Merging Realities for Better Health: A Dive Into Virtual Healthcare

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This paper delves into the transformative use of Virtual Reality in the public health domain, focusing on its psychological effects, the effectiveness of VR-based patient education interventions, and ethical considerations surrounding the use of personal data and privacy. Through the examination of peer-reviewed studies, the research found that VR offers innovative solutions on health education and mental health outcomes. The immersive digital environment of VR offers breakthroughs in delivering patient education and psychological interventions. As VR devices continuously collect vast amounts of sensitive user information to create unique experiences, the paper discusses the need for data protection and ethical guidelines to protect user privacy and gain consumer trust. However, it is important to address the significant ethical and social issues, and adverse reactions, such as cyber-sickness or escapism, to fully realize the benefits of Virtual Reality.

Keywords: public health, technology, virtual reality, augmented reality, interactive healthcare, innovation in health, medical technology, health education

INTRODUCTION

In the digital age, technology is rapidly evolving, seeing an increase in integration across various industries, including the healthcare sector. One technology that is starting to make advancements in healthcare is Virtual Reality (VR). VR is an innovative tool with vast potential. Beyond entertainment usage, its immersive capabilities provide new solutions to improve public health. This paper explores the usage of VR to improve health outcomes, specifically psychological impacts, the efficacy of VR in patient education, and ethical concerns regarding personal data and privacy.

In recent years, VR has captivated users since it offers unprecedented opportunities to further patient education and therapeutic support delivery. Due to its immersive, interactive capabilities, VR also offers

new ways to deliver educational content and therapeutic interventions, promising breakthroughs in how healthcare information is released, and psychological support is administered. However, with benefits comes risk; because VR deals with the mind, users may experience physiological responses, especially in a clinical context. Although it may help improve mental health outcomes or rehabilitation, adverse reactions such as cyber-sickness and escapism must be addressed to users. Furthermore, since VR collects sensitive information, ethical concerns surrounding VR must not be overlooked. Ensuring user privacy and establishing trust is essential to responsibly integrate VR into public health.

Psychological Effects of Virtual Reality in Public Health

Integration of Emerging Technology

VR environments elicit a sense of presence and trigger real-time cognitive, behavioral, and physiological responses to real-time situations (Valmaggia et al., 2016). Virtual environments promoting positive stimuli combined with health knowledge could be valuable for public health and mental health (Jerdan et al., 2018). Advancements in technology have continually reshaped the landscapes of many industries. Among those tech innovations, we have a transformative tool called Virtual Reality (VR). It has allowed healthcare practitioners to explore new ways of providing treatment and has improved the outcomes in the industry for those who have employed it.

In the health domain, VR has trained clinicians and medical students (Xu et al., 2023). Its immersive platform has been recognized to improve surgical efficiency enhance accessibility and accuracy of training through well-constructed simulations. VR would have remained as a simulation tool for physicians and surgeons, but its interactive nature suggested it as an applicable tool for psychological change (Jerdan et al., 2018). Results indicate that VR biofeedback is feasible and that it leads to prominent levels of satisfaction not only in children and adults with anxiety disorders but also in patients treated for pain and in the context of surgery (Kothgassner et al., 2022). It has been used to reduce patient trauma through virtual exposure therapy and in older adults, can be rehabilitative for patients with cognitive and motor function. It stands to be the precipice of penetrating and transforming the industry through multiple events in healthcare.

The medium of VR has provided new possibilities to help treat problematic behaviors that affect mental health. VR provides realistic stimuli that can help patients with depression, stress, and anxiety disorders. By using calm and soothing computer-generated worlds, the patients' natural sensory perceptions are immersed in a state of relaxation. It can be an attractive alternative to other forms of therapy, considering the costs and reusability of these environments (Jerdan et al., 2018).

Stress and Anxiety Reduction

In humans, the psychological conceptualization of stress proposes that the emotional response and physiological activation that occur in a situation depend on the interpretation of a threat and whether we think we will be able to cope with the event (Valmaggia et al., 2016). A VR program for patients with a stress-related psychiatric disorder showed that confrontation with emotionally charged VR objects improved relaxation and negative mood significantly more than conventional cognitive behavioral therapy (Veling et al., 2021). The effectiveness of VR within psychiatric treatment and its suitability for exposure-based treatment for an anxiety disorder is systemic. Virtual reality (VR)-based biofeedback is a new intervention and is increasingly being used to treat anxiety disorders (Kothgassner et al., 2022). The fundamental approaches for controlling anxiety disorder are in the attention of management of fears, building environments of care, and to an extent, exposure underlying fear. A meta-analysis published by (David et al., 2019) found that using VR systems, either as a tool of distraction or exposure, had stronger inhibitory effects than other less immersive systems like traditional video games or music alone. This multisensory stimulus of VR lessened perceived pain compared to the control group.

Pain Management

It is increasingly recognized that treating pain is crucial for effective care within neurological rehabilitation in the setting of neurological rehabilitation (Castelnuovo et al., 2016). VR in pain

management is addressed to patients experiencing acute and chronic pain. Excessive pain during medical procedures performed in unanesthetized patients is frequently reported but can be reduced with virtual Reality (VR) distraction (Hoffman et al., 2004). VR distraction was shown to be effective for reducing experimental pain, as well as the discomfort associated with burn injury care. As indicated in a study by (David et al., 2019), the immersive nature of virtual environments has supporting evidence in pain management. While the sense of presence influences the effectiveness of VR as a distraction tool, anxiety as well as positive emotions directly affect the experience of pain (Castelnuovo et al., 2016). Strong overall evidence has been found for immediate and short-term pain reduction after VR, while moderate one for short-term effects on physical function (Riva et al., 2016) allow us to examine the mechanisms of actions that induce such a discrepancy in scores.

Mechanisms of Action

In the last decade researchers have embraced virtual reality to explore the psychological process and mechanisms that are involved in the onset and maintenance of psychosis (Valmaggia et al., 2016). Virtual reality diverts a patient's attention away from pain. In a sense, it stimulates various senses like sight, sound, and sometimes touch. Its compelling, multisensory engagement technique is the core driver that occupies the brain's attention resources. VR effectively overrides pain signal processing by providing stimulus to the brain in a more immersive way.

