Challenges and Opportunities for Designing Technology-Based Ecological Momentary Interventions (EMIs) in Mental Health

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Abstract. Ecological momentary interventions (EMIs) are treatments that are provided to patients during their daily lives and in natural settings. These types of interventions are often used to improve self-management of health. Technologies such as smartphones can facilitate delivering EMIs thanks to their ubiquity. EMIs represent a novel approach for the delivery of psychological support to mental health disorders patients in daily life. In this work, we discuss current and emerging technologies and discuss the challenges associated to use them to deliver EMIs in mental health care. We focus on challenges and opportunities regarding information content and delivery in EMIs that can serve as potential avenues for future research in mental health and EMIs.

Keywords: Ecological momentary intervention (EMI) · Mental health · Technologies

1 Introduction

Ecological Momentary Interventions (EMIs) are treatments that are provided to patients during their daily lives and in natural settings [1]. Closely related to EMIs are the more popular concepts of Ecological Momentary Assessments (EMAs) or Experience Sampling Methods (ESMs), which are often used in combination with the former. EMAs and the ESMs are sampling methodologies of behaviors and experiences of subjects in real time, also in their natural environments [2]. In a way, we could say that EMAs and ESMs focus on measuring behaviors and experiences while EMI are aimed at changing them. The way and time in which the user is notified of the need to provide information is essential in EMA/ESM as it is also the case in which information is delivered via an EMI [3].

EMIs are frequently used to improve self-management of health as they can provide interventions in people's daily lives using mobile devices [4]. Based on the individual condition, interventions can be tailored to support self-management of illness and their role within the community. The times, forms, and content of the interventions can vary

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in many ways, since they are often administered randomly, predetermined, or based on events [5]. Event-based interventions are usually administered when the user interacts with a previously established location, situation, or event. For example, in [6] they used the "geofencing" technique to complement the interventions and provide greater support to children with anxiety disorder resulting in a significant decrease in anxiety-related symptoms. This type of intervention may be well suited to health-related behavior change since it involves tracking and responding to behaviors that might be missed or left unattended, especially when the user is in the wild [7].

Recent advances in EMIs research have focused on more conventional approaches to deliver interventions (e.g., smartphones). However, other emerging technologies such as virtual or augmented reality could prove challenging in many ways. Typically, there have been reported three types of notifications for EMIs for the request or delivery of information based on timeliness: at random times during the day, those that are presented during a predetermined calendar or time, and finally, those that are presented through the interaction of a predetermined event (i.e., unlock the phone) [8]. In [9] these three types of information requests were analyzed through a study with 20 participants who were asked to answer questions at different times (random, predetermined, or event-based). It was found that information requests based on the interaction with a predetermined event (i.e., unlock the phone) had a higher response rate and accuracy than those based on a random and predetermined time.

However, as it has been mentioned above, most approaches have used the smartphone to deliver interventions. In this work, we aim at discussing the challenges and opportunities around EMIs and emerging technologies in ubicomp, identifying the gaps in the literature that point to emerging areas of research in EMIs.

2 Use of Technologies and EMIs for Mental Health

Mental illness is a global threatening problem. Improving awareness, recognition, support, and treatment for this range of disorders should therefore be a priority for most administrations. As an example, more than 300 million people, i.e. 4.4% of the world's population, suffer from depression [10]. It is estimated that mental health conditions will affect a staggering one in four people at some time in their lives [11]. Despite the progress made in some regions, people with mental health conditions often experience severe human rights violations, discrimination, and stigma. Mental health has impacts on issues such as alcohol and substance misuse, abuse, and gender-based violence. As a result, failure to address mental health can have consequences for societies [12].

