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Current Perspective of Metaverse Application in Medical Education, Research and Patient Care

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Abstract: As virtual and augmented reality simulation technologies advance, the use of such technologies in medicine is widespread. The advanced virtual and augmented systems coupled with a complex interactive, immersive environment create a metaverse. The metaverse enables us to connect with others in a virtual world free of spatial restrictions and time constraints. In the educational aspect, it allows collaboration among peers and educators in an immersive 3D environment that can imitate the actual classroom setting with learning tools. Metaverse technology enables visualization of virtual 3D structures, facilitates collaboration and small group activities, improves mentor–mentee interactions, provides opportunities for self-directed learning experiences, and helps develop teamwork skills. The metaverse will be adapted rapidly in healthcare, boost digitalization, and grow in use in surgical procedures and medical education. The potential advantages of using the metaverse in diagnosing and treating patients are tremendous. This perspective paper provides the current state of technology in the medical field and proposes potential research directions to harness the benefits of the metaverse in medical education, research, and patient care. It aims to spark interest and discussion in the application of metaverse technology in healthcare and inspire further research in this area.

Keywords: virtual reality; augmented reality; mixed reality; health professions education

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1. Introduction

The use of augmented reality (AR) and virtual reality (VR) in healthcare has been on the rise, leading to an expansion in the market size for these technologies. The market size for AR and VR in healthcare was US 2.0 billion in 2020, and it is expected to continue growing at a compound annual growth rate of 27% until 2028 [1]. This suggests that there is a growing demand for AR and VR in healthcare and a potential for these technologies to transform the way healthcare services are delivered. Furthermore, the COVID-19 pandemic era boosted the adaptation of the metaverse to use the benefit of virtual and real-world space [2]. Experiences of the metaverse need to be expanded, so that the healthcare providers and educators can understand the necessity of its use [3]. Meta-education and metaverse-powered online distance education have been introduced and accelerated in development that can emerge as rich, hybrid formal and informal learning experiences in online 3D virtual environments [4]. The concept of the metaverse satisfies all the concerns of interactions between humans and computers and the integration between the virtual and real worlds [5].

Immersive learning environments involve using virtual and augmented reality technologies to create more engaging and effective learning experiences [6]. These technologies can help simulate real-world scenarios, provide interactive feedback, and personalize learning, based on the needs and preferences of individual learners. Immersive learning environments can be created using various tools and technologies, such as 3D modeling software, game engines, and specialized hardware like head-mounted displays or haptic

feedback devices. These tools can be used to simulate real-world environments, such as a hospital room, a factory floor, or a natural ecosystem, which can help learners develop skills and knowledge in a safe and controlled setting [7].

Web-based data processing innovations have been used to assess performance improvement and satisfaction levels in medical education and clinical care since 2006 [7]. Computer-based or computerized virtual patients simulating real-life clinical scenarios-based learning consistently showed higher learning outcomes [8]. As learning with computerized intervention gained popularity, trainees and students were allowed to perform anamnesis and physical exams, make diagnoses, and finalize therapeutic decisions in a safe environment; as a result, trainees could refine their clinical skills [9]. The metaverse could promote experiential learning through integrating effective educational approaches, such as problem-solving-based learning, game-based learning, and scenario-based learning [9]. These interventions have now become more realistically developed.

Surgical training simulators have been revolutionized by AR and VR, and they have coupled with machine learning tools. These revolutionized surgical simulators could provide trainees with life-like training, hyper-realistic simulations, and instant feedback [8]. Development of VR and AR simulation technologies in healthcare systems could be applied to not only surgeries, but also diagnostics, rehabilitation, training, and education [1].

Metaverse

The metaverse is an internet-based application that needs to be supported by AR, VR, and artificial intelligence [10]. Kye et al. [11] proposed a model for the metaverse that includes four primary pillars: AR, lifelogging, mirror world, and virtual worlds. It is a universal platform that supports innovation, communication, and shared knowledge. The four pillars are complementary to each other and form an interconnected roadmap to maximize the use of virtual technology for educational applications. Augmented reality expends real-world information to enhance knowledge, while lifelogging captures, stores, and shares experiences with others. The mirror world reflects the real world and provides external information, and the virtual world builds a simulated environment with digital information.