Enhanced Rehabilitation: Motivation, Progress Tracking, Adaptive Environments

This segment focuses on therapy engagement and the success of rehabilitation programs. Several VR interventions have demonstrated the promise of VR for health behavior change such as increasing intention to get the flu shot and physical activity as well as decreasing vaping interest (Xu et al., 2023). As for rehabilitative effectiveness, VR technology in disease rehabilitation has been widely applied, namely, to help disabled patients acquire lost motor skills caused by injury or illness and ensure these individuals can carry out activities of daily living. As such, the effectiveness of VR exercise on physiological and rehabilitative outcomes have been mostly related and combined (Qian, McDonough, & Gao, 2020). The seamless integration of immersion is redefining the application of virtual reality, its immersive experiences, gamification elements, responsive feedback, and personalized environments have allowed the technology to be specifically tailored to the individual and needs.

Motivation Through Gamification

Additionally, VR may be used for implementing game-based approaches for therapeutic work with children and adolescents (Kothgassner et al., 2022). By incorporating game-like elements, such as scoring systems, and achievements VR can boost participation in therapy. While gamification has been used in diverse areas, there is little evidence to date in psychiatry (Fleming, Poppelaars & Thabrew, 2023). The gamification system can be seen in many other mediums outside of VR and is not inherently exclusive to this system. However, concurrently using gamification systems with and outside of VR can be a potent tool. While there is a lack of convincing evidence that can support the impact of gamification for all patients, trivializing this approach may not be appropriate.

Within the interest of gamification, apps like Headspace, an on-demand healthcare platform primarily targeting mental wellness through guided meditation practices, etc. While it does not look like a game, it uses multiple gamification features. Content comprises short chunks that build into larger achievements: targets and progress are shown clearly: and "badges" for activities are immediate (Fleming, Poppelaars & Thabrew, 2023).

Dependence and Escapism

The realm of virtual games, video games, and e-sports has witnessed remarkable and substantial growth, captivating a diverse and global audience. However, some studies indicate that this surge is often linked to a desire to escape from real life, a phenomenon known as escapism (Marques et al., 2023). Due to the immersions of VR, users can develop psychological dependence, where they prefer the virtual world

over reality because of its ability to simulate ideal scenarios without the challenges of real life. Escapism mediates the relationship between real-world problems and virtual game use, thus being intrinsically correlated with measures related to stress, psychological distress, mental health, and life satisfaction (Marques et al., 2023). The dependence on VR serves as a coping mechanism that delays the necessary confrontation with real-world issues. One of the primary concerns with VR is the facilitation of escapism. With the advent of gaming and its convergence with virtual reality, recent research has been sought to define "Internet Gaming Disorder." Often, escapism is strongly correlated with loneliness, difficulties in emotion regulation, and has strong predictors to suggest that it affects other areas of life. Additionally, this phenomenon of escapism is also observed in other areas of life, such as addiction to alcohol, dance, pornography, and social networks (Marques et al., 2023).

This dependence caused by the internet usage affects developmental stages of youth, some of the most dominant psychiatric distresses have caused increases in social anxiety and low self-concept clarity and have a positive association with elevated levels of depression.

Treatment of Phobias and PTSD: Exposure Therapy

Previous studies reported that VR-based exposure therapy (VRET) was a clinically beneficial intervention for specific phobias (Heo & Park, 2022). Especially the use of virtual exposition therapy shows similar effects compared to traditional vivo exposition in the case of phobias or in sensu exposition in the case of posttraumatic stress disorder (Kothgassner et al., 2022). One of the key advantages of VR is its ability to create realistic and tailored environments that closely resemble traumatic events. It can provide a realistically safe, immersive session that can lead to a reduction of PTSD through cognitive exercises that restructure and build a patient's confidence. The findings suggest that VR could be a better option as it may present immersive trauma-related stimuli by monitoring the subject's responses, such as physiological or subjective stress levels (Heo & Park, 2022).

Cybersickness and Disorientation

The use of VR in therapeutic settings provides innovative options for psychological treatment. However, the integration of VR introduces concerns and challenges that need to be addressed before its widespread adoption. Primary concerns such as cyber sickness, using VR to escape reality, and privacy concerns impact the outcomes of patient treatment. Cybersickness is a condition like motion sickness but induced by immersion into a virtual environment. A study by Oh and Son (2022), found that certain attributes of VR can influence experiences negatively causing cybersickness, which results in nausea, disorientation, and visual discomfort. Attributes that influence the severity of cybersickness and disorientation include camera movement, field of view, path length, frame reference and controllability (Oh & Son, 2022).

Accessibility and Equity

To successfully integrate VR in public health, equitable access to this technology is crucial to its widespread adoption. Virtual reality introduces innovative treatments for a variety of conditions, including mental health disorders, chronic pain, and rehabilitation after injury. Based on an earlier study, there was a considerable link between VR access and gender, with more males accessing the VR equipment. Despite this, no meaningful relationship was found between VR access and age, console access and age, or gender (Hatta et al., 2022). However, socioeconomic and geographic barriers can significantly limit access to VR technologies. Due to the high costs of VR hardware and the need for compatible software and technical support, individuals from lower socioeconomic backgrounds or underserved areas might find it challenging to benefit from VR-based interventions. Public health initiatives that help lower the technological cost of VR equipment for healthcare facilities in underserved areas can be used to help address these disparities. Mobile VR programs deployed to remote locations can offer temporary access to VR therapies and educational instruction. To engage effectively with diverse populations, it is important to ensure that VR content is culturally sensitive and available in multiple languages (Hatta et al., 2022).