EMAs and EMIs represent a novel approach for the assessment and delivery of psychological support to mental health patients in daily life. At the intersection between technologies, EMIs, and mental health related disorders, different types of works have been developed. EMIs seem to be particularly useful when mental disorders are being treated at home (i.e., ambulatory care). Related to anxiety disorders, the use of Cognitive Behavioral Therapy (CBT) and gamification have been used to deliver EMIs through a smartphone application in children suffering from anxiety-related disorders, resulting in a significant reduction in symptom severity after treatment [13]. Also, smartphones are often used as a support tool in the treatment of patients suffering from substance

abuse disorders. For example, a 12-week study investigated the effectiveness of using EMAs/EMIs through smartphones in young adults during risky situations of alcohol consumption resulted in a reduction of standard drinks consumed during a heavy drinking session [14].

There is more research on the intersection of EMIs, technologies, and mental health disorders. However, most of this research is related to the use of smartphones to provide interventions, due to their ubiquity and availability. Emerging technologies such as virtual reality and haptic devices are rarely studied, providing new intervention routes to be explored, moving away from conventional interventions. Still, there are several challenges and opportunities for mental health research that these technologies can afford, which we discuss in the following sections.

3 Intervention Strategies in EMIs

Intervention strategies in EMIs often relates to the way in which feedback or content is provided to the user. In this section, we provide information regarding different types of intervention strategies found in the literature related to technology use (i.e., on-body technologies), type of interaction (i.e., touch-based interventions), and content related information (i.e., textual and multimedia content).

3.1 EMIs from a Technology Point of View

On-Body Interventions. On-body technologies can be carried by the user such as smartphones, wearables, or smartwatches. Typically, most interventions through these types of technologies are carried via smartphones, thanks to their ubiquity and accessibility [13, 15]. Smartphone-based interventions provide the user with the capability of receiving interventions at most times of the day, allowing for a more accessible type of interaction between user and technology. These types of interventions are mostly received via native applications. For example, smartphone-based interventions are widely used to prevent and treat risky alcohol consumption episodes, using EMAs to assess information about drinking episodes and EMIs to deliver text-based interventions at predetermined times [14]. Also, the use of wearables to assess symptoms related to mental disorders are often used in combination with other carry-on technologies to deliver in-time interventions. For instance, the use of wearables to identify stress-related symptoms such as changes in breathing patterns have been used in combination with smartphones to deliver real-time interventions at work, resulting in fewer stress and anxiety-related symptoms in comparison to a control group [16].

Ambient-Based Interventions. Ambient-based interventions refer to ubiquitous technologies that can be found in the real world, sometimes embedded into normal day-to-day objects such as refrigerators, TVs, or microwave ovens. These types of smart technologies provide new routes for collecting and delivering information. For example, people with eating disorders could receive interventions when interacting with the refrigerator or stove, enabling the identification of this type of behavior, which might otherwise go unnoticed, be detected and intervened. Also, smart-TV-based systems offer an opportunity to provide health related services to people at their home, especially those people who may not be familiar with newer technologies such as smartphones [17].

Desktop-Based Technologies. Desktop-based interventions have been increasingly researched and used during recent years [18]. EMIs could be delivered through desktop computers to patients who spend most of the workday on a computer (e.g., via email messages or desktop/browser notifications). Also, desktop-based video-messaging applications can be used to intervene people who cannot carry out face-to-face therapy because of mental or physical barriers. These types of interventions appear to be as effective as face-to-face treatment in mental health disorders [19]. Web interventions are considered especially effective when the user finds it difficult to carry out face-to-face therapy, or when the user, for various reasons such as the stigmatization of mental disorders, does not want to visit the therapist. Several studies using this type of intervention are used to prevent depression and anxiety related disorders, using internet-based Cognitive Behavioral Therapy (CBT) providing the user with a non-face-to-face type of intervention, resulting in decreasing symptoms of both disorders [20, 21].

3.2 Interacting with EMIs Through Participants' Senses

As mentioned before, emerging technologies such as virtual reality, haptics, or multisensorial devices are rarely studied for EMIs and could be used as new avenues for delivering real-time interventions. We discuss in the following new types of interventions that can provide novel ways to deliver more adequate and precisely tailored interventions.