The metaverse is a unique and different concept from existing virtual technologies. It is envisioned as a fully interconnected virtual space where users can move seamlessly between different environments. Unlike existing virtual technologies, typically standalone applications, or platforms, the metaverse is designed to be a network of connected virtual spaces, allowing for more extensive and diverse experiences [12,13]. The metaverse is also designed to be a persistent space, meaning that a user's digital identity and avatar can exist across different platforms and applications, allowing for continuity of interaction and experience (Figure 1). This differs from existing virtual technologies, where users' experiences are often isolated within a particular platform or application [13,14].

Figure 1. Metaverse avatar creation: Tess McKinney is pictured here (**left**) with her avatar (**right**) that she uses in the metaverse on the Horizon World platform and EngageVR platform.

Another key difference is that the metaverse is designed to be a space where users can create and share their content, interact with other users, and build communities around shared interests (Figure 2). This differs from existing virtual technologies, where users are often limited to pre-existing content or experiences [13]. Furthermore, the metaverse is designed to be an immersive environment, providing users with a sense of presence and embodiment within the virtual space. This differs from existing virtual technologies, which often rely on more limited forms of immersion, such as 2D displays or simple controllers [13,14]. The metaverse represents a significant step forward in virtual technology, offering a more extensive, interconnected, and immersive space for users to interact and create. While the technology to fully realize the metaverse is still developing, it can potentially transform how we interact with each other and the world around us [13,14]. The utilization of the metaverse for education is full of possibilities and unlimited. The metaverse creates a new dimension for students to learn new knowledge in 3D space and immersive environments. Such utilization has expanded substantially during and after the recent COVID-19 pandemic. More applications beyond science, technology, and engineering education are developing, such as medical training, research, and patient care. The following sections highlight those health-related potentials of using the metaverse.

(**a**) (**b**)

Figure 2. *Cont.*

(**c**) (**d**)

Figure 2. (**a**) Virtual Life Support utilizing passthrough VR with AR with an Oculus Quest 2 created by VR Lab. CPR and AED Training [15]. (**b**) Reulay, a mental health company, leverages virtual reality for mental wellbeing: decreasing stress and increasing focus [16]. (**c**) Class being held to learn about patients in a Metaversity using VictoryXR multiplayer IVR software [17]. (**d**) UNMC College of Nursing student working with faculty to go through a scenario on Sepsis. Faculty are involved in this simulation by becoming the patient voice or extras within the simulation to help the student practice real-world simulations. This simulation is multiplayer and contains a laptop moderator and an Immersive Virtual Reality headset [18].

2. Significance of the Metaverse in Healthcare Systems

The process to adopt the metaverse in healthcare has grown rapidly. The urgent need for digital transformation within healthcare settings was accelerated since the outbreak of the coronavirus in 2019 [19]. Furthermore, telehealth care services have gained significant attention and acceptance due to the evolving COVID-19 pandemic [20]. Before the COVID-19 pandemic, only 43% of healthcare facilities could provide services remotely [21,22]. Now, the usage of telemedicine has grown to 95% [23]. With the increased needs of digitalization of telemedicine services, the metaverse was highlighted and boosted research interests in supporting the importance of immersive VR technology [20].

The combination of augmented and mixed reality with the metaverse offers a novel approach to visualizing images and pinpointing targets in image-guided procedures [24]. The application of the metaverse can provide realistic consultations through personalized avatars that are interconnected [7]. The advent of the metaverse made it possible to interconnect online with the synergistic combination of augmented, virtual, and mixed reality. It happened to present a new era of immersive and real-time experiences to enhance human-to-human social interaction and connection [25]. The avatar is the digital representation of the player character in the metaverse [26]. The metaverse concept is increasingly used in healthcare to create personalized patient avatars. These avatars can represent a patient's unique physical, mental, and emotional characteristics and provide a more personalized approach to healthcare [26].