Future Directions and Potential

The landscape of Virtual Reality is evolving rapidly. It is critical to expand scalable approaches to improving mental health. Digital tools offer extraordinary potential for this. However, the appeal and stickiness of digital tools must be addressed (Fleming, Poppelaars & Thabrew, 2023). Regarding technological innovation in VR development, issues related to three-dimensional (3D) visualization, dynamic exploration, the trip and flow, immersive experiences, and visual interaction need to be considered by researchers, therapists, and content developers to suit the role of VR for psychological intervention (Hatta et al., 2022). As this technology continues to expand in its capability, newer trends in increased treatment efficiency will emerge. VR offers avenues for therapy, rehabilitation, and patient care; its integration and adaptation can be advantageous. Despite these upcoming, highly promising developments, it is important to keep in mind that using VR technology requires appropriate training and knowledge on the part of healthcare professionals (Kothgassner et al., 2022). Through proper guidance and training, healthcare practitioners can improve frontier innovation in mental healthcare through technology.
Here are the summarizing key points that highlight Virtual realities strengths and weaknesses.

Pros

- Repeatable sessions
- Enhanced Behavioral Therapy
- Improvements in pain management
- Phobia Treatment
- Gamification of Rehabilitation

Cons

- Privacy and Security Concerns
- Accessibility
- Malpractice and Manipulation
- Escapism
- Cybersickness

Patient Education

VR in patient education is extraordinary because it has created multiple modern techniques to approach patient education and rehabilitation. Virtual reality's ability to be immersive has allowed for a revamp of patient educational experience, increases in health literacy rates in patients, and has transformed rehabilitation therapy. While VR undeniably offers advantages, its limitations such excessive cost, limited accessibility, and technological/software constraints, raise concerns about the equitability of virtual reality in patient education. However, with a thorough understanding of virtual reality's abilities, it is imperative that virtual reality is used to the fullest extent for patient education.

VR in Healthcare Education

VR has offered countless benefits to healthcare education and has revolutionized the quality of medical training. Research shows that virtual reality can provide future healthcare professionals with an immersive learning environment. Students can now interact with virtual patients and scenarios in hyper-realistic settings (Pottle, 2019). It can allow future healthcare professionals to focus on their critical thinking skills with little to no risk. This piece of technology also offers a cost-effective alternative to traditional methods as it "allows simulation to be delivered at reduced cost with fewer resources" (Pottle, 2019). However, it is important to note that the cost of VR systems has been a known barrier for making them inaccessible for individual use.

Healthcare Training vs. Patient Education

Both healthcare training and patient education have a myriad of benefits when virtual reality is used, each serving a vastly different purpose and audience. VR-based patient education caters to patients, their families, and caregivers who want to understand medical conditions and procedures relevant to their specific health needs. VR-based healthcare education caters to healthcare professionals such as medical students, nurses, and residents who need advanced education. This type of education mainly aims to inform patients and their families about medical conditions and procedures by improving patients' perception of their health issues and encouraging better communication between patients and healthcare providers (van de Kurt et al., 2022). While VR-based healthcare education's purpose is to provide firsthand experiences for training numerous medical procedures, surgeries, and diagnostic skills, using both VR-based educational tools symbolizes a milestone in delivering medical education.

THEORETICAL FRAMEWORK

A relevant theory that coincides with VR-based patient education is the Experiential Learning Theory. This theory is relevant to using VR-based patient education because it stresses the significance of hands-on experiences within the learning process. According to Polacek (2003), successful learning happens in four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation.

When patients participate in VR-based patient education they gain concrete experience, allowing them to interact with and learn about their health conditions, management, and procedures in a controlled setting. This experience allows the patient to gain a stronger understanding of the information and retain the information for longer (Huang, 2016). Soon after, patients go through reflective observation, where they think about the VR experience, and question the connection between their health behavior and its effects that are due to health management. Abstract conceptualization allows patients to think deeply about how they can modify their existing opinions about their health. In active experimentation, patients use their new understanding in the real world to improve their overall health practices.

The Social Cognitive Theory is also a relevant theory that can be used in understanding how VR-based patient education works. This theory is best described as "a theory of human behavior that emphasizes learning from the social environment" (Schunk & Usher, 2012). This theory also stresses that learning is often due to observing others and modeling their behavior. In a VR setting, patients are in a simulated world where they can interact with health-related scenarios. This experience allows a deeper understanding of behavioral patterns and factors outside control. Since VR is meant to be fully immersive, patients are far more active in their virtual world. The patient will also witness the consequences of health choices and behaviors in a controlled environment. It is crucial for the usage of the theory because if the patients see the consequences of specific health choices in a risk-free environment, they will have a better understanding of the impact of their actions (Makransky & Petersen, 2019). This approach also aids in self-efficacy since it can help build strength and confidence. As a result, patients can overcome difficulties in the virtual world and grow their confidence to face real health issues.

The use of theories offers a unique way to understand the complexities of how VR-based patient education works. These theories imply that learning in virtual reality can only happen through action and observational learning (Huang, 2016). The use of both social cognitive theory and experimental learning theory emphasizes the need for a controlled environment for trial and error. This allows patients to understand the immediate outcomes of health behaviors with minimal risks.

Benefits of Virtual Reality in Patient Education

An important use of virtual reality in patient education is the improvement of patient engagement. According to van de Kurt et al. (2022), "14/18 studies reported that a benefit of VR as a patient education tool was increased patient understanding, knowledge or comprehension." The comprehensive review results suggest that VR addresses the divide created by older educational tools and methods such as pamphlets. Virtual reality can tackle the divide by helping patients actively learn about their health rather than taking a passive approach in their own health management.

Another benefit of using VR-based patient education is the increase in comprehensibility of medical conditions and terminology (Pandrangi et al., 2019). VR has the distinctive ability to create visuals of intricate concepts, it offers an avant-garde experience that helps patients understand their complex medical conditions. Pandrangi et al. (2019) creates this avant-garde experience for individuals diagnosed with an abdominal aortic aneurysm by creating a three-dimensional (3D) model of an AAA from a computed tomography scan and shows it to patients using VR. The study highlights VR's impact on patient education because of its ability to cater to different learning styles, including visual and kinesthetic. The finding suggested that information provided by the VR was well-received as "95% of patients listed VR as a useful educational tool compared with conventional methods" (Pandrangi et al., 2019).

