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Analyzing metaverse-based digital therapies, their effectiveness, and potential risks in mental healthcare

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The metaverse, defined as a collective virtual shared space created by the convergence of augmented reality (AR), virtual reality (VR), and the Internet, offers new opportunities for mental healthcare by delivering immersive and engaging digital therapies. This study examines the current landscape of metaverse-based mental healthcare applications, analyzing their effectiveness and potential risks. Using a systematic literature review (SLR) and case study research, four digital therapeutic applications—NightWare, Freespira, EndeavorRx, and Sleepio—were evaluated for their ability to address conditions such as PTSD, anxiety, and ADHD. The results indicate that metaverse-based therapies can provide significant benefits, with clinical validation supporting their effectiveness. However, concerns around user privacy, accessibility, and long-term efficacy remain challenges. Overall, metaverse-based digital therapies represent a promising shift in mental healthcare, offering innovative, personalized, and scalable solutions. Further research is needed to address ethical issues, improve accessibility, and confirm the long-term impact of these interventions.

Keywords Metaverse, Mental healthcare, Metaverse applications, Digital therapies

The metaverse is broadly defined as a collective virtual shared space created by the convergence of augmented reality (AR), virtual reality (VR), and the Internet, enabling real-time interaction among users in immersive digital environments. The concept extends beyond gaming and entertainment[1], influencing sectors such as healthcare, education, and business. While some metaverse platforms facilitate economic activities such as buying and selling virtual assets[2,3], this is not a universal feature across all implementations. The metaverse is continuously evolving, integrating emerging technologies to create dynamic and interactive experiences with significant implications for mental healthcare.

The healthcare sector has perceived a revolutionary impact of the metaverse in terms of how medical care is delivered, learned, and experienced[4,5]. For instance, the metaverse offers new avenues for mental health treatment, including VR therapy for conditions like PTSD (posttraumatic stress disorder), social anxiety, and different phobias[6]. For individuals with social anxiety or autism spectrum disorders, the metaverse can offer simulated social situations to practice and improve social interaction skills[7]. These immersive experiences can be more effective for some patients than traditional therapy methods. In other words, the metaverse is contributing to a paradigm shift in how industries operate and how healthcare is delivered, offering immersive, interactive, and personalized experiences. As technology continues to evolve, the potential for the metaverse to further impact these sectors grows. However, leveraging productive implementation of the metaverse in these sectors also comes with critical challenges including privacy and security, digital divide, technology addiction, and more importantly, the effectiveness and functionality of its applications.

Despite the growing interest in metaverse applications for healthcare, there remains a lack of comprehensive literature reviews that systematically examine its role in mental health interventions. Existing studies primarily focus on individual digital therapies or specific VR-based treatments, without addressing the broader metaverse ecosystem and its implications for mental healthcare infrastructure, accessibility, and ethical considerations. This study aims to fill this gap by providing a structured synthesis of current research, evaluating the technological advancements, clinical applications, regulatory concerns, and future challenges associated with metaverse-based mental healthcare. By analyzing existing studies and a case study approach, it identifies key trends, limitations, and opportunities that can inform the development of more effective, scalable, and ethical digital mental health solutions.

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Background

Metaverse

The metaverse is an evolving concept with its scope expanding through technology innovations shaping environments for social interaction, entertainment, business, education, and more. At its core, the metaverse refers to a collective virtual shared space, created by the convergence of virtually enhanced physical reality, AR, VR, and the Internet. Its evolution is discussed below.

Definition and evolution

Noted American writer Neal Stephenson was the first to coin the term 'metaverse' in his 1992 science fiction novel *Snow Crash*[8]. It described a virtual reality space used by avatars of real people to escape from a dystopian reality. The perception of the metaverse today is much more than just being a fictional concept. It is an emerging digital ecosystem that spans across different virtual worlds and platforms, allowing users to engage in a multitude of activities in real-time, within immersive 3D spaces. It encompasses elements of gaming, social media, virtual economy, and augmented reality, offering a platform where the physical and digital worlds blend. The evolution of the metaverse can be traced through several key stages marked by technological advancements and changing user interactions with digital spaces. Early manifestations of the metaverse concept can be seen between late 1990s and early 2000s in virtual world platforms like *Second Life*[9], which allowed users to create avatars, socialize, participate in activities, and trade virtual goods. Although it was not as immersive as the current metaverse visions, these platforms laid the groundwork for persistent online worlds. With the growth of massively multiplayer online role-playing games (MMORPGs) like *World of Warcraft* and social platforms like Facebook, users were introduced to the concept of virtual interactions and communities, expanding onto complex virtual economies, social networking, and collaborative experiences in digital spaces. In the 2010s, the immersive experience of virtual worlds was enhanced by the development of sophisticated VR headsets and AR technologies, enabling more realistic and engaging interactions[10]. With the advent of the Internet of Things (IoT), smart devices, and wearable technology, the boundaries between the digital and physical worlds have become increasingly blurred, enabling seamless interactions across different platforms and real-world environments[11]. Further, major tech companies have taken more interest in developing metaverse platforms (like Meta), signifying a remarkable push towards realizing the potentials of the metaverse. The metaverse continues to evolve, driven by advancements in technology, changing user expectations, and the creative innovations of content creators and developers. This evolution is constantly redefining interaction in digital spaces while offering new opportunities for collaboration, entertainment, and social interaction on a scale previously unimaginable.

Technological infrastructure

The metaverse is often confused with VR and Extended Reality (XR); however, these are distinct concepts. VR is a technology that creates immersive digital environments, often experienced through head-mounted displays (HMDs), but not all VR applications are part of the metaverse. For instance, standalone VR experiences, such as single-user simulations or training applications, do not necessarily involve the interconnected virtual spaces that define the metaverse. XR, an umbrella term that includes VR, AR, and Mixed Reality (MR), enhances real-world or virtual environments through digital augmentation. While VR and XR are essential components of the metaverse, they do not define it. The metaverse represents a persistent, interactive, and interconnected digital ecosystem where users can engage with others in real-time, facilitated by VR, AR, artificial intelligence (AI), and blockchain technologies.

The development of the metaverse as a comprehensive and immersive digital ecosystem is underpinned by several key technological advancements. These technologies not only enable the creation of detailed and interactive virtual environments but also ensure the functionality and security of transactions within these spaces[12,13]. For instance, VR creates fully immersive digital environments that can simulate real-world or fantastical settings. Through VR headsets (like Oculus Rift), users can experience a sense of presence in these virtual spaces, where they can interact with the environment and other users in a more natural and intuitive way[14]. VR is crucial for the metaverse, providing the foundation for immersive experiences that allow users to feel as if they are truly 'inside' the digital world[15]. AR is another technology that enhances users' perception of their surroundings with virtual elements visible through AR glasses (like Microsoft HoloLens) or smartphone and tablet screens. AR adds a layer of interactivity and information to the physical world, allowing metaverse experiences to extend beyond purely digital spaces and integrate seamlessly with users' real-life environments[1]. Blockchain technology records transactions across multiple computers and ensures data integrity and transparency without the need for a central authority[16]. It underpins the creation and management of digital assets (like cryptocurrencies) that can be bought, sold, or traded within the metaverse, with ownership securely recorded and verified on the blockchain. This not only facilitates a virtual economy where users can engage in real-world economic activities but also ensures users' ownership rights over their virtual possessions and creations. AI plays a significant role in creating dynamic and responsive environments within the metaverse. AI plays an important role in the development of metaverse-based mental healthcare. AI is used to personalize therapies by analyzing patient behavior, monitor real-time responses during virtual therapy sessions, and improve patient outcomes by adapting treatments. For example, AI-powered virtual assistants and chatbots are integrated into digital platforms to provide real-time feedback and guidance during therapy session. AI can also manage complex systems within the metaverse, such as traffic flow, environmental changes, and user interactions, ensuring a seamless and engaging experience for all participants[17]. AI and machine learning (ML) algorithms analyze user data to personalize therapy sessions. These technologies help tailor interventions based on individual needs, track progress, and adapt treatments in real time[18]. AI-driven virtual assistants and chatbots provide immediate support, guidance, and monitoring, enhancing the accessibility and efficiency of mental health services within the metaverse. There are also 3D scanning and modeling tools like Blender, Unity, and Unreal Engine that create detailed and realistic virtual

environments[19]. These environments are essential for exposure therapy, virtual consultations, and interactive therapeutic activities. Simulation-based platforms allow therapists to create various scenarios for patients, providing controlled exposure to stimuli in a safe virtual setting.

In addition to these technologies, the metaverse is supported by cloud computing that offers the computational power and storage capacity needed to host and manage the vast, detailed environments of the metaverse, ensuring they are accessible from anywhere in the world[1]. Metaverse generates vast amounts of data on user behavior and therapy outcomes, which is processed by big data analytics tools to provide insights into treatment efficacy and user engagement[20]. Predictive analytics models help anticipate patient needs and responses to therapy, enabling proactive adjustments to treatment plans. There are cybersecurity measures, including encryption and secure data storage solutions, that are vital to protect sensitive patient information and ensure privacy[21]. Moreover, compliance with legal and ethical regulations are essential for handling personal health information. There are 5G and future networking technologies that provide high-speed and low-latency Internet connectivity necessary for real-time, seamless experiences in the metaverse, supporting large numbers of users simultaneously[17]. Moreover, edge computing helps reduce latency further by processing data closer to the end-user, enhancing the responsiveness and fluidity of interactions within the metaverse[22]. Application Programming Interfaces (APIs) and integration frameworks are relevant tools for seamless operations of different systems and applications. This interoperability is important for integrating metaverse-based therapies with existing healthcare systems[23]. Cross-platform compatibility is also important for ensuring compatibility of metaverse applications with various devices and operating systems. In other words, the technological infrastructure of the metaverse in mental healthcare comprises VR/AR devices, high-speed Internet, AI/ML algorithms, 3D modeling tools, data analytics, cybersecurity measures, and interoperability frameworks. Figure 1 below summarizes the metaverse infrastructure in mental healthcare. It illustrates the core technological components required to build the metaverse environment for mental healthcare applications. It includes the use of VR, AR, AI, and cloud computing. These technologies work in tandem to create immersive therapy environments, enable real-time interactions, and ensure patient data security and scalability.