One potential application of personalized avatars is in patient education. By creating a virtual patient representation, healthcare providers can help patients better understand their medical conditions and treatment options. For example, a patient with a heart condition could be shown a virtual representation of their heart and how it functions, helping them to better understand their condition and how it can be managed. Personalized avatars can also simulate medical procedures and treatments, allowing healthcare providers to test different approaches before performing them on real patients. This can help reduce the risk of complications and improve outcomes. Another potential use of personalized avatars is in telemedicine. By creating a virtual patient representation, healthcare providers can conduct virtual visits and consultations, providing more personalized care even when patients are not physically present in the same location. The use of personalized avatars in healthcare is an exciting development that has the potential to improve patient outcomes

and provide more personalized and effective care. The metaverse provides a powerful platform for creating and utilizing these avatars, and it will likely play an increasingly important role in future healthcare [27].

A review study in pain management by Chan et al. [28] found that VR interventions were effective in reducing pain intensity and providing pain relief, both during and after the intervention. The VR interventions were particularly effective in managing procedural pain, such as during medical procedures like wound dressing changes or dental procedures. Additionally, the studies showed that VR interventions improved patient satisfaction, decreased anxiety and stress, and enhanced the overall healthcare experience. This review suggests that VR may be a promising tool in pain management and can be used as an adjunct to pharmacological and non-pharmacological interventions [28]. Another study by Ahmadpour et al. [29] has shown that use of computer-generated images and sounds to create a simulated environment can be a tool to distract patients from pain sensations or to provide relaxation and mindfulness exercises. In acute pain management, VR interventions have been used to provide distraction during painful medical procedures such as burn wound care, dental procedures, and injections. The immersive environment can reduce the patient's focus on the pain, providing a sense of control and reducing anxiety. In chronic pain management, VR interventions have been used to provide relaxation exercises and cognitive-behavioral therapy techniques. Patients can enter calming virtual environments and practice mindfulness exercises or guided imagery, which can reduce pain intensity and distress. There is growing evidence of the effectiveness of VR interventions for acute and chronic pain management, and it has been shown to be safe and well-tolerated by patients. The VR interventions offer a non-pharmacological approach to pain management, which can be particularly beneficial for patients who cannot tolerate or do not want to take pain medication [29].

2.1. Applications in Education for Healthcare

As the metaverse came into daily life, its applications have been applied in educational settings [11]. The metaverse can be used to create virtual classrooms and training environments, which can be particularly useful for fields that require hands-on learning or simulations, such as medicine [11,26]. One of the key benefits of using the metaverse is to provide learners with immediate and personalized feedback [30]. For example, a medical student practicing a surgical procedure in a VR environment can receive real-time feedback on their technique and performance. This feedback can help learners identify areas to improve and adjust their approach accordingly [8], as shown in Figure 2d.

Chen et al. [30] suggest that using an immersive, blended pedagogy that combines traditional classroom instruction with immersive learning experiences in the metaverse can enhance student engagement and improve learning outcomes, particularly in the areas of patient care and scientific inquiry during the COVID-19 pandemic. They noted that the pandemic has disrupted traditional classroom instruction, making it difficult for educators to provide students with the hands-on experiences and interactions with patients that are essential for learning in healthcare fields. They found that the active learning strategies implemented in the metaverse promoted engagement and scientific inquiry, providing a safe and immersive environment for students to practice and develop their skills. This approach may be beneficial for educators facing pandemic-related disruptions to traditional classroom instruction, as it provides hands-on experiences and interactions with patients that may not be possible in a physical classroom [30]. Immersive learning technology in the metaverse is an exciting and rapidly evolving field that has the potential to transform the way we learn and teach. By leveraging the latest technologies and pedagogical approaches, the metaverse can provide learners with engaging, effective, and personalized learning experiences that help them develop the knowledge and skills they need to succeed [8].

Like virtual anatomy classes, medical students can learn about human anatomy through interactive virtual lessons, including the ability to manipulate and explore virtual cadavers (Figure 3). Virtual medical education simulations can also be used for medical

students to practice diagnosing and treating patients, practice procedures, and practice decision-making in a safe, controlled environment. Furthermore, the full-scale scenario-based simulator training can be developed to help the learner acquire interpersonal communication skills, teamwork, leadership, decision-making, the ability to prioritize tasks under pressure, and stress management [31]. With the full-scale scenario-based simulator, medical students can engage in virtual patient encounters to practice their clinical skills, including taking medical histories, performing physical exams, and communicating with patients [32]. Remote collaboration, training, and learning can be near with metaverse technology to connect with one another and receive training from experts, even if they are located in different parts of the world. Virtual conferences and workshops can remotely continue their education and keep them up to date with the latest developments in their fields [32]. These are just a few examples of how metaverse technology can be used in education for healthcare.

