, K., Teague, S., & Fuller-Tyszkiewicz, M. (2021). Exploring the features of an app-based just-in-time intervention for depression. *Journal of Affective Disorders*, *291*, 279–287. https://doi.org/10.1016/j.jad.2021.05.021

Fiedler, J., Seiferth, C., Eckert, T., Woll, A., & Wunsch, K. (2023). A just-in-time adaptive intervention to enhance physical activity in the SMARTFAMILY2.0 trial. *Sport, Exercise, and Performance Psychology*, *12*(1), 43–57. https://doi.org/10.1037/spy0000311

Fissler, M., Winnebeck, E., Schroeter, T., Gummersbach, M., Huntenburg, J. M., Gaertner, M., & Barnhofer, T. (2016). An Investigation of the Effects of Brief Mindfulness Training on Self-Reported Interoceptive Awareness, the Ability to Decenter, and Their Role in the Reduction of Depressive Symptoms. *Mindfulness*, *7*(5), 1170–1181. https://doi.org/10.1007/s12671-016-0559-z

Gál, É., Ștefan, S., & Cristea, I. A. (2021). The efficacy of mindfulness meditation apps in enhancing users' well-being and mental health related outcomes: A meta-analysis of randomized controlled trials. *Journal of Affective Disorders*, *279*, 131–142. https://doi.org/10.1016/j.jad.2020.09.134

Galante, J., Galante, I., Bekkers, M.-J., & Gallacher, J. (2014). Effect of kindness-based meditation on health and well-being: A systematic review and meta-analysis. *Journal of Consulting and Clinical Psychology*, *82*, 1101–1114. https://doi.org/10.1037/a0037249

Garland, E. L., Gullapalli, B. T., Prince, K. C., Hanley, A. W., Sanyer, M., Tuomenoksa, M., & Rahman, T. (2023). Zoom-Based Mindfulness-Oriented Recovery Enhancement Plus Just-in-Time Mindfulness Practice Triggered by Wearable Sensors for Opioid Craving and Chronic Pain. *Mindfulness*, *14*(6), 1329–1345. https://doi.org/10.1007/s12671-023-02137-0

Gethin, R. (1998). *The foundations of Buddhism*. Oxford University Press.

Gilbert, P. (2009). Introducing compassion-focused therapy. *Advances in Psychiatric Treatment*, *15*(3), 199–208. https://doi.org/10.1192/apt.bp.107.005264

Goldberg, S. B., Imhoff-Smith, T., Bolt, D. M., Wilson-Mendenhall, C. D., Dahl, C. J., Davidson, R. J., & Rosenkranz, M. A. (2020). Testing the Efficacy of a Multicomponent, Self-Guided, Smartphone-Based Meditation App: Three-Armed Randomized Controlled Trial. *JMIR Mental Health*, *7*(11), e23825. https://doi.org/10.2196/23825

Goldberg, S. B., Lam, S. U., Simonsson, O., Torous, J., & Sun, S. (2022). Mobile phone-based interventions for mental health: A systematic meta-review of 14 meta-analyses of randomized controlled trials. *PLOS Digital Health*, *1*(1), e0000002. https://doi.org/10.1371/journal.pdig.0000002

Goldberg, S. B., Riordan, K. M., Sun, S., & Davidson, R. J. (2022). The Empirical Status of Mindfulness-Based Interventions: A Systematic Review of 44 Meta-Analyses of Randomized Controlled Trials. *Perspectives on Psychological Science*, *17*(1), 108–130. https://doi.org/10.1177/1745691620968771

Goldstein, J. (2013). *Mindfulness: A practical guide to awakening*. Sounds True.

Guendelman, S., Medeiros, S., & Rampes, H. (2017). Mindfulness and Emotion Regulation: Insights from Neurobiological, Psychological, and Clinical Studies. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00220

Gustafson, D. H., McTavish, F. M., Chih, M.-Y., Atwood, A. K., Johnson, R. A., Boyle, M. G., Levy, M. S., Driscoll, H., Chisholm, S. M., Dillenburg, L., Isham, A., & Shah, D. (2014). A Smartphone Application to Support Recovery From Alcoholism: A Randomized Clinical Trial. *JAMA Psychiatry*, *71*(5), 566–572. https://doi.org/10.1001/jamapsychiatry.2013.4642