This robust infrastructure supports immersive, interactive, and personalized therapeutic experiences, making the metaverse a transformative tool in the delivery of mental health services. These technological advancements together create the foundation for the metaverse, enabling not just immersive and persistent

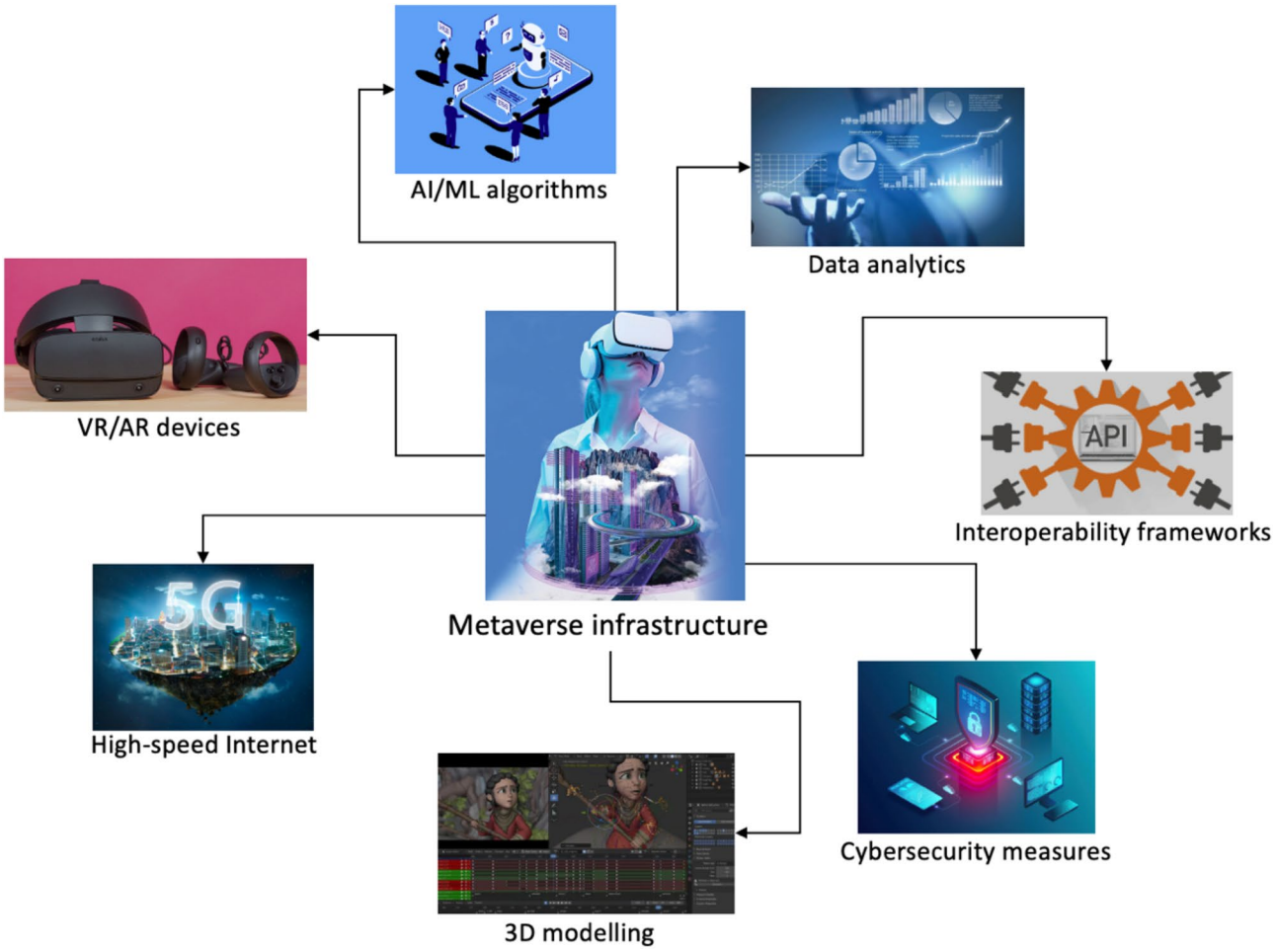


Fig. 1. Technological infrastructure of metaverse in mental healthcare.

virtual environments but also secure, transparent transactions and dynamic, intelligent worlds that respond to and evolve with user interactions.

Digitalization of mental healthcare

Communication in mental healthcare has undergone significant advancements in recent years, driven by technological innovations, evolving therapeutic approaches, and increased awareness of mental health issues. These developments have improved the way mental health professionals interact with patients, deliver care, and support overall mental wellbeing. Technological innovations revolutionized the way communication functioned in this sector, what is most known as digitalization. The current scenarios across mental healthcare can be seen in Fig. 2 below. It showcases the primary ways the metaverse is applied in mental healthcare. It highlights virtual therapy sessions, VR-based exposure therapy for phobias and PTSD, support groups conducted in virtual spaces, and personalized therapy simulations. These applications demonstrate how immersive technologies enhance traditional therapeutic methods by providing greater accessibility and engagement for patients.

Digitalizing mental healthcare involves using digital technologies and tools to deliver, enhance, and transform mental health services. This shift towards digital solutions addresses various challenges in the traditional mental health care system, such as accessibility, stigma, and limited resources, while fostering the benefits of technology to offer more personalized, efficient, and flexible care[24–26]. Some of the key technologies in digital mental healthcare include telepsychiatry, teletherapy, artificial intelligence (AI), digital therapeutics (DTx), and wearable technology. Telehealth platforms have expanded access to mental health services, allowing patients to receive care from the comfort of their homes. Telepsychiatry and teletherapy services use video conferencing to let patients – particularly the ones in remote areas or for those with mobility issues – consult with mental health professionals[27,28]. This approach has made mental health services more accessible to individuals in remote or underserved areas, reducing barriers related to transportation, scheduling, and stigma. Diagnostic processes in mental healthcare use various AI technologies, like machine learning and digital twin, to analyze data for personalized treatment plans or provide chatbots for immediate support in less severe cases[24,29,30]. Patient-specific and simulation-based digital twins can be developed for tailoring highly personalized treatment plans predicting patient response to treatments[31]. DTx services are clinically validated software tools used to treat, manage, or prevent mental health disorders through varied digital formats such as games or online modules that patients complete as part of a treatment plan[32,33]. Whereas wearable technology includes devices like smartwatches and fitness trackers that can monitor physiological data such as heart rate and sleep patterns, which can be indicators of mental health status[34,35]. Use of digital tools makes mental health services more accessible to diverse populations, including those in rural or underserved areas, by overcoming geographical and physical barriers[36]. Moreover, such digital solutions can be scaled up quickly to serve several patients, making it easier to address the widespread need for mental health services.

In terms of assessing risks associated with mental health conditions, advanced technologies like digital twins can develop predictive analytics for identifying at-risk individuals early and providing with timely interventions.

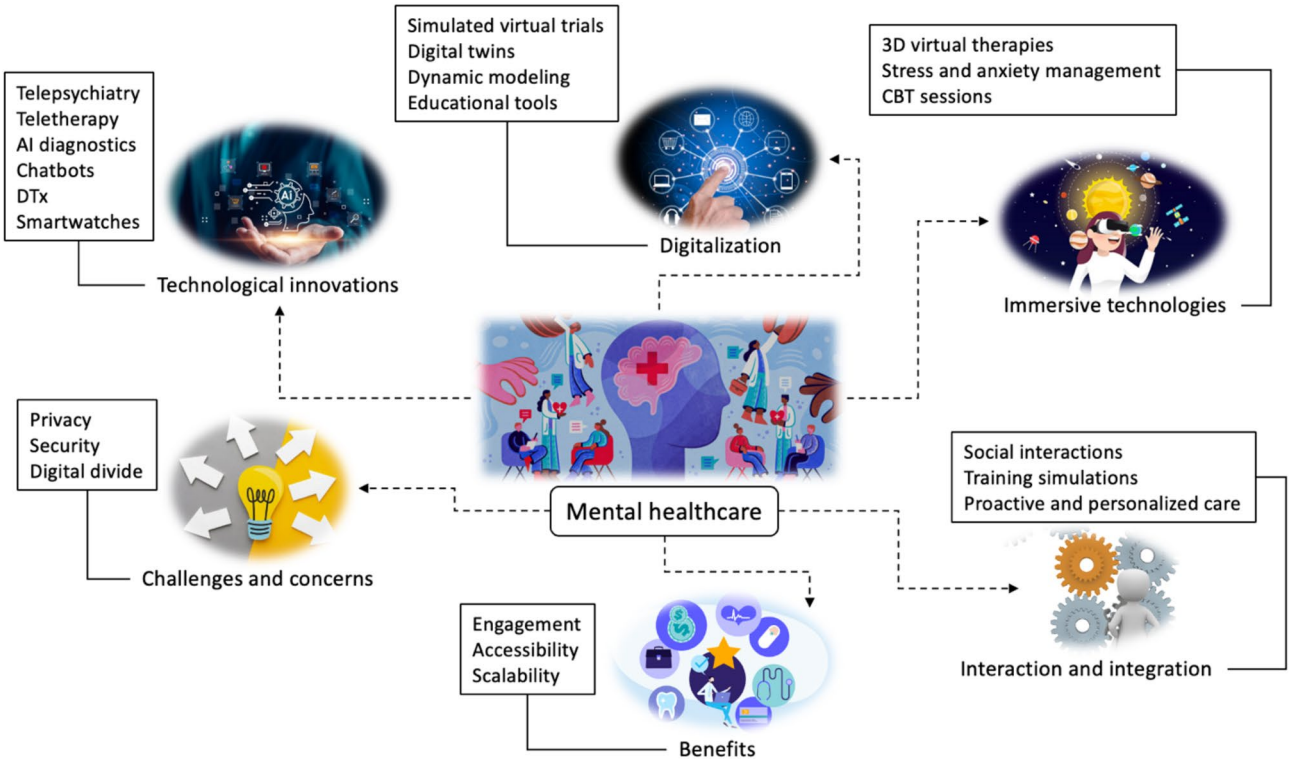


Fig. 2. Key applications of metaverse in virtual mental healthcare.

It can use data from the medical history, genetic information, behavioral patterns, and physiological data of an individual and create highly personalized treatment plans tailored to the unique needs of each patient[37,38]. Digital twins can dynamically model the progression of mental health conditions over time, considering various factors such as treatment adherence, lifestyle changes, and environmental influences. This helps in understanding the trajectory of the disease and planning long-term care strategies[39]. Digital twins can conduct simulated virtual trials to predict the potential outcomes and side effects of the treatment, reducing the risks associated with trial-and-error approaches in real patients[40]. Further, medical students and professionals can interact with the digital twin to understand complex mental health conditions, practice diagnostic procedures, and explore treatment options in a risk-free environment[41]. In short, digital twins in mental healthcare represent a significant advancement in the way mental health conditions are diagnosed, treated, and managed. Digitalization in mental healthcare can actively engage users in their health management while its privacy can reduce the stigma associated with seeking mental healthcare[42]. However, there are privacy and security concerns as handling sensitive personal health information requires stringent data protection measures to prevent unauthorized access and breaches[43]. There is also a risk that the move towards digital healthcare could leave behind those without access to necessary technology or the Internet, potentially intensifying existing inequalities in mental healthcare[44]. It is significant that digitalization of mental healthcare holds great promise for transforming the landscape of mental health services, offering innovative solutions that complement traditional therapies and making mental healthcare more integrated, personalized, and proactive.