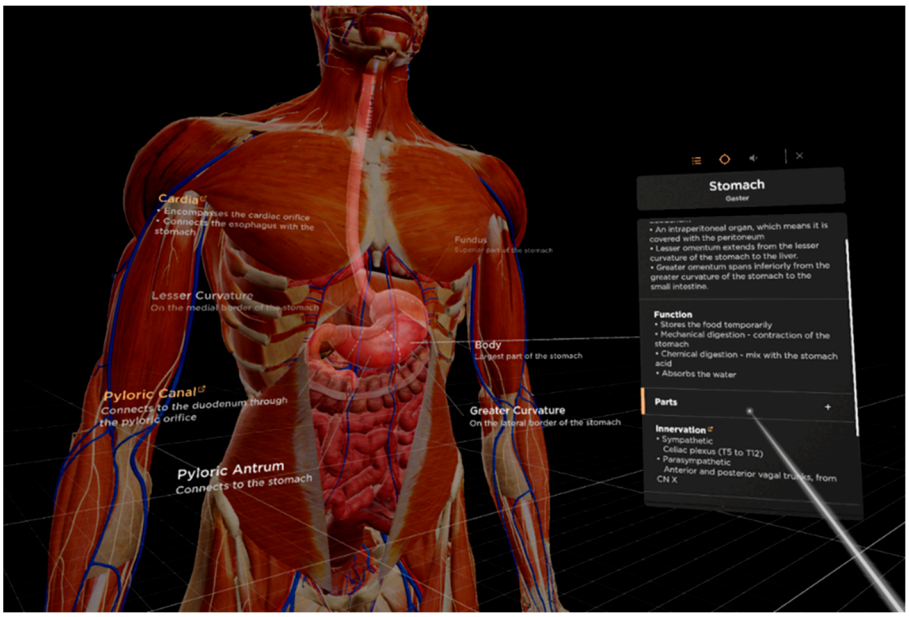

Figure 3. Dissection of human anatomy using 3D/VR/AR/and computer-based simulation application [33].

The metaverse can play a useful role in enhancing the performance of the medical trainees [34]. The metaverse has the great potential to transform medical education by providing students with realistic and engaging learning experiences. It can help to improve their skills, reduce medical errors, and prepare them for the challenges of real-world medical practice [27]. Active learning strategies can be effectively used in the metaverse to improve student engagement in a blended learning environment [30]. The authors discussed how immersive technologies can provide students with opportunities to engage in experiential learning, which can be challenging in traditional classroom settings. By integrating virtual patient scenarios and scientific inquiry into the metaverse, students can develop critical thinking skills and gain practical experience in patient care. The authors suggest that using active learning strategies in the metaverse can lead to better student outcomes, including increased student motivation, improved retention rates, and higher levels of engagement [26]. The possibilities are endless, and technology continues to evolve, so the use cases for the metaverse in education for healthcare will likely expand in the coming years.

2.2. Applications in Research

The metaverse is a concept that refers to a shared, immersive virtual space where people can interact and communicate with one another. It is an emerging technology with

many potential applications in research. With the metaverse, researchers can conduct experiments in a controlled, immersive environment. According to Bhugaonkar et al. [35], psychologists could use the metaverse to study social interactions or communication, while economists could use it to study decision-making under different conditions [35]. The authors also noted that these technologies have the potential to improve healthcare outcomes by providing more immersive and interactive training experiences, enhancing patient engagement and motivation, and enabling remote monitoring and care delivery [35].

Psychologists Krijn et al. [36] used VR to study the effectiveness of exposure therapy for social anxiety disorder. Virtual reality exposure therapy (VRET) is a type of therapy that uses VR technology to simulate anxiety-provoking situations in a safe and controlled environment. VRET is typically used to treat anxiety disorders like phobias, social anxiety disorder, and post-traumatic stress disorder. The researchers found that VRET was more effective than traditional exposure therapy in reducing social anxiety symptoms [36]. VRET has the advantage of being more flexible and accessible since it can be done remotely and at the patient's own pace [36]. In a neuroscience study by Spiers and Maguire [37], the researchers used VR to investigate the neural mechanisms underlying spatial memory. They were able to identify the brain regions that are selectively activated during spatial memory tasks and determine their role in memory consolidation. The researchers found that the hippocampus, a brain region associated with memory, was more active when participants navigated through a virtual environment than when they viewed static images [37]. This research provided insights into the neural processes underlying spatial memory and highlighted the potential of VR technology for investigating brain function in real-world contexts [37].