Touch-Based Interventions. Touch-based interventions rely on the sense of touch for assessing and delivering information to patients. These interventions measure the surface of the body to deliver stimulation to specified locations and mimic the sensations of physical touch to bring relief and assist clinical therapy for mental health [22]. Recently, haptic devices were used at the backrest of the driver's seat to reduce stress through guided slow breathing via an EMI while driving their car and when feeling stressed. Namely, an haptic stimuli was applied aimed at reducing stress related symptoms through slow breathing [23].

Sound-Based Interventions. Sound-based interventions such as soundtracks, music, or noises can be helpful in interventions, albeit their use as EMIs appears to be scarce. Most sound-based interventions are usually performed in controlled environments by therapists. Therefore, designing sound-based EMIs should consider the type of technology to be used and the situations in which it would be deemed appropriate to deliver the intervention. Still, some interventions have been reported in the literature, although they are onsite therapies and not necessarily EMIs. For example, music therapy is used in children and adolescents and can be referred as active writing or performing and passive listening to pre-recorded music [24]. Recent studies have shown that these types of interventions are able to help patients suffering from depressive disorders [25]. For instance, a study to assess the feasibility, acceptance, and effectiveness of music therapy in adolescents resulted in improvements regarding depressive symptoms in a pre-post study, thus concluding that music therapy can provide benefits regarding depressive-related symptoms [26].

Sight-Based Interventions. Sight-based interventions refer to those that predominantly use the sense of sight for the purpose of giving visual stimuli to the user such as images, videos, holograms, virtual reality (VR), and augmented reality (AR). For example, VR devices provide the possibility of performing exposure therapy in an environment controlled by therapists [27]. These types of interventions are specially used when treating with anxiety-related disorders, where VR devices and virtual environments has been used to expose patients to certain situations that triggers their anxiety episodes [28]. The emergence of commercial virtual reality devices such as HTC VIVE or Quest opens the possibility to implement EMIs using virtual reality devices. Now, most EMIs based on sight are usually made up of images, videos, or a combination of both, since it is easier to deliver them to the user through more commonplace devices such as smartphones. In the future, it will be necessary to develop less intrusive VR technologies to be able to carry out interventions in real time and at the right time. Also, a potential avenue to investigate is the use of EMIs directly into the virtual worlds or metaverses.

Smell-Based Interventions. Smell-based therapy, such as aromatherapy, refers to the use of essentials oils to achieve measurable outcomes for a healthcare condition [29]. In terms of interventions, most of the studies carried out to treat mental disorders through aromatherapy are done in controlled environments, with the supervision of therapists and experts in the field of aromatherapy. For example, a study regarding the effects of clinical aromatherapy for anxiety and depression in postpartum women resulted in improvement from anxiety and depression symptoms, although recommending future research with general populations and the use of aromatherapy in conjunct with other more classical approaches to interventions [30]. In terms of technologies used to deliver aroma-based interventions, little to no work has been done. Recently, works to recreate odors in virtual environments have been gaining interest. These studies aim to integrate the sense of smell to recreate more real experiences in virtual environments than those commonly based on sight and hearing [31]. Hence, there is much room for development of EMIs based on these types of technologies.

Taste-Based Interventions. To the best of our knowledge, taste-related interventions have not been studied in mental health. This may be due to the few technologies available to recreate the sense of taste in humans. Some approaches to recreate this sense mention the use of electrical and thermal stimulation of the taste buds to recreate flavors [32]. It is important to notice that most of the studies in terms of recreating the sense of taste are usually accompanied by other technologies such as VR/AR to create more immersive experience for the user. Developing EMIs based on the sense of taste represents a challenge not only in the development of interventions as such, but also technologies in general.