The use of personalized patient care is seen throughout VR's progress in rehabilitation. VR has been able to provide individuals with disabilities with the ability to control their personalized environment and experience different remote locations (Myers & Laenger, 1998). It was made possible using "neural signals including eye tracking, EOG (electrooculogram) and EMG (electromyogram), and 'Mind control' with EEG (electroencephalogram) and EP (evoked potential) signal manipulation," (Myers & Laenger, 1998). This allows patients with quadriplegia to able to do tasks in a virtual setting that they would not be able to do in the physical world. This study pushes for more research in the use of virtual reality, it further proves the importance that rehabilitation plays in patient education.

The fascination with VR in rehabilitation is due to its incredibly customizable and adaptable ability. Now that health professionals can modify VR experiences to meet each patient's needs, the rehabilitation process makes the engaging (Myers & Laenger, 1998). This patient-centered approach increases patient engagement, influencing the likelihood of success in physical rehabilitation.

Limitations in VR-Based Patient Education

Substantial concerns about using VR in patient education are due to cost and accessibility. VR equipment is expensive making it difficult for some healthcare facilities to use VR in areas. Also, the constant maintenance and necessary updates to the VR software and hardware can add additional costs (Baniasadi, 2020).

The need for high technological literacy is a limitation that widens the gap in accessibility. Older adults are more likely to find engaging with VR difficult. However, studies show that older people would thoroughly benefit from the use of VR in patient education, as it "strengthens their balance and aids physical rehabilitation" (Moore et al., 2023). The findings in this study suggest that VR can be a useful device that addresses age-related difficulties. Technological literacy touches on a larger issue in public health, as it might exclude a part of the population from benefiting from valuable educational tools, which can exacerbate health inequalities (Azzopardi-Muscat & Sørensen, 2019).

Further Research

Though there are numerous studies on VR-based patient education, further research must be conducted to bridge the gap caused by accessibility and inflated costs. New research could discover state-of-the-art approaches to making VR technology more affordable and accessible to vulnerable populations. However, the possibility of new research raises a question: What new interventions will be used to guarantee that VR experiences will be inclusive to all individuals? Further investigation is necessary now more than ever, especially since the use of VR-based patient education is still new. Further research can create accessibility in low-income and vulnerable communities, which could help VR-based patient education become essential for patient education and health management.

Personal Data and Ethics

VR has propelled us into a realm where lines between the digital and physical world blur, offering immersive experiences that were once confined to the realms of science fiction. However, when using VR, users willingly or unwillingly share data about their lives, and while the use of it provides some benefits, especially in healthcare, the concern about personal data collected in VR has given rise to ethical dilemmas.

Types of Data Collected

There are many types of data collected through VR. Depending on the type of device, it can collect data on physical movements and the dimensions of the user. For instance, VR Headsets such as Oculus and HTC Vive can track the direction, speed, and angle of the user's hand motion. Other examples of data collected are determining the distance between the user's eyes and the relative height of the headset (Henriksson, 2018). All VR systems can measure head orientation while most can measure head position, and less common systems can even track feet, chest, elbows, and knees to increase immersion (Miller et al., 2020). If VR devices implement more immersion, spatial data must be recorded to generate virtual environments and register the user's body movements. Other VR devices also can use eye-tracking technology. Finally, VR devices related to health can even obtain physiological signals such as heart rate, respiratory rate, skin conductance, and body temperature of patients accurately (Li et al., 2019).

Challenges and Risk

However, since VR data tracks body movements and poses, it poses some user concerns. One of the biggest concerns Ravi (2017) claimed with the data collected from VR is that the data can personally identify a person. For example, VR devices that contain eye tracking. By using near-infrared technology with a high-resolution camera, a person's gaze can be tracked. Whenever light is directed toward the user's eyes, it creates a reflection in the cornea which the camera tracks. This technology can then identify the user's gaze points placed on a document or image the user's eyes are fixated on. It can also record the amount of time spent on those places and if the eyes are locked on a specific object, called fixation, and capture saccades, which are movements from one fixation to another (Ravi, 2017).

By noting these fixation points, researchers can use these data to create heat maps of visual attention and interest, according to Ravi (2017). Additionally, it can record the time spent and what exactly a person was looking at in an image or document. If the VR device contains a pupil dilation tracker, it can assess sensitive information such as a person's mental and emotional state. Like how fingerprints can be used as a password or a way to identify individuals, gaze data can be used the same way. A person's gaze can even suggest age and gender (Ravi, 2017). Observations of pupil dilation patterns can even predict a person's sexual orientation since pupil dilation patterns are a significant indicator of sexual orientation (Rieger & Savin-Williams, 2012).

A study by Miller et al. (2020), shows how easily VR devices can track data and how it can be used to identify a person. Miller et al. (2020) recruited 548 people, of whom 511 only allowed their data to be tracked. Within the VR application, participants had to complete a demographic questionnaire prompting the program to randomly select five videos. Whichever video the participants were given, they then had to answer questions about the valence, arousal, presence, simulator sickness, and desire to share the content. Afterward, another video was prompted with another set of questions. This process repeated five times. Out of the 511 people tracked, results showed that the VR system was able to identify 95.3% of users correctly when trained on less than 5 minutes of tracking data. With these results, Miller et al. (2020) concluded that even if the interaction with VR devices is not meant to be identifying, the data it collects is enough to accurately identify users (Miller et al., 2020).

Privacy Concerns

It is important for the future that as VR use increases, companies ensure that people's privacy can be protected so as not to lose trust. With how easily and how much data can be collected from VR devices and how advanced VR systems identify a user, this can be harmful to individuals if their data is not protected properly. Nass (2009) claims that the lack of protection could lead to an invasion of privacy, falling into the wrong hands and leading to potential misuse such as identity theft and fraudulent activities. Furthermore, if a patient's health information is easily identifiable and disclosed to an employer, insurer, or family member, it can result in stigma, embarrassment, and discrimination. However, protecting the user's privacy will ensure trust between the user and the product (Nass et al., 2009).

