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Artificial Intelligence and Virtual Reality in the Metaverse: A Scoping Review of Human-Centered Applications in Public Health

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Abstract: In recent times, the introduction of new technologies, such as the Internet of Things and blockchain systems, has transformed the way healthcare is delivered. Through illness checks, chronic disease management, healthcare training, and public health initiatives, artificial intelligence (AI) and virtual reality (VR) are revolutionizing public health in the Metaverse. With substantial data and modest types of artificial intelligence, epidemiological investigations can become a valuable weapon for identifying emerging diseases and optimizing measures to cope with critical situations. Machine learning models are beneficial for determining infection type and for informing disease prevention measures during the COVID-19 outbreak. Incorporating VR enables training environments that allow practitioners to simulate emergency response plans, evaluate intervention strategies, and optimize resource allocation. Applications that use AI for remote health monitoring collect real-time patient data and help tailor treatment plans for conditions such as diabetes, hypertension, and cardiovascular disease to manage chronic illnesses. The smart garment is designed to suggest possible treatment to the patient and comes equipped with sensors that can detect early signs of disease. The use of an opioid is a simple approach to pain management. Still, it needs a VR-based cognitive behavioral therapy that can effectively address pain and its impact, hence enhancing the quality of the patient's life. Health campaigns using artificial intelligence involve the dissemination of health information that fosters behavior change.

Keywords: Artificial Intelligence, Virtual Reality, Metaverse, Public Health, Human-Centered Applications, Scoping Review, Digital Health, Extended Reality (XR)

INTRODUCTION

Virtual reality (VR) and artificial intelligence (AI) are two emerging technologies that have transformed healthcare systems (Junaid et al., 2022). They are steadily extending their applications to multidisciplinary fields, including healthcare. Regarding public health, the Metaverse, a connected digital world, enables people to interact with the world through avatars. Nonetheless, these technologies can be perceived as both promising and problematic. Applying AI in VR offers nearly limitless possibilities for developing the Metaverse, including healthcare solutions, medical education, and technologies that enhance, and even create, treatment options and preventive measures in virtual space.

Healthcare professionals utilize technical products to help patients manage their conditions. This trend has recently led to increased adoption of technology in healthcare systems. The COVID-19 pandemic highlighted the importance of contact minimization in medicine, prompting people to adopt telemedicine and remote care (Iqbal et al., 2024).

The Metaverse has taken this even further, simulating realistic, real-life healthcare scenarios with a personalized experience, including virtual consultations with doctors and even artificial intelligence-driven contact tracing. Moreover, virtual reality in medical settings offers alternative approaches to medical training, allowing procedures involving simulated patients to be performed safely.

THE CONCEPT OF THE METAVERSE IN HEALTHCARE

The Metaverse is a virtual environment where people and organizations use avatars to engage in various activities (Waykar, 2023). It has applications in areas such as healthcare, where some or all medical services may be delivered from another location. Medical education could be conducted virtually, including simulations and global health-related awareness campaigns. Through real-time predictions, personalized medicine, and automation, AI enriches the experience of the Metaverse.

The use of digital health technology was not rapidly adopted until COVID-19 began forcing the implementation of telemedicine and internet consultations (Shaver, 2022). Although it is still evolving as a space for ads and future messaging, the Metaverse connects global experts who work collectively to solve various simulated case scenarios in real-time, enhancing cooperation among healthcare workers. Through the elimination of spatial restrictions, doctors, researchers, and medical students can participate in global discussions, attend conferences, and contribute to the decisions being made.

The Metaverse, therefore, has the potential to enrich patient experience. Web-based communities and discussion boards are effective for those with mental illness or other long-term conditions to share, learn, and interact with others and professionals (Hasei et al., 2024). Teleconsultations, health advice, monitoring assistance, AI-driven chatbots, and virtual assistants further enhance patient care. This concept can be applied to physical therapy and rehabilitation using VR metaverse technologies.

