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Extended reality for mental health: Current trends and future challenges

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Virtual and augmented reality have been used to diagnose and treat several mental health disorders for decades. Technological advances in these fields have facilitated the availability of commercial solutions for end customers and practitioners. However, there are still some barriers and limitations that prevent these technologies from being widely used by professionals on a daily basis. In addition, the COVID-19 pandemic has exposed a variety of new scenarios in which these technologies could play an essential role, like providing remote treatment. Disorders that traditionally had received less attention are also getting in the spotlight, such as depression or obsessive-compulsive disorder. Improvements in equipment and hardware, like Mixed Reality Head Mounted Displays, could help open new opportunities in the mental health field. Extended reality (XR) is an umbrella term meant to comprise Virtual reality (VR), mixed reality (MR), and augmented reality (AR). While XR applications are eminently visual, other senses are being explored in literature around multisensory interactions, such as auditory, olfactory, or haptic feedback. Applying such stimuli within XR experiences around mental disorders is still under-explored and could greatly enrich the therapeutic experience. This manuscript reviews recent research regarding the use of XR for mental health scenarios, highlighting trends, and potential applications as well as areas for improvement. It also discusses future challenges and research areas in upcoming topics such as the use of wearables, multisensory, and multimodal interaction. The main goal of this paper is to unpack how these technologies could be applied to XR scenarios for mental health to exploit their full potential and follow the path of other health technologies by promoting personalized medicine.

KEYWORDS

extended reality, mental health, serious games, multimodal interaction, biofeedback, mixed reality

1. Introduction

In recent years, mental health is beginning to be acknowledged as an essential part of individual and global well-being. The World Health Organization has included it in the Sustainable Development Goals and estimates that about 25% of the world's population experiences a mental health problem at some point in their life (WHO et al., 2021). In addition, mental health conditions are among the leading causes of disabilities, comorbidity, and premature deaths[1,2]. The COVID-19 pandemic has also affected the global prevalence of disorders such as anxiety and depression by 25% worldwide [3].

Technology plays an essential role in supporting mental health, as it can be applied for screening, diagnosis, treatment of mental health conditions, and improving general well-being. Both commercial and research applications have used different types of technologies to address a diverse set of pathologies. The most common one has been the use of mobiles/tablets and e-Health applications, either for collecting data from the mobile device passively (e.g., GPS location, daily steps) or through daily questionnaires that the user has to fill in about how they are feeling (Wang et al., 2018; Habets et al., 2020). Gesture recognition devices such as LeapMotion have been used for games to improve cognitive and motor skills in people with attention deficit and hyperactivity disorder (ADHD) (Garcia-Zapirain et al., 2017), or autism spectrum disorder (ASD) (Cai et al., 2018). Body movement detection has also been used to detect anxiety or depression based on walking posture (Zhao et al., 2019), or stereotypies in ASD (Jazouli et al., 2019). Regarding eye-tracking technology, it has been helpful to observe differences in the patterns of users with or without ASD (Eraslan et al., 2019). Several studies have also been carried out with robots, which allow working on social or emotional aspects through conversation or care (Moyle et al., 2013; Yun et al., 2017; Choi et al., 2019).

One of the technologies that is gaining momentum is extended reality (XR). Extended reality (Chuah, 2018; Mann et al., 2018) encompasses virtual reality (VR), augmented reality (AR), and mixed reality (MR). Virtual reality makes reference to fully computer graphics (CG) generated environments, AR means overlaying CG elements on the real world, and MR is built on AR scheme but with VR interaction capabilities with synthetic assets. Each technology has different characteristics that could be explored to contribute to diverse mental health conditions, but, in general, they share some intrinsic immersive capabilities. Immersion represents the potential of technology to surround someone perceptually and to make them *believe* that the digital environment they are experiencing is "real" (Slater, 2018). *Believe* and *real* are words used here by simplification since users actually know that what is happening inside and XR experience is not real but, as it occurs in cinema and theater, they self-impose their cognition as a kind of temporary willing suspension of disbelief (Coleridge, 1984). Immersion generates the feeling of presence, which is a subjective construct that represents how much "real" a virtual experience might feel for a user immersed in an XR environment (Slater et al., 1994). Presence is commonly linked to the feeling of "being there," where users experiment the virtual world more intensely than the actual world. Understanding immersion and presence in XR experiences is so relevant for researchers and practitioners. These concepts are key in enabling XR as one of the most promising technologies in supporting mental health applications and interventions in the upcoming years, since they are responsible for turning virtual worlds in believable and transferable scenarios.