The advantage of using the metaverse is that it enables collaborative research. The metaverse can facilitate collaboration among researchers who are physically separated, allowing them to work together in a virtual space as if they were in the same room [38]. The state-of-the-art human–computer interaction (HCI) in the metaverse is an area of active research and development. HCI in the metaverse involves designing intuitive and natural ways for users to interact with virtual objects and other users, as well as creating immersive and engaging user experiences [38].

According to Zhao et al. [39], the metaverse can be used to create interactive 3D visualizations of data, which can be helpful for understanding complex information or communicating research findings to a wider audience. The metaverse has the potential to transform many aspects of our lives, but it also requires significant advancements in technology and conceptual design [39]. Overall, the metaverse has the potential to revolutionize the way that research is conducted and communicated, and it is an exciting area of study with many potential applications.

2.3. Applications in Patient Care

As of now, the metaverse in healthcare is still in its early stages of development and has not been widely implemented. However, there have been some initial experiences and experiments with using VR and AR technologies to enhance healthcare [40,41]. VR and AR can be used to improve patient education and engagement. Patients can use VR and AR technologies to better understand their medical conditions and treatments, which can improve adherence to treatment plans and ultimately lead to better health outcomes [40]. Virtual healthcare platforms are being developed that aim to provide a more immersive and personalized healthcare experience. These platforms use a combination of virtual and physical components to provide remote medical consultations and diagnosis [41]. In summary, while there are some initial experiences and experiments with using the metaverse in healthcare, the concept is still in its early stages of development, and it will likely be some time before we see widespread implementation of this technology in healthcare [40,41]. More potential applications of the metaverse in patient care are in Table A1 (Appendix A).

3. Limitations and Challenges

One of the main limitations of the metaverse is data management, security, and privacy of the patient's information [42]. Since it requires higher ethical standards to protect patients' information, the rules and regulations need to be cautiously reviewed and formulated [40]. The metaverse needs to provide various tools and techniques to users, so that they can preserve privacy. As metaverse technologies evolve, data management science should develop together. Furthermore, healthcare providers and medical training programs may include additional courses that can cover data ethics and cybersecurity.

Despite considerable research relating to metaverse technologies, little attention has been paid to the standardization of medical education programs. Educational research is needed to assess whether the metaverse improves the learning experience of medical students, which will help academic research departments compare and evaluate the effectiveness of different programs [8]. More educationalists, social scientists, and learning technologists need to be involved since developing and maintaining a virtual environment for medical education can be technically challenging and requires significant resources [7,11,43].

Additional limitations would be the computer capacity and internet bandwidth for image streaming, especially in rural areas with lack of internet connectivity [10]. Both students and educators also need smartphones or computers with enough processing capacity and internet bandwidth for virtual and augmented reality [1]. The hardware for virtual and augmented reality, such as visors or glasses, are required for a truly immersive experience, but these items are costly [9]. Technical and equipment supports would be required for the underprivileged areas and underserved students.

Some users may experience discomfort or other negative effects using virtual and augmented systems, such as dizziness, headaches, or nausea [12]. These factors can significantly impact their willingness to use the technology and affect their overall experience with the metaverse. While these technologies have the potential to revolutionize various aspects of our lives, it is critical to ensure that they are accessible and enjoyable for all users. Designers and developers should consider these factors and work to minimize potential side effects through improvements in hardware, software, and user interface development [12].

The use of metaverse technology in education for healthcare is a promising development with potential benefits, but it must be approached with careful consideration and ongoing evaluation to ensure its effectiveness and safety.