TELEMEDICINE AND REMOTE HEALTHCARE

Telehealth has revolutionized the way healthcare is delivered. Therefore, the combination of AI and VR in the Metaverse paves the way for a new world of healthcare events that are integrated, prompt, creative, and intelligent (Ali et al., 2023). Users can interact with AI-based chatbots and healthcare providers through numerous virtual clinics within the Metaverse, thereby eliminating geographical restrictions and reducing strain on the current healthcare system. Information about vital patient parameters can be gathered and analyzed in real-time through artificial intelligence in diagnostics. According to a review of chronic diseases, including diabetes, cardiovascular diseases, and hypertension, by Islam et al. (2022), improvements were observed in diagnostic accuracy, reduced consultation time, and increased patient satisfaction resulting from AI-based telemedicine systems.

Incorporating VR technology successfully complements remote physical examinations in telemedicine due to haptic feedback and realistic models. New situations that prevent an individual from accessing a doctor, such as distance or related complications, can then aid in the real-time evaluation of mobility, posture, and neurological status (Iqbal et al., 2024). This was much higher than traditional telehealth services, noting a 45% increase in patient engagement in 2021, as highlighted by Patel et al., describing an actual environment in which a patient with a chronic backache would use the virtual reality environment for a doctor to monitor and analyze the patient's motion, as well as prescribe specific exercises.

Another study by Haleem et al. (2024) aimed to compare the effectiveness of Virtual Reality in physiotherapy with traditional physiotherapy. The findings revealed that Virtual Reality physiotherapy was 40% more effective in enhancing mobility and 30% less effective in reducing pain in patients compared to those in the control group. With wearable devices connected to the Metaverse, it is possible to have real-time check-ups on various conditions, such as blood pressure, oxygen level, and pulse. These sensors provide constant health surveillance as algorithms alert to deteriorating medical conditions. In their systematic review paper, Lewinski et al. (2022) explain that Tel Health Solutions for chronic diseases, implemented through AI-driven telehealth systems, lead to reduced rehospitalization and emergency visits in patients with CHF and COPD.

Case Study: The Use of VR in Pain Management

Pain control is one of the most suitable areas for VR applications in telemedicine. A study conducted at Cedars-Sinai Medical Center aimed to determine the impact of VR therapy on pain. They were placed in virtual environments such as waterfalls or a beach where the chronic pain patients became so preoccupied with what was going on that they could not focus on their pain (Spiegel et al., 2019). This produced substantial findings on the reduction of pain sensation, and this means that VR has the potential for the PC to replace opioid approaches to treatment.

In a systematic analysis, Spiegel et al. (2019) estimated that VR-based treatments can decrease acute and chronic pain discomfort by 30-50%, which is closer to the preferred level, as VR therapy is non-invasive and has minimal side effects. This is especially important today because of the opioid crisis and the availability of safe pain management choices. In a randomized controlled trial by Alvarado et al. (2025) to evaluate the efficacy of VR therapy for cancer patients undergoing chemotherapy, the patients using VR therapy reported better outcome measures of pain scores and reduction in anxiety than patients who received standard pain management. In addition, VR exposure therapy helps in managing panic and pain, especially in burn cases or even physical abuse situations. As mentioned by Norouzkhani et al. (2022), a patient who underwent burn surgery was offered VR therapy, where the patient experienced a 35% decrease in pain during wound care without the use of opioids. This means that, with the emergence of VR and telemedicine in the Metaverse, specific ways will alter the management of pain and suffering without the use of drugs or surgery in the future.

MEDICAL TRAINING AND EDUCATION

Advances in AI have impacted medical education by emulating life experiences and utilizing virtual reality tools that enhance the training mode provided. Much has been written about how it can offer an opportunity to train medical students, residents, and physicians how to do their work without harming their patients (Pottle, 2019). Intelligent instructors can help respond to learners' actions and be used to design personalized education courses that enhance understanding and learning. In their systematic review, Mallek et al. (2024) found that incorporating VR as an instructional delivery method enhances the learners' knowledge level by 40% compared to conventional methods, such as textbooks. Moreover, with the help of machine intelligence, simulations can be created to determine the specific skills a trainee lacks; they can also be developed to tailor training according to the trainee's skill gap and suggest how to address it.