Hayes, S. C., Luoma, J. B., Bond, F. W., Masuda, A., & Lillis, J. (2006). Acceptance and Commitment Therapy: Model, processes and outcomes. *Behaviour Research and Therapy*, *44*(1), 1–25. https://doi.org/10.1016/j.brat.2005.06.006

Henshaw, E. J., & Freedman-Doan, C. R. (2009). Conceptualizing mental health care utilization using the health belief model. *Clinical Psychology: Science and Practice*, *16*, 420–439. https://doi.org/10.1111/j.1468-2850.2009.01181.x

Heron, K. E., & Smyth, J. M. (2010). Ecological momentary interventions: Incorporating mobile technology into psychosocial and health behaviour treatments. *British Journal of Health Psychology*, *15*(1), 1–39. https://doi.org/10.1348/135910709X466063

Kabat-Zinn, J. (1990). *Full Catastrophe Living: Using the Wisdom of Your Body and Mind to Face Stress, Pain, and Illness*. Delacorte Press.

Kabat-Zinn, J. (1994). *Wherever you go, there you are: Mindfulness meditation in everyday life*. Hyperion.

Lam, S. U., Xie, Q., & Goldberg, S. B. (2023). Situating Meditation Apps Within the Ecosystem of Meditation Practice: Population-Based Survey Study. *JMIR Mental Health*, *10*(1), e43565. https://doi.org/10.2196/43565

Linardon, J., Fuller-Tyszkiewicz, M., Firth, J., Goldberg, S. B., Anderson, C., McClure, Z., & Torous, J. (2024). Systematic review and meta-analysis of adverse events in clinical trials of mental health apps. *Npj Digital Medicine*, *7*(1), 1–22. https://doi.org/10.1038/s41746-024-01388-y

Lindsay, E. K., Young, S., Brown, K. W., Smyth, J. M., & Creswell, J. D. (2019). Mindfulness training reduces loneliness and increases social contact in a randomized controlled trial. *Proceedings of the National Academy of Sciences*, *116*(9), 3488–3493. https://doi.org/10.1073/pnas.1813588116

Liu, G., Santana-Gonzalez, C., Zeffiro, T. A., Zhang, N., Engstrom, M., & Quevedo, K. (2023). Self-compassion and neural activity during self-appraisals in depressed and healthy adolescents. *Journal of Affective Disorders*, *339*, 717–724. https://doi.org/10.1016/j.jad.2023.07.012

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences*, *12*(4), 163–169. https://doi.org/10.1016/j.tics.2008.01.005

Martínez-Pérez, B., de la Torre-Díez, I., & López-Coronado, M. (2014). Privacy and Security in Mobile Health Apps: A Review and Recommendations. *Journal of Medical Systems*, *39*(1), 181. https://doi.org/10.1007/s10916-014-0181-3

Matko, K., & Sedlmeier, P. (2019). What Is Meditation? Proposing an Empirically Derived Classification System. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02276

Mohr, D. C., Zhang, M., & Schueller, S. M. (2017). Personal Sensing: Understanding Mental Health Using Ubiquitous Sensors and Machine Learning. *Annual Review of Clinical Psychology*, *13*, 23–47. https://doi.org/10.1146/annurev-clinpsy-032816-044949

Muench, F., & Baumel, A. (2017). More Than a Text Message: Dismantling Digital Triggers to Curate Behavior Change in Patient-Centered Health Interventions. *Journal of Medical Internet Research*, *19*(5), e7463. https://doi.org/10.2196/jmir.7463

Nahin, R. L., Rhee, A., & Stussman, B. (2024). Use of Complementary Health Approaches Overall and for Pain Management by US Adults. *JAMA*. https://doi.org/10.1001/jama.2023.26775

Nahum-Shani, I., Hekler, E. B., & Spruijt-Metz, D. (2015). Building health behavior models to guide the development of just-in-time adaptive interventions: A pragmatic framework. *Health Psychology*, *34*, 1209–1219. https://doi.org/10.1037/hea0000306

Nahum-Shani, I., Shaw, S. D., Carpenter, S. M., Murphy, S. A., & Yoon, C. (2022). Engagement in Digital Interventions. *American Psychologist*, *77*(7), 836–852. https://doi.org/10.1037/amp0000983

Nahum-Shani, I., Smith, S. N., Spring, B. J., Collins, L. M., Witkiewitz, K., Tewari, A., & Murphy, S. A. (2018). Just-in-Time Adaptive Interventions (JITAIs) in Mobile Health:

Key Components and Design Principles for Ongoing Health Behavior Support. *Annals of Behavioral Medicine*, *52*(6), 446–462. https://doi.org/10.1007/s12160-016-9830-8

Nanamoli, B., & Bodhi, B. (2015). *The middle length discourses of the Buddha: A new translation of the Majjhima Nikaya*. Wisdom.