With immersive technologies increasingly utilized in mental healthcare, technologies like metaverse can be instrumental in enhancing therapeutic options, training, and patient engagement. Therapy sessions in the metaverse can transcend physical boundaries, allowing patients and therapists to interact in a 3D virtual environment[45,46]. Virtual environments can also be tailored to individual therapy needs, such as exposure therapy settings for patients with phobias or PTSD[47]. Such controlled exposure helps desensitize patients to traumatic stimuli in a safe manner. The metaverse can create controlled, immersive environments where patients can confront their fears in a safe and controlled setting, reducing their anxiety[48]. Metaverse can also host serene and calming environments that are ideal for meditation and mindfulness exercises[49]. Patients can be guided through relaxation techniques in settings designed to induce calm, such as virtual beaches or forests[50]. These experiences can help manage stress, anxiety, and depression. Teletherapy sessions can also take place within the metaverse, enabling patients to receive care from the comfort of their homes. This reduces geographical barriers and makes mental health services more accessible to remote and underserved areas[51]. Moreover, cognitive behavioral therapy (CBT) sessions in VR environments can help patients identify and challenge their negative thoughts and behaviors in an interactive manner[52]. For individuals with social anxiety or certain developmental disorders, metaverse can provide a platform for safe social interactions and skills development[53]. It can help patients identify and challenge their negative thoughts and behaviors in an interactive manner. In terms of gamified therapies, digital therapeutics within metaverse can incorporate gamified elements to enhance engagement, especially for younger populations. For instance, children with ADHD (attention deficit hyperactivity disorder) are now treated with games designed to improve their attention or resilience-building exercises for anxiety and depression[54]. Metaverse can also serve as a training ground for mental health professionals through simulations, which can enhance empathy, improve therapeutic skills, and prepare therapists for a wide range of clinical situations[29]. In other words, metaverse and other immersive technologies can revolutionize mental healthcare by providing innovative, immersive, and highly adaptable treatment options that are accessible and engaging for a wide range of patients.

The integration of metaverse in mental healthcare offers numerous research opportunities, including evaluating the long-term efficacy of virtual therapies through clinical trials and longitudinal studies[55], and enhancing personalization using AI and digital twins[56]. Research on gamified and VR therapies, especially for conditions like PTSD and ADHD, and the development of culturally sensitive content are vital. Moreover, future directions should address the issue of digital divide and improve digital literacy to ensure equitable access[57]. Further, there should be research on developing data protection and clear ethical guidelines for patient and user privacy, security, and ethical considerations. Interdisciplinary research and the integration of metaverse-based therapies with traditional methods will help optimize treatment outcomes and professional practices, ultimately transforming mental health services[58]. In the light of this discussion, it is relevant to argue that digital and immersive technologies like metaverse and their innovations have initiated the transformation of the landscape of mental health services. It has further highlighted various aspects of digitalization and immersive technologies. Figure 3 below presents the critical elements of metaverse applications in mental healthcare. It emphasizes patient-therapist interactions through 3D therapy sessions and remote accessibility, AI-driven personalized interventions, collaborative approaches, treatment modalities such as exposure and gamified therapies, privacy and confidentiality measures, and the promotion of accessibility and inclusivity through mHealth platforms and cultural sensitivity.

The metaverse also holds significant potential to address several longstanding challenges in mental healthcare. For instance, patients in remote or underserved areas usually lack access to mental healthcare due to reasons like geographical barriers, limited healthcare infrastructure, and socio-economic constraints. Metaverse can provide virtual therapy sessions and clinics worldwide, reducing the need for physical travel. Traditional therapy methods sometimes struggle to engage patients, particularly younger populations, leading to poor adherence to treatment plans. However, metaverse applications like gamified therapies and immersive experiences can create more interactive and engaging therapy sessions. Moreover, technologies like AI, machine learning, and digital twins can tailor personalized treatment plans. There are other challenges of stigma associated with seeking mental healthcare, lack of adequate training for mental health professionals. Metaverse can provide virtual environment with anonymity and privacy while training professionals virtually and through simulations. Metaverse also offers innovative solutions to issues of cultural sensitivity and cost. By leveraging immersive,

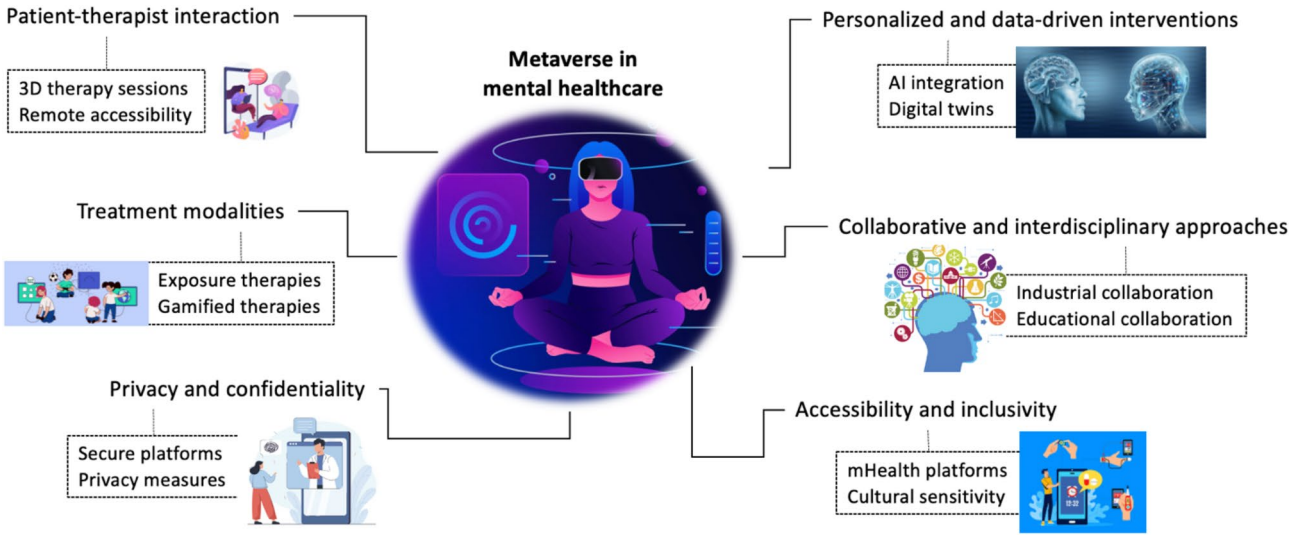


Fig. 3. Metaverse applications in mental healthcare.

interactive, and personalized virtual environments, the metaverse can transform mental health services, making them more effective, inclusive, and accessible to a broader population.

Digital technologies are continually evolving, providing numerous contributions that enhance the delivery and effectiveness of mental health services. In terms of telehealth and teletherapy, these technologies reduce barriers related to geography and mobility, making it easier for individuals in remote or underserved areas to access mental health services. This can further lead to the development of more sophisticated telehealth platforms with integrated AI for real-time patient monitoring and immediate response capabilities[59]. AI-driven tools are currently assisting in diagnosing mental health conditions, personalizing treatment plans, and providing chatbots for immediate support. More advanced AI systems with better human emotions and behavioral identifications can further improve diagnostic accuracy and treatment personalization while providing ongoing support and crisis intervention. The role of digital twins represents a significant advancement in the personalization and management of mental healthcare. More advanced and complex models that incorporate a wider range of data, including environmental and social factors, can be developed to enhance predictive accuracy as well as scenario-based simulations for more comprehensive treatment planning[38,60]. This further leaves significant room and scope for concerns like widespread and global accessibility, patient data protection and management[61], and cybersecurity frameworks and protocols design[62,63] while blending digital and traditional mental health therapies. These technologies address existing challenges, enhance therapeutic approaches, and offer new opportunities for engagement and education. As these technologies continue to evolve, they will likely play an increasingly integral role in mental health care, fostering a more integrated, responsive, and holistic approach to mental health and well-being.

Materials and methods

The current study aimed at exploring and analyzing the effectiveness of metaverse applications in the mental healthcare. It used systematic research and case studies to address various aspects of metaverse-based applications and mechanisms in mental healthcare. Details are discussed in the following sections.

Systematic literature review (SLR)

The study conducted SLR research on existing literature addressing the use of metaverse applications in mental healthcare while emphasizing the potentials of the metaverse as a transformative tool for this sector. The discussion and analysis of the SLR focused on answering the following research questions (RQs):

- **RQ1**: What are the existing and emerging metaverse-based mechanisms to address and improve mental health conditions?
- **RQ2**: How effective are these mechanisms in real-world applications?
- **RQ3**: What are the potential risks of using these mechanisms?

While discussing the effectiveness of these mechanisms, the study also emphasized possible factors ensuring the effective use of metaverse technologies in mental healthcare. In terms of evaluating risk concerns of using these mechanisms, it elaborated strategies that can mitigate these risks. The study employed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, which is known for its ability to evaluate the quality of chosen studies and synthesize outcomes effectively. The PRISMA approach offers structured interpretations, along with transparency, quality, and reproducibility in its review process. Serving as an essential instrument for conducting systematic reviews, the PRISMA method upholds high reporting standards, ensuring that such studies offer significant contributions to scientific knowledge. The current study

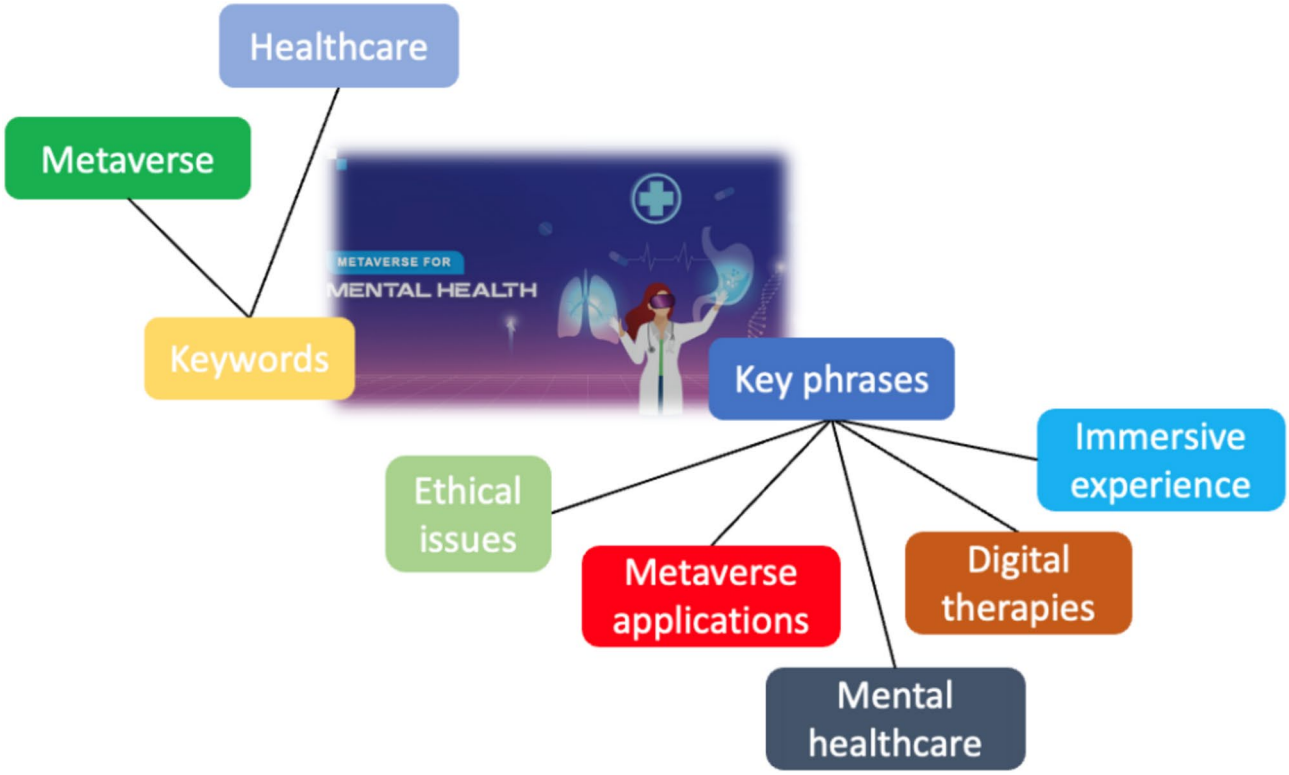


Fig. 4. Keywords search for SLR.