Some of the strengths of VR training in medical training include the ability to simulate rare and complicated scenarios during practice. This way, decisions are made with realistic simulated emergencies, such as cardiac arrest, stroke, sepsis, and significant trauma. Elendu et al. (2024) demonstrated that medical students trained through VR Simulations are 29% higher in crisis management and high workflow than students trained using conventional techniques. Similarly, a study by Huang et al. (2024) found an increase in the depth of learning and adherence to guidelines by 35% among patients trained through VR.

VR in Anatomy and Surgical Training

Technologies, including VR, are gradually transforming knowledge of anatomy. For instance, Harvard Medical School has adopted live, 3-D virtual models that facilitate modeling and analyzing internal organs and physiological processes at the learners' fingertips. Heather et al. (2019) also argued that anatomy lessons through VR improved spatial understanding and retention rates by 42% compared to other teaching forms. Responses indicated that medical students found using VR for their anatomy learning more engaging and motivating than the traditional method.

One of the primary areas where VR demonstrates its effectiveness is in surgical training, where residents must practice complex procedures in realistic conditions. Johns Hopkins University has readily embraced VR applications, where learners and residents practice surgeries with actual mock instruments (Ntakakis et al., 2023). It also enhances the skills and experience of trainees before they are allowed to operate on actual patients. Ntakakis et al. proved that surgeons trained using Virtual Reality technology took 29% less time to complete laparoscopic surgeries and committed six times fewer errors than those trained using traditional methods. This has been further supported by Seymour et al. (2002), who found that the use of VR surgery simulation reduces the likelihood of complications and enhances general surgery efficiency.

The Role of AI in Medical Training

AI enhances medical learning by serving as an online instructor who can set and grade tests and exams (Bajwa et al., 2021). In the case of ML, a trainee's performance can be monitored, and by inputting the results into the system, the system can identify areas where the trainee is struggling and change the content to reflect those areas. For example, AI can observe how a trainee performs an incision and guide them to do it properly during practice. Tran (2024) found that integrating AI into the learning process enhanced the learners' diagnostic proficiency by 23% and helped learners attain procedural competencies sufficiently.

Moreover, the advantages of virtual reality and artificial intelligence can bring medical education to a distance and provide high-quality education in different parts of the world. Hung et al. (2023) noted that VR-based distance learning appeared more advantageous when participants had limited access to medical learning environments. Thus, the use of Virtual Reality and Artificial Intelligence in the learning process helps upgrade the Competency of medical doctors regardless of where they practice. In this case, medical education becomes more accessible to everybody, which can help improve overall healthcare standards globally.

MENTAL HEALTH TREATMENT

The framework of virtual reality and cognitive behavioral therapy is being employed to enhance the treatment of mental illnesses that include anxiety, depression, and posttraumatic stress disorder (Dilgul et al., 2020). The study established that VRET is the most effective therapy since patients can expose themselves to situations that invoke anxiety in a controlled way. Virtual means of therapy and support, including chatbots and virtual therapists, are evolving as technologies for human counseling become more accessible and affordable. Compared with face-to-face CBT, Wang et al. (2024) carried out a systematic review of VR-based interventions as being effective in the reduction of anxiety symptoms.

A meta-analysis conducted by Heo and Park (2022) compared 18 RCTs and showed that VR exposure therapy was 45% more effective for reducing the symptoms of PTSD than conventional exposure therapy. It is especially valuable for patients like soldiers and police officers who experience traumatic events that can result in nightmares and flashbacks. Virtual reality permits multiple pre-specified trauma rehearsals involving intent-focused cognitive reprocessing by therapists. Unlike traditional talk therapies, VR enables patients to repeatedly face an experience in a controlled environment, where they can manage their feelings and avoid triggers.