For healthcare VR, trust between the patient and the physician is essential. Since VR can help with medical treatments such as physiological disorders, ensuring privacy, confidentiality, and security of health

information is necessary to establish effective communication between patient and physician. Patients tend to be more at ease divulging information about their health and situation when knowing their medical information can be secured (Nass et al., 2009).

Ultimately, every healthcare practice must abide by the Standards for Privacy of Individually Identifiable Health Information, also known as the "Privacy Rule." To implement the requirement of the Health Insurance Portability and Accountability Act of 1996 (HIPAA), the U.S. Department of Health and Human Services (HHS) established these rules as a set of national standards to protect all individually identifiable health information, whether it is stored or shared by a covered entity or its business associate, in any form of media. Under the Privacy Rule, this information is called protected health information (PHI). Examples include demographic data or anything about the individual's physical or mental health condition, the provision of healthcare to the individual, etc. The major goal of implementing the Privacy Rule is to protect the individual's health information while facilitating the necessary exchange of health data to provide and promote high quality health care and protect the public's health (U.S. Department of Health and Human Services, 2008). Therefore, any identifiable health information collected by VR devices when performing treatments or interactions through telehealth must abide by the Privacy Rule, which enables important use of information while upholding the privacy rights of individuals seeking care and recovery (U.S. Department of Health and Human Services, 2008).

When it comes to protecting data, there are suggestions to ensure how to better protect a patient's health information. (Moore et al., 2021) tried to reduce identifiability from motion tracking data by obfuscating motion data as a series of featurized linear and angular velocity summary vectors. They computed velocity feature vectors that matched with the position-based feature vectors but made use of the first-order derivative concerning time. They discovered that this approach decreased GBM, which is their highest performing classifier for the positional representation in their within-session condition, from 90.83% accuracy to 25.67%. Similarly, RF, another classifier used for the positional representation in their between-session condition, decreased from 42.33% to 13.83%. They determined that while the data may still contribute to identification, using the velocity-based classifiers makes identifying the participant a little bit more difficult (Moore et al., 2021).

In medical information systems, traditional security protection strategies such as identity authentication and authorization access control can ensure data integrity; Lu et al. (2013) suggest an additional step to protect a patient's privacy data from not only external illegal users but from the system's internal staff (e.g. database administrators.) They suggest first encrypting a patient's privacy data before storing it into the database of the server side of a medical information system. Their scheme also generates an additional index for the encrypted data to allow a significant portion of the query to process directly on the server side, eliminating the necessity of decrypting the data. Based on the theoretical analysis and experimental evaluation, Lu et al. (2013) concluded that the index constructed by their scheme has good security and is effective. Their protection method can oppose familiar attacks, such as statistical attacks and known plaintext attacks; support various kinds of query operations; and filter out most non-target records at the server side of a medical information system (Lu et al., 2013).

Benefits of Collecting Personal Data

While there can be challenges and risks when data is not properly protected, there are some benefits to collecting personal data. VR can revolutionize healthcare by helping patients and providers achieve better treatments and outcomes. For example, it can help improve surgical efficiency, enhance physical therapy treatments, treat mental health, and many more (Li, 2022). To achieve better results by using VR in healthcare, data is needed. Researchers or healthcare providers need data to find better ways to improve treatment plans or about the patient's health.

VR can help physicians improve telemedicine surveillance during remote healthcare monitoring by collecting data such as health signals by physiological sensors and immersive virtual scenes (Li et al., 2019). A VR health-monitoring system consists of a sensor unit to detect an individual's physiological signals, VR equipment to provide the visual interaction interface and a software program. Depending on the patient's condition, the collection of physiological signals varies. If the patient is equipped with a VR headset and

an EEG monitor when carrying out activities in their daily lives, the integrated software program can record the effects of the brain waves in real time. The physician can then track the patient's condition and obtain a wide variety of EEG samples, enabling a comprehensive understanding of the patient's information. VR devices make it easier to monitor health signals in different scenarios anytime and anywhere (Li et al., 2019).

Since VR can collect health signals, continuous monitoring of physiological data has the potential to help facilitate the early detection of health issues. Jang et al. (2023) studied whether using a VR-based cognitive assessment program could be feasible as a screening tool for mild cognitive impairment (MCI). MCI is the pre-dementia stage where cognitive impairment has not yet significantly impacted an individual's ability to perform their daily activities. MCI primarily affects older adults. Jang et al. (2023) evaluated 108 healthy older adults and 12 patients with MCI with their VR cognitive assessment program and the traditional Montreal Cognitive Assessment (MOCA) test. When caring for a grandchild, the VR cognitive assessment program evaluated the subject's memory, attention, visuospatial, and executive functions. The results showed that the VR program was more sensitive than the existing screening tool for detecting cognitive impairment in MCI. The total and sub-domain scores of the VR program and the existing MOCA test also showed a strong correlation, demonstrating the VR program could become another screening tool for MCI. Results indicated that it also has the potential to identify the type of MCI in patients and track their progression towards dementia (Jang et al., 2023). With more research and testing, VR may be able to screen for other healthcare issues.

Lastly, VR can help treat people with driving phobia through virtual reality exposure therapy (VRET). Since studies examining the efficacy of VRET for driving phobias are rare, this pilot study by Kaussner et al. (2020) explores the behavioral effects of VRET on patients with fear of driving as measured by a post-treatment driving test in real traffic. The therapy adhered to a standardized manual including psychotherapeutic and medical evaluations, two preparative psychotherapy sessions, five VRE sessions, a final behavioral avoidance test (BAT) in real-life traffic, a closing session, and two follow-up phone assessments after six and twelve weeks. The VRE sessions were conducted in a fully equipped driving simulator, with exposure scenarios customized to the different levels of the patient's anxiety. Fourteen patients participated in this pilot study, with assessments conducted across verbal, behavioral, and physiological parameters. Results showed that VRET is helpful with all fourteen patients during the final BAT since they could master the driving tasks they had avoided before. 71% of the patients showed adequate driving behavior from the driving instructor; 93% could maintain their treatment success until the second follow-up phone call. Data from further research with randomized controlled trials is needed to verify the efficacy, however, with the results shown above, VRET shows promises of being able to treat driving fear (Kaussner et al., 2020).