Nathalie Lyzwinski, L., Caffery, L., Bambling, M., & Edirippulige, S. (2018). University Students' Perspectives on Mindfulness and mHealth: A Qualitative Exploratory Study. *American Journal of Health Education*, *49*(6), 341–353. https://doi.org/10.1080/19325037.2018.1502701

Neff, K. D., & Germer, C. K. (2013). A Pilot Study and Randomized Controlled Trial of the Mindful Self-Compassion Program. *Journal of Clinical Psychology*, *69*(1), 28–44. https://doi.org/10.1002/jclp.21923

Newman, M. G., Przeworski, A., Consoli, A. J., & Taylor, C. B. (2014). A randomized controlled trial of ecological momentary intervention plus brief group therapy for generalized anxiety disorder. *Psychotherapy*, *51*, 198–206. https://doi.org/10.1037/a0032519

OpenAI. (2024). *ChatGPT* [Computer software]. https://openai.com/chatgpt

Pavlacic, J. M., Hampton, B. N., Young, J., Witcraft, S. M., Flores, C. M. N., Vázquez, A. L., & Rheingold, A. A. (2024). Systematic Review of Mindfulness-Based Ecological Momentary Interventions: Synthesizing Current Methods and Identifying Directions for Future Research. *Journal of Technology in Behavioral Science*. https://doi.org/10.1007/s41347-024-00416-8

Pavlacic, J. M., Schulenberg, S. E., Witcraft, S. M., & Buchanan, E. M. (2022). Assessing the Effectiveness and Utility of a Mindfulness-Based Ecological Momentary Intervention in

College Students. *Journal of Technology in Behavioral Science*, *7*(4), 554–566. https://doi.org/10.1007/s41347-022-00274-2

Rahula, W. (1974). *What the Buddha taught (2nd ed.)*. Grove Press.

Rauschenberg, C., Boecking, B., Paetzold, I., Schruers, K., Schick, A., Amelsvoort, T. van, & Reininghaus, U. (2021). A Compassion-Focused Ecological Momentary Intervention for Enhancing Resilience in Help-Seeking Youth: Uncontrolled Pilot Study. *JMIR Mental Health*, *8*(8), e25650. https://doi.org/10.2196/25650

Sayadaw, M. (2016). *Manual of Insight*. Wisdom Publications. https://www.simonandschuster.com/books/Manual-of-Insight/Mahasi-Sayadaw/9781614292777

Schueller, S. M., Aguilera, A., & Mohr, D. C. (2017). Ecological momentary interventions for depression and anxiety. *Depression and Anxiety*, *34*(6), 540–545. https://doi.org/10.1002/da.22649

Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2013). *Mindfulness-based cognitive therapy for depression* (2nd ed.). The Guilford Press.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological Momentary Assessment. *Annual Review of Clinical Psychology*, *4*(1), 1–32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415

Shonin, E., Van Gordon, W., Compare, A., Zangeneh, M., & Griffiths, M. D. (2015). Buddhist-Derived Loving-Kindness and Compassion Meditation for the Treatment of Psychopathology: A Systematic Review. *Mindfulness*, *6*(5), 1161–1180. https://doi.org/10.1007/s12671-014-0368-1

Siebers, T., Beyens, I., Pouwels, J. L., & Valkenburg, P. M. (2022). Social Media and Distraction: An Experience Sampling Study among Adolescents. *Media Psychology*, *25*(3), 343–366. https://doi.org/10.1080/15213269.2021.1959350

Spears, C. A., Abroms, L. C., Glass, C. R., Hedeker, D., Eriksen, M. P., Cottrell-Daniels, C., Tran, B. Q., & Wetter, D. W. (2019). Mindfulness-Based Smoking Cessation Enhanced With Mobile Technology (iQuit Mindfully): Pilot Randomized Controlled Trial. *JMIR mHealth and uHealth*, *7*(6), e13059. https://doi.org/10.2196/13059