Literature type	Journal articles, conference papers
Language	English
Publication span	2020-24

Table 1. Inclusion and exclusion criteria.

used it to collect data from two leading online databases: IEEE and Google Scholar. It collected a total of 49 publications addressing different concerns of the metaverse and its applications in the mental healthcare sector and its therapeutic practices. The primary keywords and phrases used for its data search are shown in Fig. 4 below. It illustrates the key phrases and concepts identified through a keyword search related to the use of the metaverse in mental healthcare. It highlights important themes such as metaverse applications, digital therapies, ethical issues, immersive experiences, and mental healthcare, all of which are central to discussions about the integration of metaverse technologies in the healthcare domain.

Using the PRISMA guidelines, the study selected 49 articles published within the span of 2020 and 2024. This span was chosen for the study because technological advancements including metaverse and other immersive technologies witnessed a transformative shift in different sectors including everyday life. In the context of mental healthcare, the use of metaverse applications is a relatively recent and innovative development in the field of telemedicine and digital health that offers a new dimension for delivering mental health services with several potential benefits. Therefore, the current study selected the 2020-24 span of publication addressing related issues in the concerned field. It also used MMAT (Mixed Methods Appraisal Tool) for evaluating the relevance of the selected data and further synthesizing the findings of the SLR. MMAT is used mainly for the validity and reliability of these synthesized findings while maintaining the transparency and consistency of PRISMA-based selection process of the collected and screened data[64]. Parameters chosen for the selection of the publications are shown in Table 1 below.

The selection process involved four main phases: identification, screening, eligibility, and inclusion. The study identified 49 articles out of which 25 met the chosen criteria. The selection criteria were adapted from the standard PRISMA guidelines of[65]. The selection process is shown in Fig. 5 below. It depicts the selection process for the systematic review, following the PRISMA methodology. The figure outlines the stages of identification, screening, eligibility, and inclusion, along with the MMAT application for quality assessment. A total of 25 studies were included in the final review after evaluating records from IEEE and Google Scholar databases, with exclusions based on non-English content and non-alignment with the research scope.

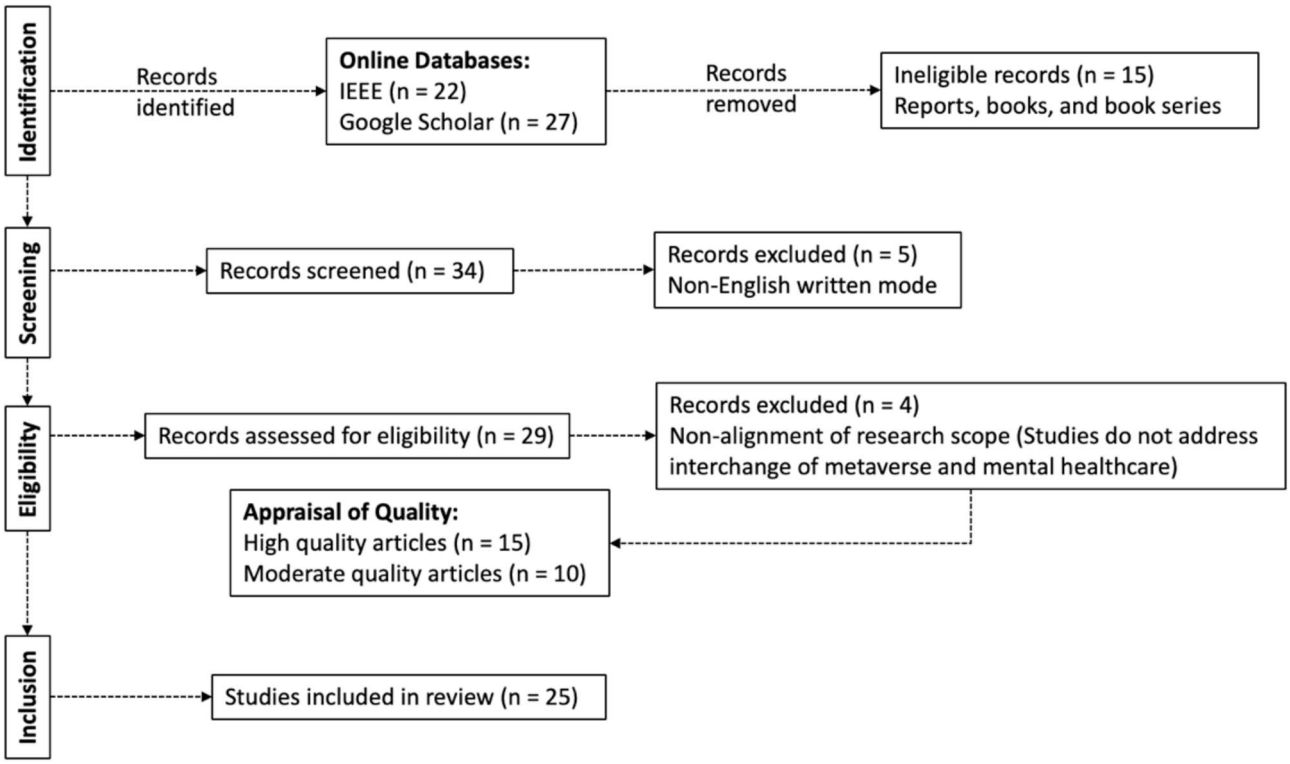


Fig. 5. Selection process using PRISMA and MMAT.

Case study

The current study conducted case study research emphasizing metaverse-based digital therapies or DTx. DTx solutions are evidence-based therapeutic interventions driven by high-quality software programs to prevent, manage, or treat a medical disorder or disease. These solutions are an emerging trend in healthcare that uses digital and online health technologies to stimulate changes in patient behavior and provide remote monitoring to improve long-term health outcomes. In the context of mental healthcare, DTx solutions are used in a wide array of mental health conditions including depression, anxiety, PTSD, and substance abuse while providing new ways to deliver care that can complement or, in some cases, substitute traditional therapeutic practices. The current study selected four DTx practices to support mental healthcare: NightWare, Freespira, EndeavorRx, and Sleepio. These applications demonstrate the potential of digital and Metaverse-based technologies to provide effective, accessible, and user-friendly treatment options for various mental health conditions. Figure 6 below illustrates the research design adopted for the study. It combines SLR research using databases such as IEEE and Google Scholar, along with tools like PRISMA and MMAT, to assess existing mechanisms, effectiveness, and potential risks of metaverse-based mental healthcare. Additionally, a case study on DTx practices is included to provide practical insights into the application of metaverse technologies in mental health interventions.

Findings of the SLR and case study are discussed in the next section.

Results and discussion

The current study conducted SLR and case study research on metaverse-based applications in mental healthcare highlighting the existing mechanisms, their effectiveness, and potential risks associated with them. This section includes its results and discussion.

Digital therapies

Digital therapies in mental healthcare are rapidly evolving, facilitating technology to provide evidence-based interventions. These therapies aim to treat, manage, or prevent mental health disorders through software programs, often used alongside traditional treatment methods or as standalone therapies. Among the common DTx in mental healthcare include CBT apps, the most prevalent digital therapies, designed to deliver CBT for various conditions such as anxiety, depression, and insomnia. Many CBT apps offer interactive therapy sessions that guide users through various cognitive and behavioral exercises[66]. These sessions often emulate face-to-face therapy in structure but are delivered through text, audio, or video formats. To facilitate self-awareness and track progress, CBT apps typically include features for monitoring mood, thoughts, and behaviors[67]. Users can log their feelings, symptoms, and any noteworthy events, helping them and their therapists identify patterns and triggers. Consistent with traditional CBT, these apps often assign 'homework' – activities or practices that users must complete outside of therapy sessions to reinforce learning and apply strategies in real-life situations[68]. Moreover, CBT apps usually provide educational materials that help users understand the principles of CBT and

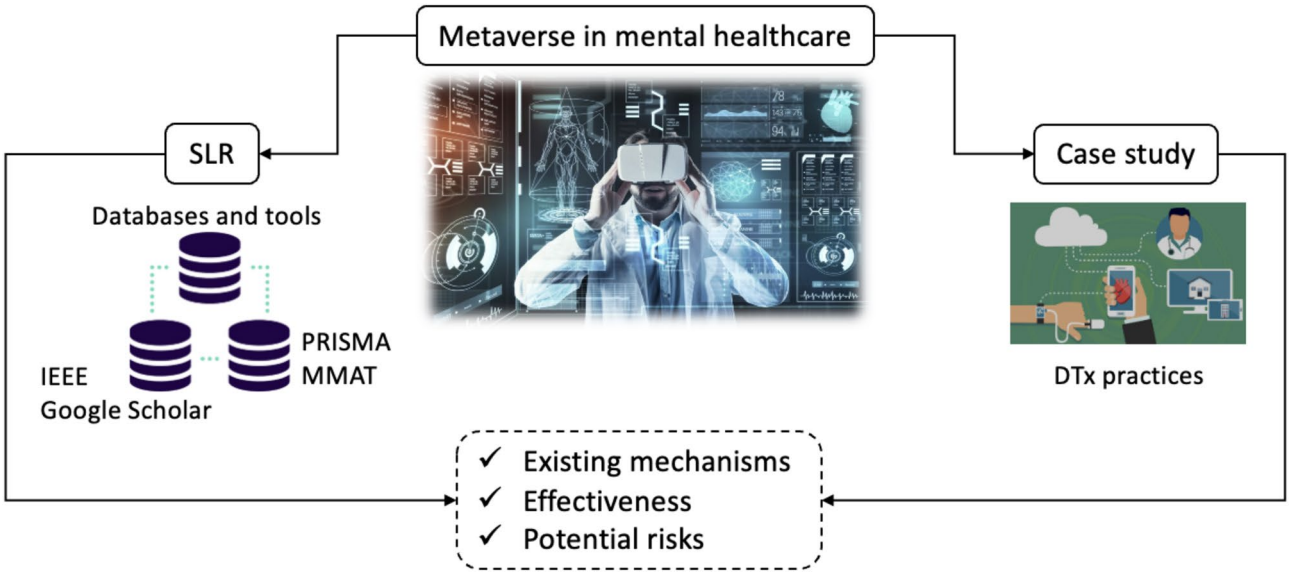


Fig. 6. Research design.

how they apply to managing conditions like anxiety, depression, and stress[69]. Apps like Sleepio (to be discussed later under case studies) use CBT principles to help users manage sleep problems, while others like Woebot and MoodKit offer tools and exercises for anxiety and depression. Woebot uses AI to deliver CBT through friendly and supportive conversations while monitoring users daily by providing personalized responses based on their inputs[70]. Whereas MoodKit uses CBT principles to help users improve their mood by engaging in mood-enhancement activities and thought checking[71].