3.3 Textual and Multimedia Content Within EMIs

Text based interventions are usually delivered via text messaging or native applications, which typically have a few sentences using simple language. The application of text-based conversational agents such as virtual coaches in mental health is varied

and includes diagnostic tools, symptom monitoring, and treatment or intervention for depression, schizophrenia, substance abuse, major depression, anxiety disorder, and post-traumatic stress disorder (PTSD). Multimedia content, such as audios, videos, and images are delivered through EMIs in mental healthcare to provide mindfulness, psychoeducation, and substance-abuse-prevention to users [5].

These types of interventions aim at encouraging appropriate behavior or reducing dangerous behaviors by suggesting solutions (e.g., "my friend has depression… tell her not to think so hard") as well as providing empathetic responses (e.g., "I know what it's like, I have anxiety and depression too, sorry to hear that"). Researchers proposed that such text messages should be tailored to those interacting with the intervention. For instance, special requirements for screen reading technologies such as smartphones are needed by individuals with visual impairment making it accessible to them [33]. Also, the language used in said text-based interventions should be tailored to the population interacting with them. For instance, women tend to use more informal language when carrying out text-based interactions, such as instant messages, compared to men, especially when interacting with another women [34].

4 Challenges and Opportunities for EMIs in Mental Health

In Table 1, we show the challenges and opportunities in regards of designing technology-based ecological momentary interventions for mental health that we believe need to be considered for future design of new ubicomp technologies. Also, in the next sections we detail challenges and opportunities related to designing, delivery, tailoring, and technologies within interventions that need to be studied for the future design of EMIs.

Table 1. Challenges and opportunities for designing technology-based Ecological Momentary Interventions (EMIs) in mental health

Category		Challenges	Opportunities
EMIs from a technology point of view	On-body	Unconventional wearables such as jackets, belts, or smart clothing can prove challenging to display readable information	Design appropriate interfaces based on textiles for on-body interventions
	Ambient based	Technologies such as smart-fridges or microwaves are devices used occasionally in particular situations, such as a food-craving episode	Design ambient-based technologies which could be integrated as part of richer interface environments

(*continued*)

Table 1. (*continued*)

Category		Challenges	Opportunities
	Desktop-based	Inappropriate use of personal information provided in online-support groups or social media support groups may result in distrust within the users	Design stricter security rules regarding the type of information that is shared and with whom
Interacting with EMIs through participants' senses	Touch-based interventions	Touch-based technologies can be difficult to integrate into users' daily lives, due to the design of the technology itself. For instance, haptic devices are most of the times intrusive to the user to interact in real life situations	Design portable, non-invasive touch-based technologies that can be integrated into users' daily life
	Sound-based interventions	Sound-based interventions are normally given in controlled environments, the use of portable music devices, like headphones, could prove new ways of delivering interventions, especially when being in real situations	Designing sound-based interventions should consider the type of technology to be used and the situations in which it would be considered more appropriate to give the intervention
	Sight-based interventions	Sight-based technologies such as high-end VR devices can be challenging to carry on daily, due to the non-portability of these technologies	Design less intrusive, portable virtual reality technologies to be able to carry out interventions in real time and at the right time

(*continued*)

Table 1. (*continued*)

Category		Challenges	Opportunities
	Smell-based interventions	Smell-based technologies have not yet been studied in EMIs	Design unobtrusive, portable smell-based technologies to accompany other sense-based technologies to provide a better user experience when interacting with EMIs
	Taste-based interventions	Taste-based technologies have not yet been studied in EMIs	Design unobtrusive, portable taste-based technologies to accompany other sense-based technologies to provide a better user experience when interacting with EMIs
Textual and multimedia content within EMIs	Textual and multimedia content	The individualization of textual and multimedia content can be harsh to do, especially when dealing with large numbers of users	Design tailored, individualized textual and multimedia content using data collection techniques from the users to whom the intervention will be directed

4.1 Designing Interventions

As mentioned before, intervention strategies in EMIs often relates to the way and content in which the intervention is provided to the user. It is important that information provided to the user is relevant, so that they can use it for their immediate needs and make well-informed decisions. Also, information may come in different ways and forms, for instance haptic devices uses the sense of touch to deliver information to the user, text-based interventions may use instant messaging applications to deliver information to the users, or VR interventions could combine visual, sound, and haptic information. Ultimately, researchers may need to decide which kind of intervention delivery is the most adequate to the users they are working with.