2. Extended reality for mental health

Usually, XR experiences for mental health are based on Cognitive Behavioral Therapy (CBT, focuses on identifying and changing cognitive distortions) and exposure therapy (involves gradually exposing the patient to the discomfort source or its context) to make patients face an uncomfortable or fearful situation in a controlled scenario. Following the therapist's guidance, the patient works on understanding the cognitive biases and thoughts that trigger their well-being, such as increased anxiety or panic. Across the literature in XR for mental health, VR technology has received more attention than AR, being MR research almost non-existent. Related works have explored the use of VR for treating acrophobia (Donker et al., 2019; Bălan et al., 2020; Giraldy and Novaldo, 2022), agoraphobia in patients with panic attacks (Lundin et al., 2022) or psychosis (Freeman et al., 2022), social phobia (Wechsler et al., 2019), or obsessive-compulsive disorder (OCD) (Laforest et al., 2016; Francova et al., 2019; Miegel et al., 2022). These interventions are highly effective thanks to the sense of presence that VR environments allow. This is because users' psycho-cognitive reactions to XR exposure are entirely similar to those in the real world (Loomis et al., 1999) to the same stimuli even though they know that the environment is synthetically generated.

Comparative studies demonstrate that VR and AR exposure therapy are useful alternatives to traditional *in-vivo* treatments for small animal phobia (Suso-Ribera et al., 2019). For example,

1 https://www.mentalhealth.org.uk/explore-mental-health/statistics/uk-worldwide-statistics

2 https://www3.paho.org/hq/index.php?option=com_content&view=article&id=15481:mental-health-problems-are-the-leading-cause-of-disability-worldwide-say-experts-at-paho-directing-council-side-event&Itemid=72565&lang=en

3 https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide

there are works exploring AR mobile apps for exposure therapy with cockroaches (Botella et al., 2010) or spiders (Zimmer et al., 2021), which obtained very positive results, and recent works have also combined tactile feedback in these experiences (Kurscheidt et al., 2019).

However, other mechanisms and procedures within CBT allow working on reducing cognitive biases and negative thoughts without relying on direct exposure to scenarios that elicit anxiety or fear. For example, compassion-focused therapy (CFT, encouraging people in treatment to be compassionate toward themselves and other people) have been shown to be effective in increasing cognitive empathy and compassion, and reducing stress, anxiety, and depression. Falconer et al. (2016) developed a VR experience to practice self-compassion in patients with depression, in which they delivered compassion in one virtual body and then received it in another one. Cebolla et al. (2019) designed a multi-sensory VR experience to induce a body swap illusion, in which participants saw themselves from a third perspective and had the illusion of touching themselves from outside. Recent works have studied different ways of managing mental health conditions with technological interventions other than XR experiences. For example, by personalizing and then destroying avatars that represent a patient's anxiety or fear (Pimentel and Kalyanaraman, 2020), or using games to manage anxiety (Schoneveld et al., 2016) and depression (Fleming et al., 2019).

Extended reality scenarios have also been applied for clinical assessment of specific treats of a disorder such as ASD (Alcañiz et al., 2022) or ADHD (Goharinejad et al., 2022), as well as to help those individuals to practice skills such as attention (Vahabzadeh et al., 2018), social, and communicative behaviors (Mesa-Gresa et al., 2018; Thai and Nathan-Roberts, 2018; Marto and Almeida, 2019).