Ethical Considerations

The use of VR in public health raises various ethical considerations that must be carefully addressed to ensure responsible deployment of this relatively modern technology. One of the major ethical considerations is the privacy and data security of an individual's health information collected through VR. However, other ethical considerations must also be addressed, especially when conducting research either on VR or using VR as a tool. Madary and Metzinger (2016) discussed some of the concerns such as the limits of experimental environments, informed consent regarding the lasting psychological effects of VR, risks associated with clinical applications of VR, and the possibility of using the results of VR research for malicious purposes (Madary & Metzinger, 2016).

When experimenting with VR, Madary and Metzinger (2016) recommend following the principle of non-maleficence: not harm. If an experiment could lead to an outcome involving foreseeable consequences that will cause involuntary suffering or serious/lasting harm to the subjects, it should not be conducted. Unless the experiments are designed with the beneficent intention of discovering the psychological impact of immersion in VR, then it is ethically permissible (Madary & Metzinger, 2016).

Since VR experiences may have a lasting psychological impact, this information must not be withheld from subjects in new VR experiments. Out of respect for the subject's autonomy, they should be made

aware that immersive VR can have lasting behavioral influences and that some of these risks may be unknown. Exposure to VR may cause disorientation, leading to conditions such as depersonalization or dissociation from the physical self (Bryant et al., 2020). Madary and Metzinger (2016) suggest one way to prevent threats to the subject's autonomy is by simply informing the subject of the possible lasting effects. Another suggestion to prevent this threat is that research participants' exposure to VR should be maintained in research environments to minimize psychological risks and ensure participants maintain their sense of agency (Bryant et al., 2020).

Another ethical issue would be the many promising applications for VR research in treating disease, damage, and other health-related issues, especially mental health (Madary & Metzinger, 2016). Patients may have "therapeutic misconception, " a sense of false hope that treatments using VR are better than traditional interventions due to recent technology or an experimental application of existing technology. Researchers should be honest about the experiment and take care to not create false hope in patients by communicating their own sense of uncertainty in a clear manner. VR also enables a powerful form of non-invasive psychological manipulation, potentially inducing desirable mental states and behavioral dispositions in subjects which can cause conflict between beneficence and autonomy. If the subject does not seek to alter their psychological profile as intended by the VR intervention, then such intervention may be seen as infringing upon their autonomy (Madary & Metzinger, 2016).

Last, Madary and Metzinger (2016) notes dual use could potentially be a concern regarding technological advancements. In the context of VR technology, it can be used to harm subjects through "virtual suicide attacks" or interrogation procedures and torture. Subjects could for example go through simulations where they could decrease their empathy or induce any other emotions that could be used deliberately to cause suffering. Although the subject is immersed in a virtual environment, torture is still torture; it does not mitigate the subject's suffering (Madary & Metzinger, 2016).

While the possibility of misuse of VR technology raises valid concerns about its ethical implications, if users are informed properly about the associated risks, VR is a valuable tool capable of performing many functions that could help public health.

MR (Mixed Reality) In Healthcare

Introduction to Mixed Reality in Healthcare

Mixed reality (MR) is the result of the merging virtual (VR) and augmented reality (AR). It provides a range of experiences that seamlessly blend the virtual and physical worlds. There are significant implications for several industries, particularly the healthcare sector, from this confluence of technology. MR has great promise for enhancing medical education, patient care, and treatment by creating immersive and interactive environments (Martin et al., 2020; Silvero Isidre et al., 2023; Vervoorn et al., 2023).

Data Collection in Mixed Reality

Like VR, MR systems can capture vast amounts of data on user movements, interactions, and physiological responses. These innovative devices, which can record hand gestures, eye movements, and spatial awareness, provide a wealth of user behavior and engagement data. This feature gives the healthcare industry more chances to gather and analyze data, enabling a thorough grasp of how patients engage with digital information and actual situations. By overlaying digital data on real-world environments, magnetic resonance imaging (MRI) devices facilitate the instantaneous assessment of surgical procedures, patient diagnoses, and treatment strategies. By making it easier to create customized medical solutions, this extensive data collection enhances the efficacy and precision of healthcare delivery (Asadi et al., 2024; Rus et al., 2024; Lundin et al., 2023).

In addition, mixed reality applications in healthcare go beyond data gathering to improve surgical planning and performance. Surgeons can use mixed reality to acquire three-dimensional representations of their patients' anatomy, allowing for accurate preoperative planning and intraoperative assistance. More precise and less invasive operations are made possible by this technology, which lowers the possibility of problems and enhances patient outcomes (Vervoorn et al., 2023; Asadi et al., 2024). As an example, the

potential for remote surgeries and improved precision in complicated operations is demonstrated by mixed reality-guided teleoperation of collaborative robots in surgical procedures (Rus et al., 2024).

Mixed reality offers an unmatched platform for immersive learning experiences in medical education. Professionals and medical students can hone their abilities in a safe, regulated setting resembling actual situations. This experiential learning method is very advantageous in domains such as neurosurgery, where meticulous and exact practice is essential (Silvero Isidre et al., 2023). According to studies (Kolecki et al., 2022; Malik et al., 2023), employing MR as a teaching tool can improve students' comprehension and recall of difficult anatomical and surgical concepts.

Additionally, MR has played a key role in advancing telemedicine and remote consultations. MR can close the gap between patients and experts by allowing medical personnel to engage with patients in immersive virtual worlds, especially in underserved or rural locations (Naidu & Sunkaraboina, 2022). According to Martin et al. (2020), this technology allows thorough remote exams, diagnoses, and even treatments, improving accessibility and efficiency in healthcare. The incorporation of MR into telemedicine systems highlights its capacity to transform patient care and broaden the scope of medical knowledge (Stretton et al., 2024).