Interventions should be simple, reliable, and timely, while it should be brief and not overload the user with unnecessary information [35]. Therefore, users should be able to acquire information at their convenience, in a way that will not be too burdensome for them. There should not be complex user interfaces (e.g., using tabs or menus) that only increase the level of frustration for users when they must access information. EMIs

should be as responsive as possible, and provide the best possible user experience, while at the same time keeping information simple and accessible.

Lastly, interventions should consider the user group to whom the intervention is aimed at. This, to make use of the most appropriate technology to deliver information for a given population group. For example, smartphones are typically better perceived and used in young people in comparison with older adults as a media of receiving information. Considering the technological capabilities of each group, researchers should consider more valid and adequate interventions according to the users' needs.

4.2 Tailoring of Interventions

The content and technologies used for EMIs in mental health should be assessed and analyzed according to the patient characteristics, diagnostic status, and treatment response. Elevating their personal preferences about their own information will provide them with a more personalized intervention. For instance, there are studies that mention that women are more inclined to interact with text-based interventions when using a more informal language, especially when they know they are in contact with another woman [34].

Also, we believe that the type of technology used for interventions must be appropriate for the user interacting with it. For example, a person suffering from an eating disorder may need to be intervened when interacting with a refrigerator, a microwave, or before they enter a restaurant. Thus, the use of these type of emerging smart technologies may provide with new ways to deliver adequate EMIs.

Lastly, it is important for users to feel a sense of individualization when tailoring interventions. Thus, we propose using data collection techniques such as interviews, to understand the specific needs of each user, to provide interventions with a high sense of individualization. For instance, identifying what triggers a depressive episode in a particular patient and what strategies can be used to deal with it could be used to provide an individualized intervention based on the patient needs.

4.3 Technologies for Interventions

As mentioned, most of the technologies used to deliver EMIs are smartphones, due to their availability and ubiquity. Emerging technologies such as the use of VR or haptic devices are rarely studied in this field, providing with new intervention routes to be explored.

Secondly, it has been reported that low-income people are more at risk of suffering mental disorders [36], so we believe in the importance of developing cheap and easy-to-learn technologies for these most marginalized and stigmatized populations. For instance, a more community-oriented approach type of interventions in marginalized communities may be a better solution than providing one-on-one interventions, either with embedded technology in public schools and hospitals or community programs that facilitate access to these types of technologies.

Lastly, technologies used for interventions to reduce stigma, support those with mental health conditions and improve people's access to care are constantly evolving. For instance, internet use and social media have had an increasing impact on public health.

Online social networking platforms provide opportunities for individuals to engage in psychosocial support, as well to express their emotions, especially if they do not have the opportunity to attend support groups offline. Therefore, we believe that the use of internet related interventions such as social networks, can provide the user with tools to cope with their mental disorder, even if it is impossible for them to physically attend a session with a therapist. Finally, it is important to take care of personal information, which if used wrongly, can generate distrust among the same users about who has access to their information and how they use it.

5 Conclusions

Mental health disorders in comparison with traditional diseases require a specific approach to treatment and it has been increasingly evidence-based. Using ecological moments and technological solutions are a way to address the current challenges. For example, the use of new technologies such as virtual reality, mobile devices, and conversational agents to improve the mental state of patients are being used more often. This is because technology can help people to achieve a better quality of life. It allows for an increase in self-knowledge and offers the possibility of interaction with others. Moreover, it can be used to explore and understand the different factors involved in mental disorders. For this to happen, a greater dialogue between the medical and computational science, as well as a more effective and well-structured approach of psychiatric services, is needed. However, there is no easy solution to this problem, which must be handled in a multidisciplinary way.

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