There are devices and apps that provide biofeedback and neurofeedback enable users to control or modify their physiological processes (such as heart rate variability) to improve mental health conditions[72,73]. Freespira (to be discussed later under case studies) is one such app, which treats panic disorder by training users to stabilize their breathing. Platforms like Headspace and Calm deliver guided meditation sessions and mindfulness exercises that help reduce stress, anxiety, and symptoms of depression, enhancing overall mental well-being[74]. There are also VR therapies used for immersive therapy sessions, particularly for conditions like PTSD, phobias, and anxiety disorders. As a transformative approach, a VR-based therapy allows patients to confront fears in a controlled and safe virtual environment under the guidance of a therapist. The VR environment is designed to help patients confront and process their memories safely, which can reduce the power of those memories to trigger distress[75]. The controlled setting also helps therapists to carefully manage the exposure, ensuring the patient is not overwhelmed. For instance, Bravemind is a VR application developed specifically for military veterans with PTSD. It recreates battle scenarios they experienced, allowing them to work through their trauma with a therapist. Developed by researchers of Institute for Creative Technologies at the University of Southern California, Bravemind uses VR technology to create highly detailed and immersive simulations of various combat scenarios that are commonly experienced by service members[76]. These scenarios include a range of environments such as Middle Eastern cityscapes, desert roadways, and Afghan villages, among others. Under the guidance of a trained therapist, the veteran is gradually exposed to traumatic stimuli within the safety of a virtual environment. The therapist can control every aspect of the simulation, adjusting the intensity of the environment to tailor the therapy according to the patient's response. This controlled exposure helps to evoke memories in a manageable way, allowing the veteran to confront and work through their trauma.

Some digital therapies incorporate game elements to engage patients, particularly children and adolescents. These 'gamified' therapies are designed to be visually appealing and fun, using colorful graphics, interactive narratives, and character-driven stories[77]. These elements make the therapeutic process more engaging for users, particularly for younger audiences who are naturally drawn to video games. EndeavorRx (to be discussed later under case studies), for instance, is a prescription video game designed to improve attention in children with ADHD. SuperBetter is another game for designed to help users build personal resilience and mental well-being that includes challenges and quests focusing on achieving personal health and psychological goals[78]. Gamified digital therapies provide immediate feedback on users' actions, which is crucial for learning and behavior modification[79]. This feedback helps users understand what they are doing right and where they need improvement, facilitating a more active learning process. These therapies often include reward systems such as points, levels, badges, or unlockable content designed to reinforce positive behavior and encourage users to stick with the treatment by completing therapeutic tasks or achieving goals[80]. Therefore, gamified digital therapies represent a merging of technology, psychology, and entertainment, creating powerful tools that appeal to users while delivering clinically effective interventions addressing mental health issues in younger populations.

In the light of this discussion, it is evident that CBT-based digital therapies are instrumental in breaking down geographical barriers, making mental health support accessible to individuals in remote or underserved areas while providing viable options and on-demand support at lower costs[81,82]. Many digital therapy apps

leverage AI to tailor interventions based on user inputs and progress, incorporating interactive features like mood tracking, thought logging, and interactive exercises. The integration of digital therapies into traditional care models can result in a more comprehensive approach to mental health treatment, combining the strengths of both methods[83]. Although many digital therapies show promise, ongoing research is necessary to validate their effectiveness across diverse populations and mental health conditions. Additional studies are needed to assess the long-term outcomes of digital therapies and their sustained impact on mental health. For example, the gamification aspect in digital therapies requires further research to enhance therapeutic activities and user engagement to achieve desired outcomes[84–86]. Gamified digital therapies blend technology, psychology, and entertainment, creating engaging tools that deliver clinically effective interventions. These therapies have demonstrated significant potential in addressing mental health issues, particularly in younger populations. However, concerns regarding their usefulness, accessibility, and potential overuse are significant for their sustainable integration into mental healthcare[87,88]. Digital therapies collect sensitive personal information, raising data privacy and security concerns that require thorough investigation[89]. Robust measures must be implemented to protect user data from breaches and unauthorized access. Additionally, the digital divide issue needs addressing, as not everyone has access to the necessary technology or internet connectivity required for digital therapies[90]. Some populations, particularly older adults or those with limited digital literacy, may struggle to use digital therapy apps effectively. Therefore, providing education and support to improve digital literacy is essential. To fully realize the potential of CBT-based digital therapies, it is critical to address concerns related to effectiveness, user engagement, and the digital divide, among other issues. Biofeedback, neurofeedback, and VR therapies offer promising advancements in mental healthcare by providing personalized, evidence-based, and immersive treatment options. While these technologies have shown significant potential, addressing concerns related to long-term efficacy, user engagement, privacy, accessibility, and ethical use is essential for their sustainable integration into mental healthcare.

Case studies

The current study investigated four metaverse-based and evidence-based applications used in mental healthcare including NightWare, Freespira, EndeavorRx, and Sleepio. NightWare[91] is a prescription digital therapeutic system that uses an Apple Watch and an Apple iPhone to help improve sleep for people suffering from nightmare disorders or nightmares related to PTSD. The device monitors heart rate and body movement during sleep to deliver interventions when nightmare-related stress is detected, all without waking the user. This innovative approach is aimed at improving sleep quality without the need for medication. Freespira[92] is designed for patients experiencing panic attacks or PTSD symptoms. Freespira uses a sensor to monitor breathing patterns and provides feedback to help users adjust their breathing rhythm to reduce symptoms. It involves two 17-minute sessions per day over a four-week period, guided by a coach. This non-pharmaceutical approach aims to train users to control their breathing to manage and significantly reduce symptoms. Originally designed for children with ADHD to improve attention, EndeavorRx[93] is a digital therapeutic system that involves engaging the patient in a video game-like treatment that is clinically validated to improve attention function. It requires the use of specific iOS and Android devices and can be used without continuous internet connectivity, although initial setup and regular updates require Internet access. Sleepio[94] is an innovative digital therapeutic system designed to improve sleep and manage insomnia in adults. Details of these digital therapeutics are summarized in Table 2 below. It summarizes key digital therapeutic solutions for various mental health conditions, highlighting their treatment targets, main features, functions, and operating requirements. The table includes NightWare for managing PTSD-related nightmares, Freespira for panic attacks and PTSD, EndeavorRx for attention improvement in children with ADHD, and Sleepio for insomnia. Each therapeutic application utilizes different technological platforms and intervention methods to provide personalized, condition-specific treatments.

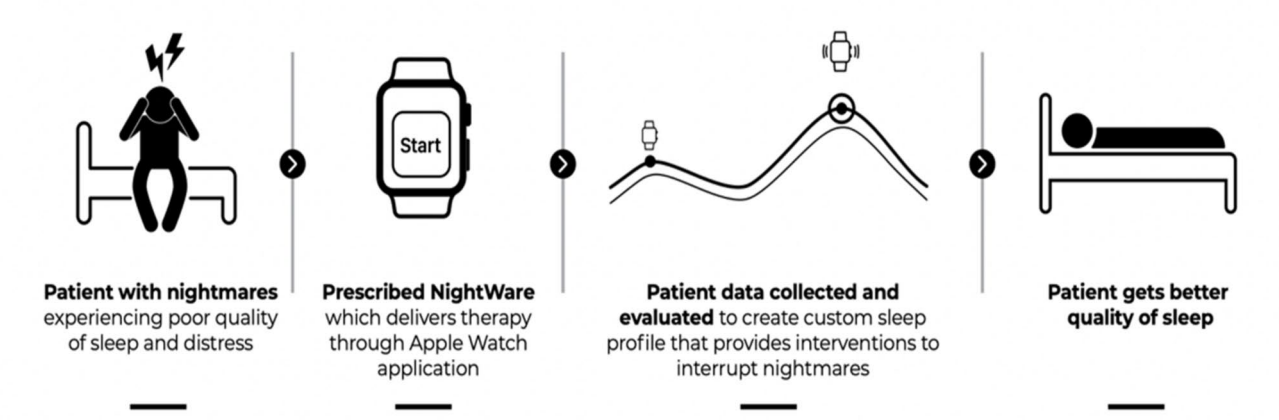
As a prescription digital therapeutic, NightWare helps patients with severe nightmares related to PTSD and trauma improve their sleep quality. It needs an Apple watch and iPhone along with Internet access to capture sleep data (from heart rate, body movement or acceleration, and body position or rotation) and analyze sleep

DTx	Treatment for	Features	Functions	Operating requirements
NightWare	Nightmares associated with PTSD	Uses Apple Watch and iPhone to monitor sleep patterns. Delivers gentle vibrations to disrupt nightmares without waking the user.	Sleep monitoring to identify signs of nightmares. Intervention to alter sleep stage and reduce nightmare frequency.	iPhone 7, Apple Watch 3, iOS 13, and WatchOS 6, or newer, Internet access
Freespira	Panic attacks and PTSD	A sensor to monitor breathing rate and CO_2 levels. Audio feedback to guide breathing.	Trains users to breathe at a therapeutic rate to normalize CO_2 levels and reduce symptoms. Performed twice daily over a four-week period.	Breathing sensor, smartphone/tabloid with Android/iOS platform, Internet access
EndeavorRx	Attention in children with ADHD	Interactive video game interface designed to target attentional control. Available on iOS and Android devices.	Enables users navigate through tasks and obstacles that require focus and task-switching abilities. Intended to be part of a comprehensive ADHD treatment plan.	iOS 13, Android OS 9 or newer, Internet access
Sleepio	Insomnia and poor sleep disorder	Personalized sleep improvement program based on cognitive behavioral therapy principles. Interactive sleep diary and weekly modules.	Provides cognitive techniques to tackle the root causes of insomnia. Behavioral strategies to reset sleep patterns.	Smartphones/tablets/computers with iOS/Android OS/Windows/macOS, Internet access, user account