Benefits of Mixed Reality in Healthcare

Mixed reality is revolutionizing the field of therapeutic interventions by providing individualized, immersive experiences that boost therapy efficacy. In the context of physical rehabilitation, for example, mixed reality can design customized workout regimens in which patients may participate in an interactive and engaging setting, boosting their motivation and adherence to rehabilitation procedures (Neves et al., 2022). By offering virtual spaces where patients may safely face and control their phobias or anxieties with the assistance of a therapist, MR can also be beneficial to cognitive behavioral treatment (CBT) (Lundin et al., 2023). There are novel treatment options for a range of psychological and physical health disorders thanks to MR's capacity to provide realistic and regulated therapy situations (Gerup et al., 2020).

Furthermore, MR technology revolutionizes patient education by enabling patients to perceive their medical conditions engagingly and understandably. Kersten-Oertel et al. (2013) state that patients can view the steps involved in their upcoming surgical procedures, understand their diagnosis specifics and study three-dimensional anatomy models. This immersive education approach can significantly lower patient anxiety and improve adherence to treatment procedures by simplifying complex medical material (Gerup et al., 2020). Additionally, because MR can simulate post-operative results, patients may have more reasonable expectations for their recovery times, enhancing patient engagement and general satisfaction (Kolecki et al., 2022).

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Notwithstanding these advantages, addressing the privacy and ethical issues surrounding mixed reality in healthcare is imperative. Because MR equipment can collect substantial data, strong data protection protocols are required to guarantee patient privacy and informed consent (Asadi et al., 2024). To avoid abuse and guarantee that the advantages of mixed reality are fairly dispersed among various patient populations, there must also be explicit rules and laws controlling the use of mixed reality data (Kersten-Oertel et al., 2012). The healthcare industry may fully utilize MR's promise to improve patient care and treatment results by resolving these ethical and privacy concerns (Vervoorn et al., 2023).

Privacy and Ethical Considerations in Mixed Reality

As with any technology that collects sensitive personal data, there are significant ethical and privacy concerns when applying mixed reality in the healthcare industry. The ability to collect extensive data on users' physiological and mental health requires a careful assessment of privacy protections and informed consent (Asadi et al., 2024). Healthcare providers must ensure patient data is handled securely and ethically, with well-defined policies governing its use and retention. This calls for the implementation of trustworthy data encryption methods, secure data storage solutions, and transparent patient communication on the intended use of their data (Vervoorn et al., 2023). To ensure that every patient receives unbiased care, it is imperative to create fair and equitable algorithms considering the potential for bias in mixed reality systems (Kersten-Oertel et al., 2012).

Additionally, to guard against data and technological exploitation, integrating mixed reality in healthcare must undergo thorough ethical evaluation. Because MR equipment can collect large amounts of data, strong data protection protocols are required to guarantee patient privacy and informed consent (Gerup et al., 2020). Clear policies and procedures controlling the use of mixed reality data must be established to guard against abuse and guarantee that the advantages are distributed fairly across various patient populations. Patients should have the choice to refuse data collection if they are uncomfortable with it, and healthcare practitioners must make sure that patients are fully informed about how their data will be used and preserved (Kolecki et al., 2022).

To address the ethical implications of mixed reality technology, ethical norms must be updated and monitored continuously to keep up with technical improvements. Since mixed reality technologies are developing faster than current regulatory frameworks, there needs to be constant communication between technologists, legislators, and healthcare professionals to make sure ethical standards are applied correctly and continue to be useful (Kersten-Oertel et al., 2013). To prevent ethical dilemmas and guarantee that patient rights and welfare are always prioritized, mixed reality systems should undergo routine audits and evaluations (Neves et al., 2022). The healthcare industry may fully utilize mixed reality technology to enhance patient care while upholding the highest levels of ethical conduct by proactively addressing these ethical and privacy concerns.

In summary, implementing mixed reality in healthcare offers significant benefits but also requires careful attention to ethical and privacy considerations. Data security, informed consent, and unbiased treatment are paramount to effectively leveraging mixed reality technology. Continuous ethical scrutiny and adaptation to technological advancements will help maintain trust and integrity in the healthcare system as mixed reality becomes more integrated into medical practice.

Addressing Ethical Challenges in Mixed Reality

Setting patient autonomy, informed consent, and data security as top priorities is essential for stakeholders who want to address the moral problems that mixed reality (MR) in the healthcare industry presents. Creating detailed guidelines for the appropriate use of MR technology is necessary to ensure patient rights are respected throughout therapy (Kolecki et al., 2022). Healthcare facilities should establish protocols for getting informed consent from patients by describing the benefits and drawbacks of mixed reality applications in detail (Gerup et al., 2020). As magnetic resonance technology advances, it will be crucial to do continual research and have ongoing conversations to identify and address new ethical issues. Policymakers, healthcare professionals, ethicists, and technology developers will need to work closely together to design and implement these standards (Kersten-Oertel et al., 2013).

Healthcare personnel and technicians involved in the implementation and administration of mixed reality technologies must get thorough ethical training and instruction. This entails teaching students about patient permission, the possible biases in mixed reality systems, and the ethical implications of data collection and utilization (Neves et al., 2022). Healthcare organizations may ensure that all parties involved are prepared to tackle moral conundrums that occur with mixed reality technology by cultivating a culture of ethical awareness and accountability. According to Lundin et al. (2023), this strategy protects patient rights and fosters openness and confidence in the healthcare system.

To guarantee that the recommendations are inclusive and consider the concerns of all stakeholders, active engagement from a variety of patient groups should be involved in the development of comprehensive guidelines for the ethical use of MR technologies (Silvero Isidre et al., 2023). Patient advocacy organizations may be extremely helpful in gaining understanding of patients' viewpoints and influencing laws that put patients' needs first. Healthcare practitioners should create more patient-centered approaches to mixed reality technology and make sure that the advantages of these advancements are shared fairly by involving patients in the discussion (Martin et al., 2020).