4. Future Direction and Recommendation

The metaverse is coming to us. As technology advances, it will bring us new immersive and imaginary worlds [10]. An immersive 3D environment could provide a better perception of the surrounding environment. It could be applied in diverse medical fields such as neuroscience, psychology, dentistry, and other interventions that allow immersive places [33]. The synergy effect of collaboration across multiple disciplines remains a crucial opportunity for educational research in the metaverse. The future of the metaverse in education for healthcare is promising and can potentially enhance medical education and training [9–11]. If integrated with artificial intelligence and machine learning, advances can enhance the interactivity and realism of metaverse environments, providing a more immersive and practical learning experience.

The metaverse's diverse applications are evolving daily, and developers' perception is changing as they create new metaverses [42]. The developers may create a more sustainable and economic metaverse platform that can be easily applied to medical education and healthcare providers. Healthcare professionals would be needed to educate medical trainees and prepare them to advance to meet new opportunities [9–11], and medical educators need to pinpoint the incorporation of these applications. The metaverse is revolutionizing medical education, patient care, treatment, surgical training, and research [9–11,44]. It could

enhance the overall quality of patient care and improve the quality of medical procedures, diagnosis, and treatment.

5. Summary

The metaverse cannot take the place of clinical practice. Interactions with patients are essential skills that healthcare professionals acquire [42]. However, the metaverse in education in healthcare has great potential to be an interactive and immersive application that can be modified for each person [21]. It can support educators to implement interactions with patients as well as trainees that can be more caring in many ways.

The metaverse can be included to enhance the quality of education, research, and patient care. It could bring new possibilities to facilitate healthcare professionals having a positive experience within a risk-free environment [33]. The metaverse is a fully immersive virtual world that integrates human life's social, economic, and cultural aspects. The metaverse extends virtual worlds, aiming to provide users with a more comprehensive and engaging experience [14,45]. Revolutionized technologies and the metaverse can be used in diverse medical fields, and the application can benefit patients, healthcare providers, and trainees. The use of metaverse technology in education for healthcare is a promising development with potential benefits. However, it must be carefully considered and evaluated to ensure its effectiveness and safety. Collaboration with multiple disciplinary areas would be anticipated to evaluate the long-term effects of the metaverse for medical education in the future.

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Appendix A

Table A1. Application in Patient Care.

Types	Pros	Cons
Virtual reality (VR) therapy [44] VR can be used as a therapeutic tool to help patients with a range of conditions, including anxiety, phobias, post-traumatic stress disorder (PTSD), and pain management.	i. Controlled Environment: VR allows therapists to create a controlled and safe environment in which patients can confront their fears and anxieties. ii. Customizable: VR experiences can be customized to suit individual needs, making the therapy more effective. iii. Being Immersed: VR creates an immersive experience that can be more effective than traditional therapy methods in treating conditions such as phobias and PTSD. iv. Accessibility: VR therapy is more accessible to patients who may not be able to participate in traditional exposure therapy due to physical limitations or fears of leaving the house.	i. Cost: VR equipment can be expensive, making it less accessible to some patients. ii. Limited Research: The use of VR for treating anxiety, phobias, and PTSD is still in the early stages of development and there is limited research on its long-term effects. iii. Unrealistic: Some patients may not respond well to VR therapy because they perceive the experience as unrealistic or too artificial.