Spears, C. A., Bell, S. A., Scarlett, C. A., Anderson, N. K., Cottrell-Daniels, C., Lotfalian, S., Bandlamudi, M., Grant, A., Sigurdardottir, A., Carter, B. P., Abroms, L. C., & Wetter, D. W. (2019). Text Messaging to Enhance Mindfulness-Based Smoking Cessation Treatment: Program Development Through Qualitative Research. *JMIR mHealth and uHealth*, *7*(1), e11246. https://doi.org/10.2196/11246

Spears, C. A., Houchins, S. C., Bamatter, W. P., Barrueco, S., Hoover, D. S., & Perskaudas, R. (2017). Perceptions of Mindfulness in a Low-Income, Primarily African American Treatment-Seeking Sample. *Mindfulness*, *8*(6), 1532–1543. https://doi.org/10.1007/s12671-017-0720-3

Tangari, G., Ikram, M., Ijaz, K., Kaafar, M. A., & Berkovsky, S. (2021). Mobile health and privacy: Cross sectional study. *BMJ*, *373*, n1248. https://doi.org/10.1136/bmj.n1248

UMass Memorial Medical Center. (n.d.). *MBSR or MBCT: Tuition and Payment*. Retrieved October 29, 2022, from https://www.ummhealth.org/umass-memorial-medical-center/services-treatments/center-for-mindfulness/mindfulness-programs/mbsr-or-mbct-tuition-and-payment

Versluis, A., Verkuil, B., Spinhoven, P., Ploeg, M. M. van der, & Brosschot, J. F. (2016). Changing Mental Health and Positive Psychological Well-Being Using Ecological Momentary Interventions: A Systematic Review and Meta-analysis. *Journal of Medical Internet Research*, *18*(6), e5642. https://doi.org/10.2196/jmir.5642

Wallerstein, N., & Duran, B. (2010). Community-Based Participatory Research Contributions to Intervention Research: The Intersection of Science and Practice to Improve Health Equity. *American Journal of Public Health*, *100*(Suppl 1), S40–S46. https://doi.org/10.2105/AJPH.2009.184036

Wang, L., & Miller, L. C. (2020). Just-in-the-Moment Adaptive Interventions (JITAI): A Meta-Analytical Review. *Health Communication*, *35*(12), 1531–1544. https://doi.org/10.1080/10410236.2019.1652388

Wasil, A. R., Gillespie, S., Patel, R., Petre, A., Venturo-Conerly, K. E., Shingleton, R. M., Weisz, J. R., & DeRubeis, R. J. (2020). Reassessing evidence-based content in popular smartphone apps for depression and anxiety: Developing and applying user-adjusted analyses. *Journal of Consulting and Clinical Psychology*, *88*(11), 983–993. https://doi.org/10.1037/ccp0000604

Webb, C. A., Hirshberg, M. J., Davidson, R. J., & Goldberg, S. B. (2022). Personalized Prediction of Response to Smartphone-Delivered Meditation Training: Randomized Controlled Trial. *Journal of Medical Internet Research*, *24*(11), e41566. https://doi.org/10.2196/41566

Weisel, K. K., Fuhrmann, L. M., Berking, M., Baumeister, H., Cuijpers, P., & Ebert, D. D. (2019). Standalone smartphone apps for mental health—A systematic review and meta-

analysis. *Npj Digital Medicine*, *2*(1), Article 1. https://doi.org/10.1038/s41746-019-0188-8

Xie, Q., & Chen, W. (2025). Enhancing the Scalability and Impact of the Motherly App for Postnatal Depression. *Psychotherapy and Psychosomatics*. https://doi.org/10.1159/000543542

Xie, Q., Dyer, R. L., Lam, S. U., Frye, C., Dahl, C. J., Quanbeck, A., Nahum-Shani, I., Davidson, R. J., & Goldberg, S. B. (2024). Understanding the Implementation of Informal Meditation Practice in a Smartphone-Based Intervention: A Qualitative Analysis. *Mindfulness*, *15*(2), 479–490. https://doi.org/10.1007/s12671-024-02304-x

Xie, Q., Riordan, K. M., Baldwin, S. A., Simonsson, O., Hirshberg, M. J., Dahl, C. J., Nahum-Shani, I., Davidson, R. J., & Goldberg, S. B. (2024). Is informal practice associated with outcomes in loving-kindness and compassion training? Evidence from pre-post and daily diary assessments. *Behaviour Research and Therapy*, *177*, 104537. https://doi.org/10.1016/j.brat.2024.104537