AI-Powered Mental Health Interventions

The usage of artificial intelligence is expanding for mental health services. Machine learning has been utilized in virtual solutions, such as chatbots and virtual counselors, to deliver real-time interventions (Luxton, 2014). These systems can capture the spoken language in the dialogue between a patient and a therapist and analyze text input to generate an answer based on the therapy models. Haque and Rubya (2023) examined the effectiveness of Woebot. This AI chatbot dispenses CBT-based treatments and discovered that those participants' depressive signs dropped by 25% within two weeks of using the tool.

AI is also being used in the early identification of mental disorders and prevention. Machine learning and deep learning algorithms are capable of processing speech and other contextual information to isolate the language features that are associated with depression and anxiety disorders. A systematic review by Mao and Chen (2023) demonstrates that AI had an 85% accuracy rate for predicting the presence of depressive episodes when measuring negative affectivity, speech disfluency, and first-person pronoun usage. Such predictive abilities are immensely valuable during early detection, leading to immediate treatment in efforts to manage mental health disorders.

Case Study: Virtual Reality Exposure Therapy for PTSD

A study conducted by the University of Southern California examined the effectiveness of VR exposure therapy in treating such veterans with combat PTSD. Participants were 92 patients who volunteered to engage in an experimental, six-week program of VR therapy that recreates combat scenarios. The results showed that 72% of the participants had an improvement in their PTSD symptoms, and 76% of the participants could sustain these improvements after six months of follow-up (Vianez et al., 2022). This aligns with the participants' reports of reduced hyperarousal, avoidance behaviors, and improved emotion regulation, pointing to the potential of using VR as a complement to pharmacological interventions.

According to Kothgassner et al. (2019), VR exposure therapy can lead to significant improvement in PTSD, phobias, and SAD. Pooled results from 24 clinical trials demonstrated a moderate to significant effect for VR interventions, with an estimated decrease in symptoms by about 40 to 50% for different anxiety-related disorders. Also shown was improved patient compliance with VR therapy compared to traditional exposure therapy, due to the stimulation provided by the simulated environment.

PUBLIC HEALTH CAMPAIGNS AND AWARENESS IN THE METAVERSE

Some potential benefits of Metaverse for a public health organization include preventive treatment, education, promotional activities, and health fairs. This is because the principal means of sharing messages in traditional campaigns, namely mass media and social networks, allow for scant direct engagement with the audience, and the latter becomes easily bored (Ghaempanah et al., 2024). The Metaverse fosters participation and provides a sense of immersion that reinforces the goals of health communication to a great extent. Wilson et al. (2024) noted that AI integration in campaigns enables the tracking of user engagement and/or population engagement, as well as the possibility of changing specific behaviors. Digital campaigns with interaction and feedback options are more effective in encouraging healthy behavior change than traditional static media campaigns.

The Role of VR in Public Health Campaigns

Notably, one of the most effective uses of VR has been in raising public awareness and illustrating the long-term health impacts. VR helps people remain informed about various issues. It translates strategies and threats into scenarios that appear real. For example, an educational campaign on the ill effects of smoking could use VR to depict how hard it is to breathe due to COPD. Zhuang et al. (2015) compared the VR smoking cessation programs with traditional educational approaches and realized a 30% increased abstinence rate. According to Tatnell et al. (2022), a virtual reality intervention involving smoking cessation, obesity, substance abuse, and disease awareness resulted in a 45% increase in knowledge about the disease and a self-reported behavior change of 25%. These findings support the notion that applying informed/passive exposure with VR to high-risk audiences for public health promotion is feasible. By improving behavior, Virtual Reality is an educational tool to enhance knowledge and promote a healthy diet.