Table A1. *Cont.*

Types	Pros	Cons
Virtual consultations [35] The metaverse can be used to facilitate virtual consultations between patients and healthcare providers, allowing patients to access care from anywhere. This can be particularly useful for patients in remote or underserved areas, or for those who have mobility issues.	i. Accessibility: Virtual consultations can increase access to healthcare for patients who may have difficulty traveling to see a healthcare provider in person, such as those with mobility issues or who live in rural areas. ii. Convenience: Virtual consultations can be more convenient for both patients and healthcare providers as they can be done from the comfort of one's own home or office. iii. Timesaving: Virtual consultations can save time compared to traditional in-person consultations as they eliminate the need for traveling. iv. Reduced costs: Virtual consultations can potentially reduce costs associated with travel and parking.	i. Technical issues: Virtual consultations can be disrupted by technical issues such as poor internet connectivity or equipment malfunctions. ii. Reduced personal interaction: Virtual consultations may lack the personal interaction and human touch that can be important in building a therapeutic relationship between a healthcare provider and patient. iii. Limited examination: Virtual consultations may limit the examination that can be performed compared to an in-person consultation, as the healthcare provider may not be able to physically touch or observe the patient. iv. Data security: Virtual consultations may raise concerns about the security of personal and medical information, as it is transmitted electronically.
Telerehabilitation [46] The metaverse can be used to deliver rehabilitation services to patients remotely, enabling them to complete therapy exercises at home or in other locations.	i. Increased access to rehabilitation services: Telerehabilitation with the metaverse can increase access to rehabilitation services for patients who may not have access to traditional rehabilitation facilities due to geographic or mobility limitations. ii. Improved outcomes: The systematic review by de Araújo et al. found that VR rehabilitation was effective in improving outcomes such as motor function, balance, and activities of daily living in individuals with spinal cord injuries. iii. Customized and immersive rehabilitation experience: The metaverse allows healthcare providers to create customized virtual environments that simulate real-world scenarios, providing a more engaging and motivating rehabilitation experience for patients. iv. Increased safety: VR rehabilitation provides a controlled and safe setting for patients to practice and improve their skills, minimizing the risk of further injury.	i. Access to technology: Not all patients may have access to the necessary technology and equipment for telerehabilitation with the metaverse, such as VR headsets. ii. Cost: The cost of technology and equipment for telerehabilitation with the metaverse can be a barrier for some patients and healthcare providers. iii. Technical difficulties: Technical difficulties or malfunctions of the equipment can disrupt the rehabilitation experience and may require additional support. iv. Limited ability to assess physical performance: The virtual environment may not fully replicate real-world scenarios, making it difficult for healthcare providers to accurately assess physical performance.

Table A1. *Cont.*

Types	Pros	Cons
Telemedicine [35] The metaverse could be used to provide remote medical consultations, allowing patients to see a doctor or specialist in a virtual environment. This could be especially useful for people living in remote or underserved areas.	i. Convenient for patients: Telemedicine enables patients to access healthcare services from the comfort of their homes, saving them time and effort in traveling to see a doctor. ii. Improved access to care: Telemedicine can provide healthcare services to patients in remote and underserved areas, improving access to care. iii. Increased efficiency: Telemedicine can reduce wait times for appointments and improve the efficiency of the healthcare system. iv. Cost-effective: Telemedicine can be a more cost-effective solution compared to traditional in-person visits. v. Better continuity of care: Telemedicine can improve the continuity of care for patients, as they can easily communicate with their healthcare provider between appointments.	i. Technical challenges: Telemedicine can be limited by technology and may require patients to have access to reliable internet, a computer or smartphone, and other necessary equipment. ii. Quality of care concerns: The quality of care provided through telemedicine may not be as high as in-person visits, as certain physical exams and procedures cannot be performed remotely. iii. Limited patient-provider interaction: Telemedicine may not provide the same level of patient–provider interaction as in-person visits, as patients may feel less connected to their healthcare provider. iv. Privacy and security risks: Telemedicine can also pose privacy and security risks, as personal health information may be vulnerable to hacking and cyberattacks. v. Reimbursement issues: Telemedicine may also face reimbursement issues, as insurance companies may not cover all telemedicine services.
Patient education [47] The metaverse can be used to provide interactive, immersive patient education experiences, which can be more engaging and effective than traditional methods.	i. Improving rehabilitation outcomes: The study focuses on the use of VR as a rehabilitation tool after knee surgery. By incorporating VR exercises into the rehabilitation process, patients can improve their physical performance, balance, and gait, resulting in a faster recovery and better outcomes. ii. Increased patient satisfaction: Patients in the study reported a high level of satisfaction with VR-based rehabilitation compared to traditional physical therapy. iii. Personalized rehabilitation: The study found that the level of difficulty of the VR exercises had a significant impact on patient outcomes. By tailoring the exercises to the patient's specific abilities and progress, the rehabilitation program can be personalized to meet each patient's unique needs.	i. Potential for technological limitations: The use of VR technology for rehabilitation may be limited by the availability and accessibility of the equipment, as well as the technical skills required to operate it. Patients may also experience discomfort or motion sickness while using VR, which could limit the feasibility of this approach for some patients.