In addition, there are mental disorders that historically have received more attention and effort from a technological point of view, such as ASD or depression (Riva et al., 2015). However, other mental health conditions such as schizophrenia (Bisso et al., 2020), OCD (van Loenen et al., 2022), borderline personality disorder, or anxiety have been less explored, especially within XR scenarios.

Age is also an essential factor to consider in designing proper XR interventions. So far, research has been mainly oriented toward adults. Extended reality for elders, especially VR, has shown good usability and acceptance (Tuena et al., 2020), and has primarily focused on dementia and its derived consequences on well-being and cognition (D'Cunha et al., 2019; Lee et al., 2019). Extended reality experiences for children have mainly focused on neurodevelopmental disorders such as ASD or ADHD. However, recent reports show a rapid increase in anxiety and depression disorders in children and teenagers, especially after COVID'19 pandemics (Hafstad et al., 2020; Zhang et al., 2020; Pizarro-Ruiz and Ordóñez-Camblor, 2021; Bera et al., 2022). Technological XR interventions could play an essential role in supporting not only mental health conditions but also emotional management (Colombo et al., 2019; Macey et al., 2022) and self-compassion in these age ranges (Ventura et al., 2018; Baghaei et al., 2019).

In this regard, ludic experiences can be better suited to appeal to children and teenagers. Recent works explore how VR and AR games can help children with ADHD improve their attention (Davis et al., 2018). Montaner-Marco et al. (2021) propose a mobile AR application allowing the customization of gamified tasks aimed to facilitate everyday activities for families and children with ASD.

Given the wide range of existing scenarios, technologies, and mental health conditions, there are still many challenges and opportunities to unravel regarding the use of XR technologies to improve mental health conditions. The following sections will review several aspects to be considered by researchers working in this area, defining promising lines of work to advance the field.

3. Challenges

This section will discuss the three key challenges that XR needs to address to maximize its potential in the mental health field. These challenges are also shown on the left side in Figure 1.

3.1. Engagement

One of the main issues with current e-Health applications and technological interventions is the lack of motivation for patients to maintain a sustained and periodic use of the technology (Yang et al., 2022). Among the factors that cause this lack of interest are not perceiving the usefulness of the intervention and poor adaptation to the users' level of expertise with the technology leading to frustration (Donkin and Glozier, 2012; Nickbakht et al., 2020). Mobile apps that require the user to update their status periodically, feelings, or thoughts can be tedious to use on a daily basis, and users frequently stop providing updates to the app over time (Rickard et al., 2016). On the other side, there are applications and platforms that gather information from the user's patterns in the background without actively trying to engage the user in any kind of interaction. Active participation of patients in their therapeutic activities is essential to improve the impact that technological advances might have on these interventions (Yang et al., 2022). Extended reality scenarios offer an auspicious opportunity in this regard: the user has to participate in the activities actively, but the application can extract information from their performance transparently and unobtrusively.