AI-Driven Analytics in Public Health Initiatives

AI is a crucial component in strengthening and enhancing campaigns for public health. Automated behavioral assessment for habit formation measures the likelihood that the person of interest follows through with healthful behavior change plans and the proposed interventions. The typical messaging and media practices are derived from a big data analysis of user experiences in VR related to health (Olawade et al., 2023). These authors noted that digital interventions supported by artificial intelligence increased by 20% compared to traditional health campaigns. This demonstrated the power of AI in spreading the messages and raising awareness. Additionally, utilizing artificial intelligence-based virtual health consultants provides efficient and easy access to health information within the Metaverse.

EPIDEMIOLOGICAL RESEARCH AND DATA COLLECTION

AI and VR have been accepted in epidemiological studies as new tools that enable the instantaneous modeling and the predictive, dynamic analysis of disease. It examines the massive volume of health information, recognizing patterns and the likelihood of disease emergence before it spreads (Jiao et al., 2023). In contrast, VR offers researchers a scenario in which they can try potential approaches to delivering public health interventions without interfering with real-world outcomes (Khatri et al., 2023). These technologies enhance disease surveillance, outbreak investigation, and preparedness for population health emergencies by integrating time series data into forecast models.

Epidemiological models became particularly influential during the COVID-19 pandemic, as machine learning enabled governments to utilize data inputs such as mobility, cases, and hospitalizations to estimate the spread of the virus (Wang et al., 2022). These models were employed to predict the incidence of infections, evaluate the effectiveness of lockdown measures, and plan vaccine rollout programs. The Metaverse enables epidemiologists to enhance such tools, simulate pandemics as events, and refine crisis interventions and responses (Ifdil et al., 2023).

Digital tracing and isolation measures, improved vaccines, and healthcare management are best conducted in artificially generated communities with an epidemiological profile that mimics real populations.

AI-Enhanced Early Disease Detection and Public Health Response

AI modeling helps diagnose communicable diseases before they spread in regions that would otherwise require time-consuming disease surveillance. This involves analyzing data from trending information on social media platforms, admissions, health monitoring devices, and self-reported symptoms to identify signs of a possible outbreak (Parums, 2023).

Near real-time disease surveillance feeds AI models with various data sets to support containment before the outbreak progresses. Another aspect of virtual supervision is using AI to control the health status of specifically identified neighborhoods in the Metaverse. AI systems can track reported symptoms, the total number of health-associated posts, and virtual engagements, enabling the identification of new health risks (Ghaempanah et al., 2024). That level of surveillance allows early interventions or responses in cases where diseases do not spread, unlike reduced public health measures.

VR in Epidemiological Training and Crisis Preparedness

As a powerful tool in simulation training, virtual reality has principal applications in epidemiology and crisis management. Some key learning activities include catastrophe simulations, which are typically experimental emergencies in virtual environments open to students and practicing public health professionals (Alshowair et al., 2024). Such epidemiological models utilize VR environments to simulate the spread of diseases, enabling policymakers to assess the impact of various containment measures, resource allocation, and information dissemination during crises.

Zhang et al. (2021) explain that VR-based training for public health workers increases decision-making accuracy and reduces response time for emergencies, such as pandemics, by 35%. Simulation is valuable to healthcare personnel, mainly because it provides practical experience that helps prepare them for the actual field.

AI-Driven Personalized Risk Assessments and Public Health Interventions

Virtual epidemiology concerning AI entails anticipating and employing strategies to prevent, contain, and manage the spread and consequences of communicable diseases based on inherited predispositions or susceptibilities, behavioral patterns, physical and social environments, and demographic settings. Such findings help provide the proper preventive measures, especially for individuals at higher risk (Alshowair et al., 2024). AI-supportive care approaches enhance immunization access and feasibility, particularly in limited formal healthcare settings (Rahimi et al., 2021). Consequently, health initiatives will achieve better results and secure funding across regions and demographics by mapping disease rates using artificial intelligence.