Zainal, N. H., & Newman, M. G. (2023). A randomized controlled trial of a 14-day mindfulness ecological momentary intervention (MEMI) for generalized anxiety disorder. *European Psychiatry*, *66*(1), e12. https://doi.org/10.1192/j.eurpsy.2023.2

Zautra, A. J., Davis, M. C., Reich, J. W., Sturgeon, J. A., Arewasikporn, A., & Tennen, H. (2012). Phone-based interventions with automated mindfulness and mastery messages improve the daily functioning for depressed middle-aged community residents. *Journal of Psychotherapy Integration*, *22*(3), 206–228. https://doi.org/10.1037/a0029573

Table 1. Features of MB-EMI Examples

Study	MBI	Decision points	Intervention options	Tailoring variables	Decision rules	Proximal outcome	Distal outcome
Spears, Abroms, et al. (2019)	Mindfulness-Based Addiction Treatment	Unclear	Reminders for mindfulness practices	None	None	Engagement in mindfulness practices	Smoking cessation
Garland et al. (2023)	Mindfulness-Oriented Recovery Enhancement	Unclear	Audio-guided mindfulness practices OR no practice	Physiological stress	If presence of physiological stress is detected Then IO = prompting mindfulness practices Else IO = providing nothing	Engagement in mindfulness practices	Opioid craving, pain, positive affect
Rauschenberg et al. (2021)	Self-help compassion intervention plus psychologist guidance	Random prompts within set blocks of time	Prompting compassion practices OR no practices	Momentary stress, negative affect, or threat anticipation	If momentary stress, negative affect, or threat anticipation > threshold Then, IO = prompting compassion practices Else IO = providing nothing	Momentary stress sensitivity and threat anticipation	Emotional resilience to stress
Zainal and Newman (2023)	Self-help mindfulness intervention plus therapist guidance	Specific times of day (about 9am, noon, 3pm, 6pm, and 9pm)	Text instructions to engage in mindfulness practices	None	None	State anxiety, depression, and mindfulness	GAD severity, perseverative cognition, cognitive inhibition, trait mindfulness
Everitt et al. (2021)	Self-help mindfulness and gratitude intervention	Random prompts between 9am and 9pm	Reminders to use the audio files OR no reminders	Momentary depressive mood	If momentary depressive mood ≥ threshold Then, IO = reminder to use audio files Else IO = providing nothing	Momentary depressive mood	Depressive and anxiety symptoms, negative automatic thoughts

Pavlacic et al. (2022)	Self-help mindfulness intervention	Specific time of day (5pm) and days of week	Prompting audio- or written-format mindfulness practice	None	None	Engagement in mindfulness practice	Daily negative affect, emotion dysregulation, positive affect, and mindfulness

Note. MBI = Meditation-based intervention, IO = Intervention options, GAD = generalized anxiety disorder. The components of just-in-time adaptive interventions (i.e., decision points, intervention options, tailoring variables, decision rules, proximal outcomes, and distal outcomes; Nahum-Shani et al., 2018) are used to describe features of ecological momentary interventions. As can be seen in the table, some ecological momentary interventions did not include certain components of just-in-time adaptive interventions, such as tailoring variables and decision rules.

Table 2. Recommendations for Future Research

Scientific Question	Recommended Approach
Do EMI components indeed make MBIs more accessible, acceptable, and efficacious?	1. Conducting well-powered RCTs that compare MBIs with and without an EMI component 2. Comparing MB-EMIs that do not rely on human support with traditional MBIs 3. Evaluating effects of MB-EMIs on both proximal and distal outcomes
How can we increase personalization, reduce user burden, and enhance user-friendliness of MB-EMIs?	1. Leveraging innovations in passive data collection to support personalization 2. Gathering information from target users regarding their experience of MB-EMIs 3. Investigating novel strategies for promoting engagement in informal meditation practice
How can we ensure health equity in the development of MB-EMIs?	1. Developing MB-EMIs for and with members of underserved populations by leveraging input from them

How can we improve the safety of MB-EMIs?	1. Being transparent about what data are being collected, how and why these data are being used, and potential adverse effects of interventions 2. Having strong security measures in place to protect the privacy of MB-EMI users

Note. EMI = ecological momentary intervention, MBIs = meditation-based interventions, MB-EMIs = meditation-based ecological momentary interventions, RCTs = randomized controlled trials.