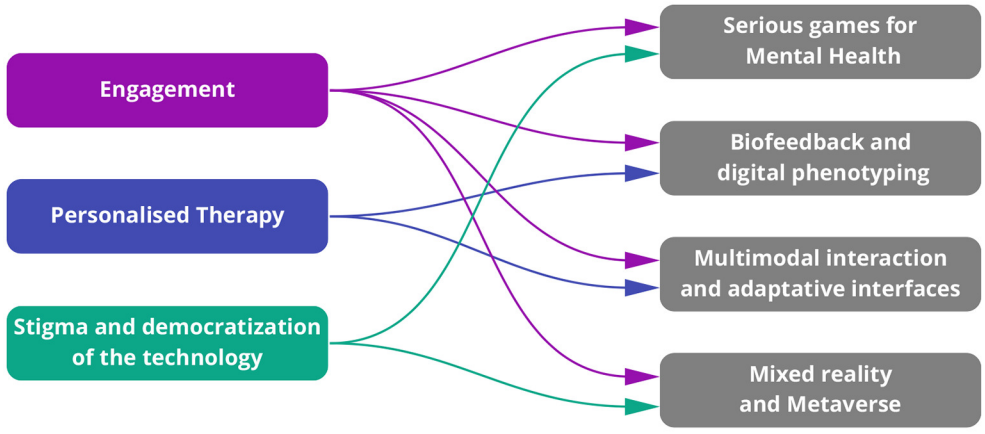

FIGURE 1
Relationships between challenges and opportunities in XR technologies for mental health.

Extended reality applications provide a novel and motivating way for patients to perform their therapeutic activities. However, the novelty effect might deteriorate as the user explores the application. Interventions that always propose the same activities without adaptation or professional supervision tend to result in treatment dropout (Donkin et al., 2011). It is, therefore, vital to find a balance between the learning curve and the novelty factor to create a suitable and engaging patient experience to facilitate treatment adherence.

However, while mobile apps, websites, and games have a wide historical background in user experience research, XR scenarios are still in their infancy regarding heuristics and UX standards. Hence, when developing mental health experiences for XR, it is essential to understand how to correctly map the specific use cases to a good UX design in the selected XR platform.

3.2. Personalized therapy

Personalized medicine has been identified as key in "achieving optimal individual health-care decisions"[4]. Artificial Intelligence has allowed us to apply personalized medicine to several fields within the health domain, such as image diagnostics or genomics (Schork, 2019). It is, therefore, time to boost personalized therapy in mental health applications.

From a psychological perspective, each mental health condition has a different kind of treatment and approach. Hence, technological solutions aimed toward a specific condition cannot usually be generalized to others. Moreover, patients diagnosed with the same disorder might present different symptoms, triggers, and experiences that can not be solved with a non-adaptive and rigid technological activity. Therapists and patients are likely to perceive those generic tech solutions as poor or inadequate for their interest if they fail to adapt to the vastly assorted cases they deal with on an everyday basis.

Technological solutions aimed at supporting professionals and patients with mental conditions should provide a certain degree of customization. This process needs to be also participatory involving all stakeholders: technology designers, researchers, and developers should collaborate closely with mental health professionals and end users in order to design and develop adequate and flexible technological solutions (Muller, 2002). Additionally, these customization features have to be easy to understand and learn so that they do not interfere with clinicians' regular practice or cause rejection in patients. Regarding XR setups, a significant challenge will be the development of such adaptive and customizable experiences that could adapt their interfaces and digital 3D content to the patient and context.

3.3. Stigma and democratization of the technology

There is still a significant stigma around people who go to therapy, and mental health disorders are yet misunderstood and poorly considered by society. People are less likely to report mental health issues compared to other health conditions (Bharadwaj et al., 2017). Mental health stigma might even be accentuated in specific communities and vulnerable groups (Egede et al., 2020). Social and self-stigma could lead to many consequences (Sickel et al., 2014), being under-diagnose as one of them. Technology could help a great deal in breaking these stereotypes: XR experiences can help people feel what other beings are feeling, for example, when they suffer from psychosis

4 http://www.engineeringchallenges.org/challenges/medicines.aspx

or a panic attack (Formosa et al., 2018). This exposure could help increase compassion toward individuals suffering from those conditions, creating more inclusive societies.

Another factor that could help break the stigma around mental health is democratizing access to healthcare resources. The WHO (2022) has emphasized the need for accessible community-based mental health services, stressed that the traditional business model for mental health is not enough, and steemed urgent the need for a wide-ranging transformation toward mental health.