Table A1. *Cont.*

Types	Pros	Cons
Social support [44] The metaverse can be used to connect patients with similar conditions and provide a sense of community and social support.	i. Greater control: Virtual reality exposure therapy (VRET) provides the therapist with greater control over the patient's exposure to anxiety-provoking stimuli, allowing them to carefully tailor the treatment to the patient's specific needs and progress at a pace that they can handle. ii. Increased engagement and motivation: VRET provides a highly immersive and engaging experience, which can increase patient motivation to participate in therapy and adhere to treatment plans. iii. Safe and controlled environment: VRET allows patients to confront anxiety-provoking stimuli in a safe and controlled environment, without the risks associated with exposure in real-life situations. iv. Efficacy: VRET has been found to be effective in reducing symptoms of anxiety disorders, with some studies reporting results that are comparable to traditional in vivo exposure therapy.	i. Limited generalizability: VRET may not always generalize to real-life situations, as the stimuli presented in VR may differ from those encountered in the real world. This can limit the effectiveness of the therapy in some cases. ii. Technical limitations: The quality of the VR experience can be impacted by technical limitations, such as the quality of the graphics or the performance of the hardware. This can potentially detract from the effectiveness of the therapy. iii. Cost: VRET can be expensive to implement, as it requires specialized equipment and software. This can limit its accessibility to some patients who may not have access to the necessary resources.
Medical Visualization [39] The metaverse could be used to create interactive 3D visualizations of medical data, such as CT scans, MRI images, and microscopic samples. This could make it easier for doctors and researchers to understand and analyze medical data and could also be used to create VR experiences that help patients understand their diagnosis and treatment.	i. Improved understanding of medical data: By creating interactive 3D visualizations of medical data, doctors and researchers can better understand and analyze complex medical data. This can lead to more accurate diagnoses and better treatment decisions. ii. Enhanced patient education: Using VR experiences, patients can better understand their diagnosis and treatment, which can improve their engagement in the treatment process and their overall outcomes. iii. Greater efficiency: Medical visualization can help doctors and researchers process complex medical data more efficiently, leading to faster diagnoses and treatment decisions. iv. Reduced risk: Using VR to visualize medical data can reduce the need for invasive procedures or surgeries, which can reduce the risk of complications and speed up recovery times.	i. Cost: Developing high-quality, interactive VR visualizations can be expensive, which may limit their availability to certain institutions or patients. ii. Technical challenges: Creating 3D visualizations of medical data requires specialized technical expertise and resources, which may be a barrier to adoption. iii. Limited accessibility: VR technology may not be accessible to all patients, particularly those with certain disabilities or conditions that make it difficult to use. iv. Ethical concerns: There may be ethical concerns around the use of VR to visualize sensitive medical data, particularly if there are privacy or confidentiality risks.

Table A1. *Cont.*

Types	Pros	Cons
Mental Health treatment [44] This could be used for providing virtual therapy sessions, creating virtual support groups, and providing VR exposure therapy for people suffering from anxiety and post-traumatic stress disorder (PTSD).	i. Increased access to care: Virtual therapy sessions and virtual support groups can be more accessible and convenient for people who may have difficulty accessing in-person mental health services due to geographical, financial, or other barriers. ii. Greater anonymity: Virtual therapy and support groups can provide a greater sense of anonymity and privacy, which may make it easier for people to share about their mental health struggles. iii. More engaging and immersive therapy: VR exposure therapy can create a more immersive and realistic experience for people receiving treatment for anxiety and PTSD, which may lead to more effective therapy outcomes. iv. Customizable experiences: Virtual technology can be used to create personalized and customizable therapy experiences, such as virtual environments that are tailored to a person's specific fears or triggers.	i. Technical issues: Virtual technology may be subject to technical issues that could disrupt therapy sessions, such as internet connectivity problems, hardware failures, or software glitches. ii. Lack of personal connection: Virtual therapy and support groups may lack the personal connection and face-to-face interactions that some people may prefer in traditional therapy settings. iii. Potential for distractions: Virtual therapy sessions may be more susceptible to distractions from the person's environment, such as notifications from their phone or other digital devices. iv. Ethical and legal concerns: Virtual therapy may raise ethical and legal concerns related to privacy, security, and informed consent. For example, ensuring that personal health information is kept confidential and secure may be more challenging in a virtual environment.

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