Strong supervision mechanisms must be put in place to watch the application and deployment of Mixed reality technologies to further address ethical issues. Regulatory organizations must be created or given authority to supervise the moral use of Mixed reality in healthcare, guaranteeing adherence to set standards and swiftly resolving infractions (Vervoorn et al., 2023). These supervision procedures must be flexible enough to be updated and modified as magnetic resonance technology advances and new moral quandaries surface. The healthcare industry may manage the challenges of mixed reality technology while keeping the highest levels of ethical behavior by taking a proactive approach to ethical supervision (Asadi et al., 2024).

FUTURE DIRECTIONS FOR MIXED REALITY IN HEALTHCARE

Mixed reality has the potential to transform medical education, patient care, and other aspects of healthcare delivery in the future. By providing future healthcare professionals with access to real-world experience in a risk-free environment, integrating mixed reality into medical curriculum can significantly revolutionize their training (Silvero Isidre et al., 2023). By providing more precise and customized patient care treatments, mixed reality may contribute to better patient outcomes. As an illustration, mixed reality may be utilized to plan complex surgical operations, enabling medical professionals to see and manipulate a patient's anatomy in three dimensions before beginning therapy (Asadi et al., 2024). We may effectively employ mixed reality while upholding moral principles and protecting patient anonymity by encouraging collaboration between tech developers, medical practitioners, and ethicists (Kersten-Oertel et al., 2013).

Mixed reality integration into standard medical practice also improves patient education and involvement. Interactive magnetic resonance imaging (mixed reality) visualizations can help patients better comprehend their symptoms and treatment plans, enhancing treatment adherence and patient satisfaction in general (Martin et al., 2020). This patient-centered approach can promote a more open and cooperative healthcare setting by bridging the communication gap between patients and healthcare practitioners. Positive health outcomes are more likely when people are more informed and actively participate in their own care (Kolecki et al., 2022).

By enabling immersive, real-time interactions between patients and healthcare professionals wherever they may be in the world, mixed reality has the potential to completely transform telemedicine. This can be especially helpful in places that are underprivileged or distant and have limited access to expert medical care (Gerup et al., 2020). Medical robotics (mixed reality) can potentially decrease healthcare expenses and improve care delivery by eliminating the need for travel and in-person visits by allowing comprehensive remote exams and consultations (Vervoorn et al., 2023).

It will be crucial to address the moral and legal issues raised by applying mixed-reality technology as it develops. Creating strong norms and standards may guarantee the responsible and ethical use of mixed reality technology in healthcare. Informed consent must be obtained, patient data privacy must be maintained, and any biases in mixed reality systems must be addressed (Kersten-Oertel et al., 2013). As mixed reality technology develops, it will be imperative to identify and address any new ethical issues that may surface through further study and stakeholder interaction (Neves et al., 2022).

When utilizing mixed reality, healthcare institutions must take a calculated approach that balances morality with innovation. Using mixed reality technology appropriately can create new opportunities to improve patient happiness and healthcare outcomes (Lundin et al., 2023). As mixed reality advances, it is critical to prioritize patient rights and privacy while being mindful of ethical considerations. With collaborative efforts and ongoing research, the healthcare industry may fully realize the transformative

potential of mixed reality, paving the way for a day when cutting-edge technology and compassionate care coexist (Silvero Isidre et al., 2023).

The use of mixed reality in healthcare is a noteworthy technical development that can revolutionize many areas of medical practice. mixed reality offers immersive and interactive environments that can improve treatments, patient care, and medical education by fusing virtual and real-world experiences (Silvero Isidre et al., 2023). The capacity of magnetic resonance imaging (MRI) devices to obtain comprehensive data on physiological responses and user interactions presents novel opportunities for personalized medicine and in-the-moment assessment of medical procedures, which in turn improves the precision and effectiveness of healthcare delivery (Asadi et al., 2024; Kersten-Oertel et al., 2013).

The application of machine learning in healthcare is not without difficulties despite its enormous promise. To preserve patient confidence and regulatory compliance, ethical and privacy issues, such as the requirement for strong data protection and informed permission, must be properly addressed (Lundin et al., 2023). To resolve these problems, legislators, medical professionals, ethicists, and technology developers must work together to create precise norms and guidelines for the moral use of mixed reality technology (Neves et al., 2022).

In the future, mixed reality has the potential to completely transform patient care, particularly when it comes to its uses in telemedicine and remote consultations, which can increase access to healthcare in underprivileged regions (Gerup et al., 2020). Furthermore, by incorporating Mixed reality into medical education programs, future medical professionals can get practical experience in a safe and regulated setting, developing a new pool of highly qualified practitioners (Silvero Isidre et al., 2023). To maximize the advantages of magnetic resonance imaging in healthcare and overcome its limitations, stakeholders must continue to collaborate and do research.

In summary, mixed reality offers the healthcare industry a revolutionary chance by providing cutting-edge approaches to patient care, education, and therapeutic interventions. The healthcare sector can fully realize the promise of Mixed reality technology to improve patient outcomes and overall healthcare delivery by addressing ethical concerns and guaranteeing appropriate usage. The application of Mixed reality in healthcare appears to have a bright future as technology advances, opening the door to more effective, efficient, and patient-centered approaches to healthcare.

CONCLUSION

In conclusion, this paper highlights the innovative possibilities of virtual reality for improving mental health, enhancing patient rehabilitation, ethical concerns, and data collection. The benefits of VR offer a fresh take on therapies for mental health issues such as reducing stress and anxiety, helping with PTSD or phobias, and faster rehabilitation. However, virtual reality is not without its problems, side effects tied to VR include cybersickness and disorientation, and patient dependence or escapism. Integrating virtual reality technology into healthcare, while offering innovative possibilities in treatment and early detection of health issues, also presents significant ethical, privacy, and data security barriers. As VR technology increasingly collects comprehensive data on user's physical status and emotions, these concerns must be properly addressed to not lose consumer trust.

Considering these limitations, virtual reality stands to be a transformative tool for healthcare technologies. Prioritizing accessibility in low-income or vulnerable communities promotes health equity, reduces disparities, and drives innovation in healthcare delivery. Future research endeavors are needed to establish standards for governing mental health outcomes, patient education, and patient data's ethical collection and utilization.

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