The recent COVID pandemic has shifted the paradigm from traditional face-to-face therapy and popularized the possibility of online therapy in such a way that online therapy is still demanded in our post-pandemic society (Weinberg, 2020). These online opportunities could also help to lower the barrier of access to treatment for certain, especially vulnerable, demographics such as elders, people with limited mobility, or people living in rural areas far from access to specialized therapy. Extended reality technologies can also be regarded as online and remote therapies, with the added value that the patient can experience them both online at the same time with the therapist or offline to practice at their own pace. In both cases, therapists will need additional tools to manage the interventions and keep track of the patients' evolution.

Overall, digital and technology-driven interventions like those based on XR would help reduce the consequences of mental health stigma, reduce the barriers, and democratize access to mental health therapy.

4. Future trends and opportunities

This section will review how the aforementioned challenges can be addressed in XR scenarios by means of different technological opportunities. Figure 1 shows the relationship between the different challenges and opportunities presented.

4.1. Serious games for mental health

Over the last decade, serious games are increasingly gaining popularity as an alternative way of tackling different challenges on a wide range of topics. Even when there is no unique and standard definition of the serious games term, it exists some agreement between researchers and practitioners about their core conceptions: Serious games are games designed to have a main intended use apart from entertainment.

In the mental health domain, serious games have a significant positive impact on the effectiveness of certain therapies, as they are able to harness the appealing aesthetics, engaging interactions, and instantaneous feedback of video games for the benefit of individuals (Kato, 2010; Wattanasoontorn et al., 2014). Due to their ability to add interest to activities that may otherwise be boring or repetitive, serious games have the potential to overcome the engagement issues that conventional e-Health apps face.

As new research on the topic emerges, it is necessary to determine how much any link between using video games (serious games or commercial off-the-shelf) and training-related outcomes is mediated by adherence and whether this adherence is long-lasting (Primack et al., 2012).

Focusing on specific mental health therapies, there is also strong evidence about the positive effects of serious games on cognitive-behavioral treatments (Fleming et al., 2017). Moreover, even the United States Food and Drug Administration (FDA), has started to certify software as a drug and has implemented a Software Precertification Pilot Program version 1.0 Working Model (FDA, 2019) in order to clarify the risks/benefits balance of a therapeutic virtual experience. Serious games that have been approved by the FDA and other certification entities aim to tackle mental health conditions such as nightmare disorder or post-traumatic stress disorder[5], insomnia[6], and substance use disorder[7]. Additionally, FDA provides some mechanisms, like the *De Novo* request, to evaluate how appropriate an XR device is for its clinical utilization, attending to its potential hazards when used by patients (FDA, 2022).

4.2. Biofeedback and digital phenotyping

A common form of intervention in mental health is through the use of wearables and sensors that allow measuring a patient's physiological parameters, with recent trends on using heart-rate, respiration, and electrodermal activity (Alneyadi et al., 2021). Capturing biofeedback offers quantitative and objective information about the patient's state to the therapist. It also makes it possible to identify relevant patterns in the captured data for the prediction or diagnosis of pathologies such as depression (Tazawa et al., 2020) or ASD (Torrado et al., 2017). This moment-by-moment quantification of the user's data captured from digital devices is known as digital phenotype (Sequeira et al., 2019). It can be gathered passively from smartphones, wearables, or sensors, but it can also be collected within game-like experiences (Mandryk and Birk, 2019).

Combined with XR technology and XR serious games, biofeedback and digital phenotyping offer a mechanism to increase user engagement: an XR playful experience could

5 https://nightware.com/

6 https://www.somryst.com/

7 https://www.resetforrecovery.com/

gather data from different wearable sensors and IoT devices while the user is playing, identifying meaningful information that could be used to inform therapists. In addition, the data gathered from the patient could help adapt the interaction in real-time, personalizing the interventions, and keeping the user motivated. Adaptive interfaces could be envisioned, in which the experience could be tailored to the patient's current mental state. For example, the XR experience might offer different options depending on whether the user is feeling more or less stressed, happy, or anxious.