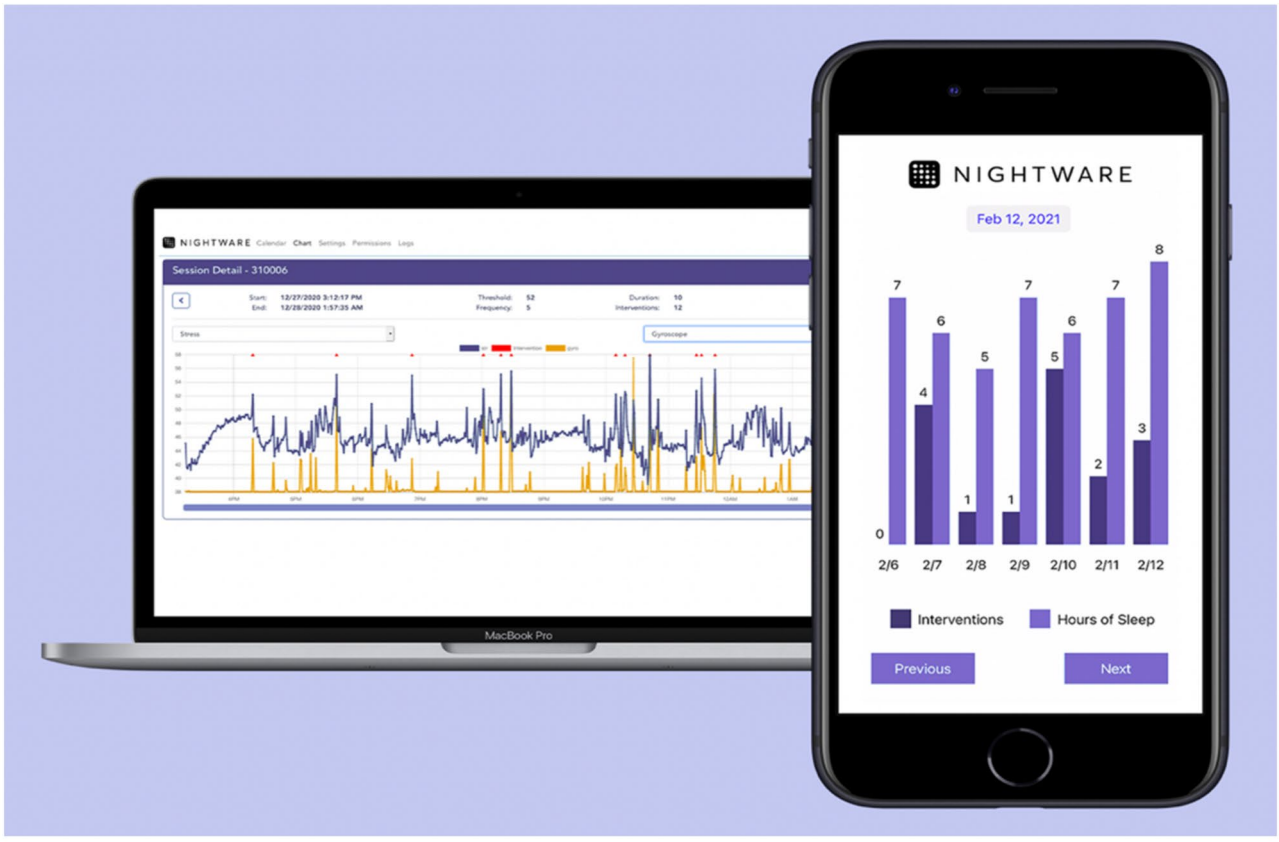
Table 2. Overview of DTx case study details.

patterns of patients. It offers an easy-to-use interface along with clear instructions for providers and patients, as shown in Figs. 7(a-b) below.

Figure (a) demonstrates the NightWare system, showing the step-by-step process from a patient with nightmares receiving a prescribed NightWare therapy through an Apple Watch application. The system collects patient data, analyzes it, and provides customized interventions to interrupt nightmares, ultimately improving sleep quality. Whereas Figure (b) shows the user data collected and displayed by NightWare, including graphical representations of interventions performed and hours of sleep over a period. The data helps track patient progress and adjust interventions to improve therapeutic outcomes. As an evidence-based system, a double-blind, sham



(a)



(b)

Fig. 7. NightWare system for managing nightmares in patients. (**a**) Instruction details for NightWare users, (**b**) User data statistics in NightWare[91].

controlled, randomized clinical trial supports the safety and efficacy of NightWare (NW101002)[91]. NightWare is regulated as a medical device and has received clearance from the US Food and Drug Administration (FDA) to ensure its safety and effectiveness[95]. Results of the clinical trials indicated that using NightWare led to a significant reduction in the impact of nightmares on sleep quality compared to a control group, supporting its efficacy as a therapeutic tool[96,97]. This is significant because rigorous clinical validation and patient safety are primary concerns in regulatory frameworks when it comes to reviewing the increasing trends of rapid innovation in the field of digital therapeutics[98]. The regulatory approval, clinical validation, and focus on patient safety make NightWare a pioneering example in the field of digital therapeutics for mental health, particularly for managing sleep disturbances associated with PTSD. It highlights how digital solutions can be effectively integrated into therapeutic practices, provided they undergo rigorous testing and adhere to strict regulatory standards.

Freespira is a medication-free, FDA-approved digital therapeutic treatment for patients with panic attacks and PTSD, which addresses the underlying breathing irregularities (breathing rates and CO_2 levels) of patients, as shown in Figs. 8(a-b) below. Figure (a) illustrates the use of Freespira, where a data logger is employed to monitor patient respiratory conditions during a remote session with a healthcare provider. The device is used to track real-time data that assists in delivering personalized therapy. Whereas Figure (b) presents the respiratory data recorded by Freespira, showing the measurement of end-tidal CO2 levels over multiple therapy sessions. The graph displays the variability of CO2 levels across different measurement points (B CO2, P CO2, T CO2), which is used to assess the patient's respiratory patterns and the effectiveness of the therapy. It is clinically proven effective to reduce symptoms of panic disorder up to 40% or more[99].

Freespira operates using a specially designed sensor that patients wear around their torso. This sensor measures the breathing rate and exhaled CO_2 levels critical for the efficacy of the therapy. The sensor is connected to a data logger that records the breathing data. This device typically has a display or interfaces with a tablet or smartphone app (and Internet) that provides real-time feedback to the user about their breathing patterns. Moreover, patients receive initial training from a healthcare provider or a trained Freespira specialist on how to properly use the device and interpret the feedback it provides. Freespira treatment typically involves two daily sessions of 17 min each over a four-week period. Freespira highlights an innovative use of digital therapeutics in mental health, which can be used effectively to help patients manage and potentially overcome panic disorder and PTSD symptoms.

The FDA-approved EndeavorRx is one of the first video game-based treatments, marking a significant milestone in the integration of technology and healthcare. Its clinical clearance was based on five clinical studies in over 600 children with ADHD, which demonstrated significant improvements (up to 73%) in children with ADHD (ages 8–12) during a four-week treatment period[93]. It is a prescription-based treatment, shown in Figs. 9(a-b) below, intended to be used as part of a therapeutic program that may include other treatments such as counseling and education. Patients can use compatible mobile devices like iPhone or iPad to play the video game designed to challenge their attentional control during the gameplay with focus and flexibility to manage multiple tasks at the same time[93]. Its prescribed usage is approximately 25 min per day, five days per week, and for at least four consecutive weeks. Figure (a) shows the data monitoring feature of EndeavorRx, a digital therapeutic platform designed for children with ADHD. It displays a player's daily and weekly progress, tracking the number of therapy sessions completed and the total time spent on cognitive tasks. Whereas Figure (b) illustrates the game-based therapy mode of EndeavorRx. It shows how cognitive tasks are gamified, engaging patients in therapeutic activities through immersive game design aimed at improving attention and focus on children with ADHD.

The non-drug approach of EndeavorRx is particularly appealing for those seeking alternatives to traditional ADHD medications, which can come with more significant side effects. EndeavorRx exemplifies how digital therapeutics can be developed, validated, and regulated as bona fide treatments in mental healthcare. It accentuates the potential of innovative technologies to create new treatment paradigms, especially in areas where traditional therapies are insufficient or come with considerable drawbacks.

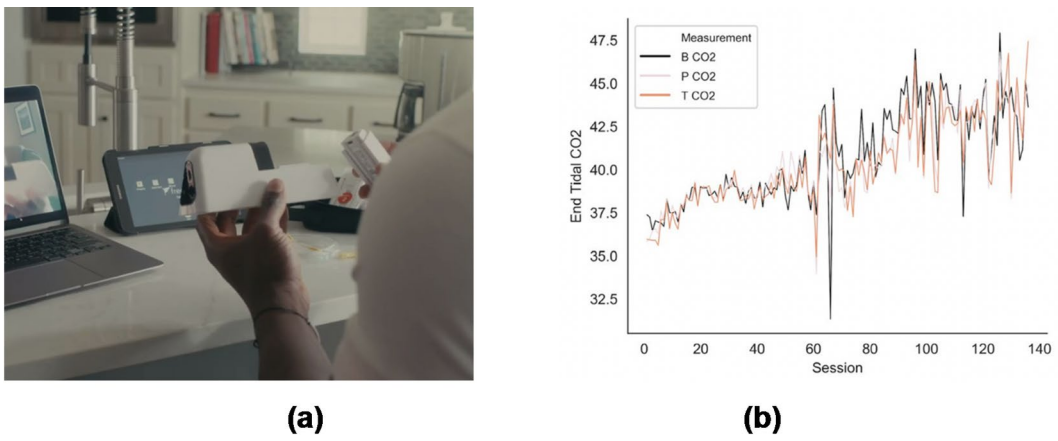


Fig. 8. Freespira system for managing respiratory conditions (**a**) Data logger in Freespira[92], (**b**) Respiratory recording details in Freespira[99].