4.3. Multimodal interaction and adaptive interfaces

Extended reality experiences are mostly visual, but designers and developers cannot forget about other senses and stimuli that will surely help to increase users' engagement. One of the recent trends in XR is exploring tangible and haptic feedback. There is evidence about how tangible pervasive tools can facilitate monitoring and sensing affect within mental health care (Guribye et al., 2016). Tangible interfaces offer a bridge between real and digital objects. In the context of XR, tangible interfaces have the potential to improve natural support for collaborative activities, physical interactions, and external representations and, also provide users with the feeling of directness.

In addition, multimodal interfaces for XR are still under-explored. Researching other modalities of interaction as well as multimodal XR experiences, could provide interesting opportunities to cater to different patients' needs and scenarios. Capitalizing on new advances in designing novel interfaces for XR such as olfactory (Wang et al., 2020), gustatory (Anbarasan et al., 2022), and haptic feedback could also provide options for building adaptive interfaces that provide a customized user experience in therapeutic applications. An ambitious but very promising opportunity lies in the development of XR serious games for mental health that allow for multimodal interactions while capturing the patients' biofeedback. These scenarios will allow the system to adapt intelligently to the patients' state and progress while offering suitable modes of interaction depending on the XR context and the patient's capabilities.

4.4. Mixed reality and metaverse

The increasing spread of XR technologies suggests a future in which MR becomes a ubiquitous component. Improvements in MR enabling technology have the opportunity to make it more accessible to the general public and to enable practitioners to build more immersive and multimodal experiences. Mixed reality technologies have the chance to enhance the way traditional therapies are made and facilitate easier access to such therapies, especially in a remote setting.

In the mental health field, therapists will be able to conduct more realistic MR therapeutic experiences that could be applied to more diverse demographics overcoming barriers present in other XR technologies such as VR: motion sickness (Chun et al., 2022), stress, or strain. Mixed reality also allows to create experiences in the real world instead of simulated environments, which could reduce the gap between exposure and *in-vivo* therapy.

Technological advancements will also bring the opportunity for creating collaborative experiences, both co-present and remote. Such experiences could give a chance to therapists and users to create interventions taking into consideration social aspects, lower the barrier for patients to practice social interventions in a controlled environment, and enable social therapeutic experiences such as group therapy.

The idea of metaverse represents a diffuse and variable concept that serves to identify a digital, persistent, multi-user world with high levels of interaction. This metaverse is shown as a scenario with great potential to host, in the not too distant future, collective environments for mental health work, where patients and therapists coexist and the interventions extend, physically and temporarily, beyond the consultation room.

5. Conclusion and future work

Universal and effective psychological treatment is a major challenge for clinical practitioners, governments, and society, even more so today, where mental health and well-being have become a priority for everyone. The use of XR experiences in the mental health domain represents an unstoppable trend supported by high-quality, affordable immersive technologies.

From early standard VR environments for exposure therapies to current studies on customized MR-based social treatments, the paradigm of technology mediated interventions has evolved to more customized, comfortable, democratized, and accessible approaches.

Future work opportunities on the field include transforming XR experiences into serious games by including game mechanics, interactive storytelling, and compelling aesthetics to increase patient engagement and the efficacy of treatments. Additionally, including biofeedback, multimodal, and adaptive experiences into XR serious games will help to create compelling and effective digital therapies. In this regard, MR experiences with such capabilities have the potential to be the medium to deliver engaging, personalized, and democratic mental health assistance in a global way. In order to support

this approach, global efforts must be made to produce comfortable and affordable MR devices and creative and significant interactive therapeutic experiences. A whole new research topic has been unveiled where pervasive, multiuser, and multimodal XR environments have to be developed for supportive, accessible, and democratic mental health assistance. This new topic will require also new research methodologies such as remote XR experimentation (Ratcliffe et al., 2021).

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author/s.

Author contributions

All authors made substantial contributions to the conception and development of the work.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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