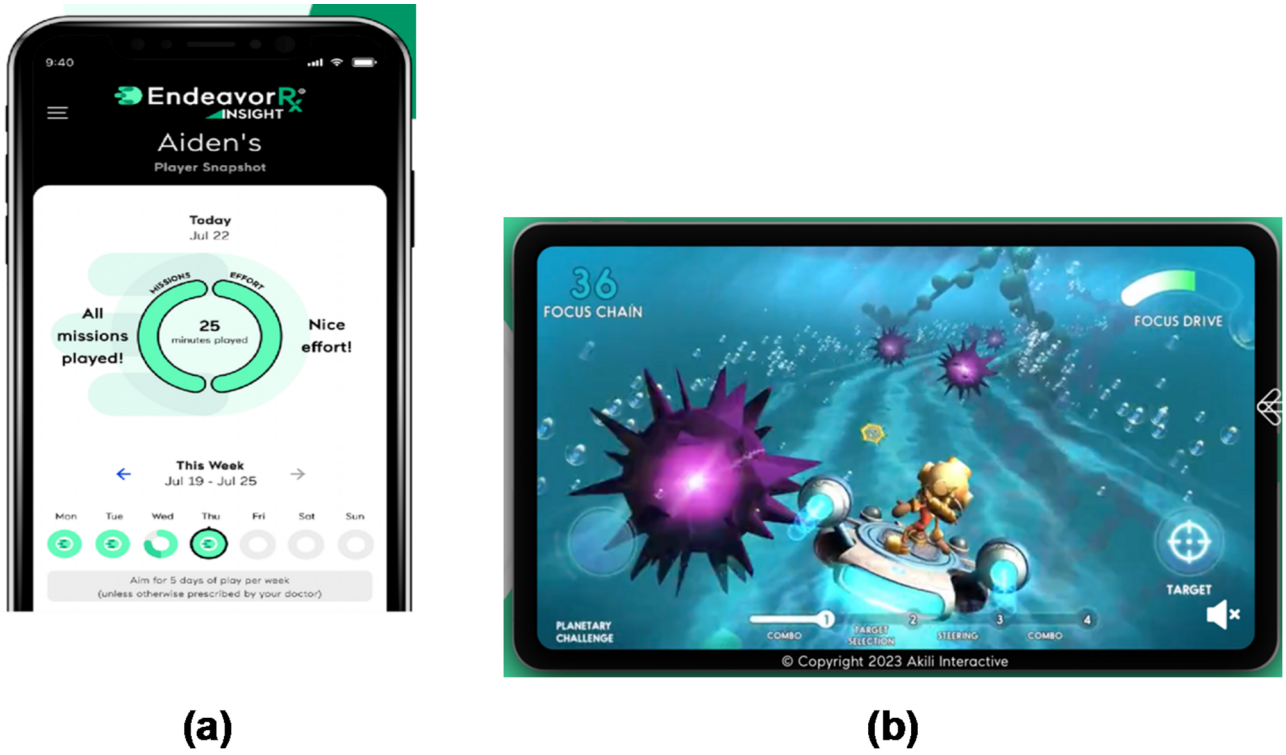


Fig. 9. EndeavorRx system for ADHD management. (**a**) Data monitoring in EndeavorRx, (**b**) Video game mode in EndeavorRx[93].

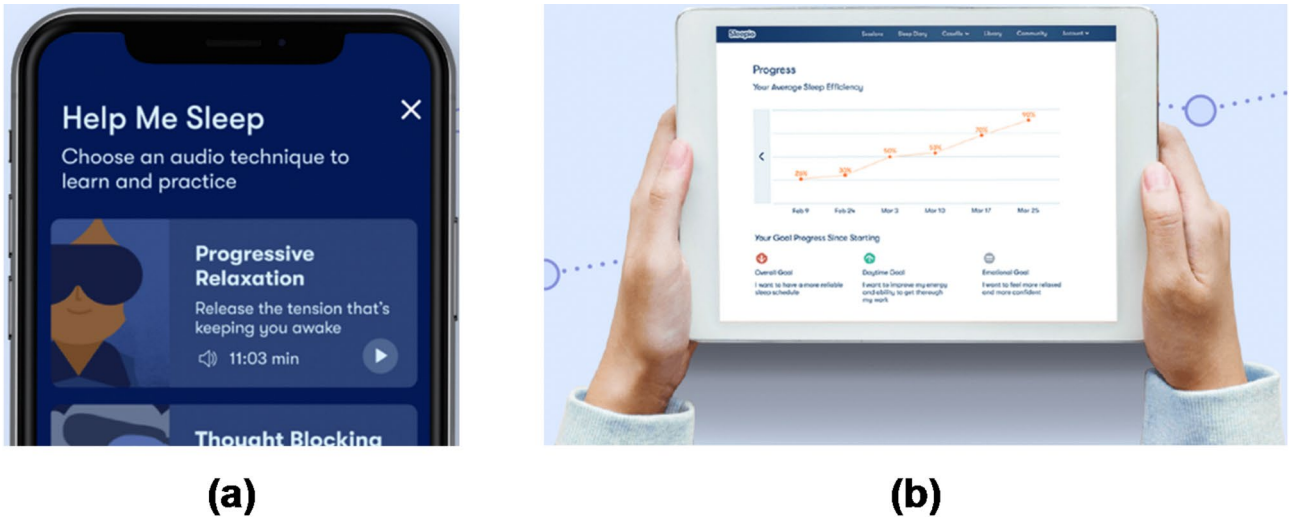


Fig. 10. Sleepio digital therapeutic for sleep improvement. (**a**) Sleepio on mobile device, (**b**) Data monitoring in Sleepio[94].

Sleepio is a digital therapeutic designed to help individuals manage and improve their sleep quality using CBT for insomnia. Developed by Big Health, Sleepio represents a significant advance in the digital treatment of sleep disorders. It is a six-week self-directed program for improving poor sleep quality. Its clinical studies reported remarkable improvement in 76% of insomnia patients[94]. It can be accessible through smartphones, tablets, or computers with Internet connectivity as shown in Figs. 10(a-b) below. Figure (a) shows the Sleepio app's interface on a mobile device, where users can access various audio-based techniques, such as Progressive Relaxation, to aid in improving sleep quality. Whereas Figure (b) illustrates the data monitoring dashboard in Sleepio, where users can track their sleep efficiency over time and monitor progress towards their sleep-related goals, such as improving sleep quality and emotional well-being. The Sleepio app can be downloaded on mobile devices from the Apple App Store or Google Play Store. Users must create an account with Sleepio, providing

necessary information to personalize their treatment program. This typically involves answering questions about sleep patterns, lifestyle, and general health.

Each of these digital therapeutics brings a unique approach to treating specific health conditions, backed by clinical research, and designed with user-friendly interfaces to ensure engagement and efficacy. The use of digital and technology-assisted therapies is relevant in terms of effectiveness and efficacy in mental healthcare, particularly for conditions like panic disorder where traditional treatments (pharmacotherapy and psychotherapy) might not be sufficient or preferred by all patients. These digital therapeutics are also a significant step towards the adoption of an effective and efficient mental healthcare. Recent and ongoing clinical studies have emphasized on the aspects discussed (see Table 3 below), leading to the capabilities and potentials of these digital therapies to manage and improve various mental health irregularities. It outlines the ethical and regulatory requirements, research background, and documented outcomes of four digital therapeutics: NightWare, Freespira, EndeavorRx, and Sleepio. Each therapeutic application has undergone clinical validation and regulatory approval to ensure patient safety and efficacy. The table also highlights key research studies that have demonstrated their effectiveness in reducing symptoms related to PTSD, panic attacks, ADHD, and insomnia, along with long-term benefits and endorsements by regulatory bodies like the FDA and NICE.

In the light of this discussion, it is evident that these digital therapeutics demonstrate the potential for innovative, technology-driven solutions to transform mental healthcare[119]. These therapies offer personalized, evidence-based, and immersive treatment options that address various mental health conditions. However, addressing concerns related to long-term efficacy, user engagement, privacy, accessibility, and ethical use is essential for their sustainable impact across mental healthcare. Conducting long-term studies and expanded research is essential for validating the sustained impact of digital therapies across diverse populations and conditions while exploring the effectiveness of gamified and immersive digital therapies[120]. Importance should also be given to continuous updates of interactive and innovative therapeutic content for optimizing user engagement and treatment outcomes. Moreover, issues like data protection, privacy, and transparency should be highlighted with the aim of developing clear and transparent policies. Further research should explore and address concerns of digital literacy, cultural inclusivity, sustainability, and ethical practices in digital therapies to evolve and provide effective support for mental health conditions, enhancing the overall therapeutic landscape. In other words, integration of mental healthcare with emerging technologies like AI, metaverse, and big data analytics is instrumental in enhancing the personalization and effectiveness of digital therapies. Such advancements could lead to expanding into new therapeutic areas for a broader range of mental health conditions, such as bipolar disorder, schizophrenia, and substance abuse disorders[24,121]. More specifically, the extensive use of AR and VR technologies can result in creating more immersive and interactive therapeutic experiences. With a global audience in focus, mobile health (mHealth) platforms can also play important roles to provide accessible and affordable mental health support[122]. This further necessitates the relevance of collaboration and interdisciplinary research to explore the intersections of mental health, technology, and social factors ensuring broader reach and impact.

Effectiveness of immersive therapies

Immersive therapies in mental healthcare, particularly those involving VR and AR, have shown considerable promise in treating a variety of mental health conditions. These therapies utilize immersive technology to create controlled, simulated environments that can facilitate therapeutic interventions in ways that traditional methods cannot. As discussed in the case studies above, immersive therapies have proven especially effective in treating anxiety disorders and specific phobias. The controlled and safe environment of VR allows for systematic exposure therapy, where patients gradually confront their fears in a controlled setting. Studies[47,123,124] have consistently shown that VR exposure therapy can reduce fear and anxiety to a similar extent as in-vivo exposure, and these effects are maintained over time. In the case of PTSD treatments, immersive VR therapy allows patients to revisit and process traumatic events in a safe and controlled manner[125]. Therapists can tailor the virtual environment to each patient's experiences, facilitating the processing of traumatic memories without the need for actual physical return to the traumatic site. Research[126] indicates that VR exposure therapy can significantly reduce PTSD symptoms, with some studies[127] showing effectiveness comparable to or better than traditional exposure therapies. Immersive therapies can also be used to treat depression, particularly by promoting experiences that can help improve mood, increase motivation, and foster emotional resilience. VR can create positive,

DTx	Ethical/regulatory requirements	Research	Outcome
NightWare	Regulatory approval, clinical validation, patient safety	Clinically tested and FDA-approved for reducing nightmare frequency[100,101]	Demonstrated effectiveness in reducing the frequency and intensity of nightmares in PTSD patients[102,103]
Freespira	Regulatory approval, clinical validation, patient training and support, patient data privacy regulations	Studies[104,105] show significant reduction in panic symptoms and improvement in overall quality of life	Many users experience long-term relief from panic disorder and PTSD symptoms after completing the treatment[106,107]
EndeavorRx	Regulatory approval, clinical validation, patient safety, usage monitoring and support	The first FDA-approved digital therapeutic for ADHD; shown to improve attention in clinical trials[108,109]	Improved attentional function in children with ADHD, as reported in clinical studies and ongoing real-world feedback[110,111]
Sleepio	Regulatory approval, clinical validation, patient safety, data privacy and security standards	Extensively researched with numerous published studies demonstrating effectiveness[112,113] Endorsed by the UK's National Institute for Health and Care Excellence (NICE) for treating insomnia[114,115]	Significant improvements in sleep latency, duration, efficiency, and overall quality of sleep[116,117] Reduction in reliance on sleep medications in many users[118,119]

Table 3. Ethical and regulatory requirements, research, and outcomes of DTx in mental healthcare.

RQ1: Digital therapies	RQ2: Effectiveness	RQ3: Risks
Evidence-based	Controlled and simulated scenarios	Overstimulation
Clinically approved	Safe VR exposure therapies	Trauma triggers
Interactive therapy sessions	Improved cognitive and coping skills	Cybersickness
Self-monitoring	Enhanced emotional resilience	Data privacy and ethical concerns
User control and feedback	Relaxation and mindfulness	Virtual overdependency
Gamified immersive therapies	Increased self-esteem	Technical malfunctions

Table 4. Key highlights of RQ finding.

calming environments for relaxation and mindfulness[128], or simulate scenarios where patients can practice social interactions or achieve tasks that help improve self-esteem and coping skills[129]. Initial studies and pilot programs[130] have shown promising results in using VR to alleviate symptoms of depression, particularly in cases where traditional therapy has been ineffective.

VR therapies are used in cognitive rehabilitation to help recover skills lost due to injury or illness[131]. Immersive games and scenarios can help patients practice cognitive skills like memory, attention, and problem-solving in an engaging and motivating way. VR has been successfully used in the rehabilitation of cognitive function in stroke survivors, individuals with traumatic brain injuries, and older adults experiencing cognitive decline[132]. In the light of this discussion, findings highlight significant potential of immersive therapies for enhancing mental health treatment outcomes across various conditions along with innovative approaches.

Risks and concerns

While the metaverse offers significant potential for enhancing mental healthcare, it also introduces notable risks. Data privacy and cybersecurity are primary concerns, as the collection and storage of sensitive patient information in immersive environments raise the risk of data breaches. Additionally, the interconnected nature of metaverse platforms may expose users to cybersecurity vulnerabilities, which could compromise the security of mental health services. Furthermore, over-reliance on digital therapies might limit patient engagement in real-world social interactions, while the immersive nature of the metaverse could lead to overstimulation or cybersickness in some users. Mitigation strategies, such as strong encryption, robust data protection protocols, and clear privacy policies, will be essential to address these risks. Immersive environments can be intensely stimulating for individuals with anxiety disorders or sensory processing issues, leading to feelings of being overwhelmed or panicked[133,134]. For therapies aimed at treating PTSD, revisiting traumatic events even in a controlled environment could retraumatize the patient or evoke strong emotional responses that could be difficult to manage[135]. Re-traumatization in PTSD treatments, particularly in metaverse-based therapies, occurs when virtual exposure inadvertently triggers intense distress or re-experiences of trauma[136]. Digital interventions like NightWare, which use haptic feedback to disrupt nightmares, may unintentionally heighten anxiety instead of providing relief[100]. Similarly, VR-based exposure therapy for PTSD can overwhelm patients if the simulations are too intense or lack proper clinician supervision[137]. To mitigate these risks, personalized therapy settings, gradual exposure protocols, and clinician oversight are essential to ensure safe and effective treatment without exacerbating trauma symptoms. There are also physical health risks like cybersickness, a common side effect of VR use featuring nausea, dizziness, and disorientation and eye strain or headaches due to prolonged VR use[138,139]. While digital therapies increase accessibility to mental health resources, there remains a digital divide augmented by issues like technical malfunctions or high cost of equipment disrupting therapy sessions and affecting the therapeutic process[140]. But the digital therapies discussed earlier address issues like digital divide and cultural inclusivity with easy accessibility of widely used tablets and Internet connection along with multilingual support and personalized adaptations to ensure cultural inclusivity[141,142]. These therapies continue to evolve with healthcare partnerships and accessibility initiatives to mitigate disparities in digital health solutions. Furthermore, handling sensitive mental health data requires stringent security measures to protect patient privacy, comply with health data regulations, and build trust with users[43]. Extensive VR use can also potentially lead to overdependence on immersive experience posing a threat to even conceptualizing reality[143]. Despite these challenges, the potential benefits of immersive therapies in treating a variety of mental health conditions are significant. Synthesized findings of the SLR are summarized in Table 4 below. It addresses three key research questions concerning digital therapies: RQ1 explores the components of digital therapies, including evidence-based interventions, clinical approvals, and interactive therapy sessions. RQ2 evaluates the effectiveness of digital therapies in improving cognitive skills, emotional resilience, and self-esteem. RQ3 highlights the potential risks, such as overstimulation, trauma triggers, cybersickness, privacy concerns, virtual overdependency, and technical malfunctions.

Addressing these concerns involves a collaborative effort among technologists, clinicians, researchers, and regulatory bodies to develop guidelines and best practices for the safe and effective use of immersive technologies in mental healthcare. Developers and engineers responsible for creating and maintaining immersive technology hardware and software can ensure that the technology is user-friendly, reliable, and secure while implementing robust data security measures to protect patient information. Psychiatrists, psychologists, and other mental health professionals who use these technologies to treat patients can provide insights into the practical applications of these technologies and feedback on their effectiveness and user experience. While identifying potential psychological risks and devising therapeutic protocols that use immersive technologies safely and effectively, clinicians can help establish ethical guidelines for the use of such technologies. In the context of

academics and clinical researchers who study the effects, efficacy, and safety of immersive therapies, empirical studies can be conducted to validate the clinical benefits and potential risks of VR and AR in mental health treatments. Their findings also inform guidelines and best practices to refine therapeutic approaches and identify long-term effects and efficacy of treatments while contributing to the literature used by regulatory bodies. The regulatory bodies provide a legal framework for the use of immersive technologies, ensuring that they meet stringent safety and efficacy standards before being approved for clinical use. Regulatory bodies also monitor the ongoing use of these technologies to ensure compliance with healthcare regulations and patient safety standards. Regular communication between technologists, clinicians, researchers, and regulators with shared goals and standards can help align technology development with clinical needs and regulatory requirements, improve patient care through immersive technologies, and implement industry standards that prioritize patient safety and data security.

Limitations and ethical considerations

While this study provides a comprehensive analysis of metaverse-based digital therapies in mental healthcare, certain limitations must be acknowledged. The SLR relies on selected databases (IEEE and Google Scholar), which may exclude relevant but non-indexed or unpublished studies. Additionally, case study findings from NightWare, Freespira, EndeavorRx, and Sleepio may not be fully generalizable to all metaverse-based mental health applications. Another constraint is the short-term focus of available research, with limited long-term data on sustained efficacy, user retention, and potential side effects. Furthermore, the absence of large-scale randomized controlled trials (RCTs) limits the robustness of current clinical evidence. From an ethical standpoint, data privacy and cybersecurity are key concerns, as metaverse-based therapies collect sensitive mental health information. Strong encryption protocols, privacy regulations (e.g., GDPR, HIPAA), and clinician oversight are essential to prevent data breaches and ensure ethical AI-driven interventions. Additionally, re-traumatization risks in PTSD treatments using VR exposure therapy (VRET) must be carefully managed. Poorly designed virtual simulations or excessive exposure could trigger distressing flashbacks rather than facilitate recovery. Therapists must implement gradual exposure strategies, real-time patient monitoring, and customizable therapy settings to mitigate these risks. Future research should focus on large-scale validation studies, cross-cultural inclusivity, and regulatory frameworks to ensure long-term efficacy, safety, and equitable access to metaverse-based mental healthcare solutions. Addressing these limitations will enhance trust, accessibility, and the ethical integration of immersive technologies into mental health treatment.

Addressing the digital divide and cultural inclusivity

While metaverse-based digital therapies offer significant promise in transforming mental healthcare, challenges related to the digital divide and cultural inclusivity must be addressed to ensure equitable access and effectiveness across diverse populations. One of the major barriers to the widespread adoption of metaverse technologies in mental healthcare is the digital divide, which limits access for individuals in rural areas, low-income communities, and developing regions[144]. Many users may lack the high-speed Internet, VR/AR devices, and digital literacy required to engage effectively with immersive therapies. Additionally, the cost of hardware and subscription-based digital therapies presents an economic challenge, further restricting access to those who might benefit the most. Addressing this issue requires the development of low-bandwidth and mobile-friendly solutions that function on widely available smartphones, reducing dependency on expensive VR headsets. Policymakers and healthcare institutions should also work toward subsidizing devices and Internet access for mental healthcare applications while implementing digital literacy training programs to empower both patients and healthcare professionals in utilizing these technologies effectively[122].

Beyond accessibility, cultural inclusivity is another key factor that influences the adoption and effectiveness of metaverse-based mental health interventions[145]. Many of these therapies are designed within Western clinical frameworks, which may not fully account for cultural differences in mental health perceptions, treatment preferences, and therapeutic engagement. To ensure greater inclusivity, metaverse-based therapies should incorporate multilingual interfaces, localized content, and culturally adapted treatment models that align with regional beliefs and practices[146]. Involvement of culturally diverse mental health professionals in the development and validation of these therapies is necessary to ensure that interventions are relevant and acceptable across different populations. Additionally, clinical validation studies should be conducted across diverse demographic groups to assess the efficacy of these interventions in varied cultural contexts[147]. As metaverse-based mental healthcare continues to evolve, addressing disparities in access and cultural representation will be essential for its long-term success. Future research should prioritize developing cost-effective, globally accessible, and culturally adaptable digital mental health interventions. Collaborative efforts between technologists, mental health professionals, and policymakers are needed to bridge the digital divide and promote inclusivity, ensuring that metaverse-based therapies reach and benefit a broad spectrum of users worldwide.

Conclusion and recommendations

Metaverse-based digital therapies represent a transformative shift in mental healthcare, offering immersive, scalable, and personalized solutions for various mental health conditions. This study has explored the technological foundations, effectiveness, and risks associated with these therapies, highlighting both their potential and the challenges that must be addressed. While clinical validation supports their efficacy, key concerns regarding data privacy, regulatory oversight, and ethical implementation remain critical areas for further exploration.

To ensure successful integration of metaverse-based mental healthcare solutions, collaborative efforts among policymakers, technologists, and healthcare professionals are essential. The following actionable recommendations can guide future developments:

- For Policymakers: Establish clear regulatory guidelines that define safety, privacy, and ethical standards for metaverse-based digital therapies. Provide funding support for long-term clinical studies and incentivize public-private partnerships to expand access.
- For Technologists: Focus on developing secure, privacy-preserving AI models, ensuring transparent and bias-free algorithms in mental health interventions. Improve usability and accessibility, particularly for individuals with limited digital literacy or technological access.
- For Healthcare Professionals: Advocate for evidence-based adoption of digital therapies in clinical practice. Invest in training programs to equip mental health practitioners with the skills to effectively integrate metaverse-based tools into patient care.

By addressing these considerations, stakeholders can facilitate the safe, ethical, and effective adoption of metaverse-based mental healthcare solutions, ultimately transforming mental health service delivery on a global scale. Future research must continue to refine these technologies, ensuring they remain inclusive, clinically effective, and accessible to all individuals in need.

Data availability

All the data are available in the manuscript.

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Declarations

Competing interests

One of the authors " Sushank Chaudhary" is serving as Associate Editor in Scientific Reports journal.

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