Advanced technologies, such as artificial intelligence and disease surveillance, have been utilized in epidemiological studies, especially when incorporated into virtual reality programs. These applications provide important and relevant data on disease propagation and the effectiveness of interventions that can be of great use to researchers and healthcare systems in formulating effective strategies for tackling such diseases. Epidemiologic research that integrates the features of disease prevention, prediction, avoidance, and crisis management enhances the use of artificial intelligence predictive analytics alongside virtual reality training and simulation.

CHRONIC DISEASE MANAGEMENT

AI and VR manage chronic ailments and enhance wellness through home monitoring, self-care activities, and motivation. Diabetes, hypertension, and cardiovascular diseases are examples of long-term ailments requiring constant observation and adherence to a regimen that is not easily manageable for many patients. Through wearables and EHR, inpatients reported sensations, which are automatically monitored in real-time for any deviation that may require immediate action (Kothgassner et al., 2019). For example, it can examine the blood sugar level of patients with diabetes to calculate the insulin dosage required to prevent conditions such as hyperglycemia and hypoglycemia.

Wang et al. (2023), in their systematic review of 20 trials, found a 20% improvement in glycemic control with the use of AI compared to self-monitoring. Furthermore, AI can function harmoniously with telemedicine solutions, allowing healthcare providers to adjust medications and treatments remotely, thereby reducing the number of visits and improving the long-term effects of various diseases.

AI-Assisted Hypertension Management

The usefulness of AI in hypertension management lies in its ability to detect changes in blood pressure, identify warning signs or abnormalities, and pinpoint potential contributing factors. Smart blood pressure monitors analyze the users' daily readings with an in-built AI and detect emerging hypertensive crises (Hung et al., 2023). These systems offer lifestyle advice, including dietary and exercise modifications, which may help manage blood pressure in patients.

The study indicates that using AI support leads to a 15% increase in patient compliance with medications and a decrease of 10 mmHg in systolic blood pressure compared to traditional interventions (Alshowair et al., 2024). Technological interventions, including tailored information and communication technologies such as virtual assistants and health chatbots, enhance client engagement by presenting patient-specific health information, time prompts, and details about medication adherence and behavioral modification. The introduction of AI in managing hypertension helps increase patient concordance, resulting in better cardiovascular risk and more remarkable improvement in long-term outcomes.

VR in Rehabilitation for Stroke and Cardiac Patients

The utilization of virtual environments in rehab is one of the most efficient approaches to treating stroke patients, cardiac patients, and patients with musculoskeletal system injuries. Many standard rehabilitation methods can be tedious, leading to poor patient compliance; however, with virtual reality, rehabilitation is often associated with fun activities, resulting in higher compliance. For stroke rehabilitation, VR provides simulated environments and programs that allow real-life tasks to be practiced multiple times for motor recovery. Hung et al. (2023) noted that motor function improved by 30% since the implementation of VR-based approaches for stroke patients compared to conventional rehabilitation. Similarly, VR is implemented in cardiac rehabilitation, where environments created for patients are used to guide them through programmed exercises based on their rehabilitation stage.

VR for Pain Management and Behavioral Therapy

Arthritis and fibromyalgia are chronic pain conditions that can benefit from the use of Virtual Reality. VR offers promising non-drug pain management strategies that help reduce the reliance on opioids and other drugs (Dy et al., 2022). This VR CBT can also reduce pain perception and generally improve the quality of life by 25%, as reported by Singh et al. in a 2023 meta-analysis. Some virtual reality chronic pain therapies entail auditory and visual cues, biofeedback training, and peaceful scenes to help patients relax or reduce pain. It is particularly valuable in chronic pain states, in which it can be used as a non-drug approach to pain control. Applying VR in chronic disease management helps manage pain, enhances the overall quality of life, and ensures the patient receives the required care at all stages of their life.

CONCLUSION

AI and VR in the Metaverse have emerged as positive influences in healthcare, bearing the potential to advance public health promotion, epidemiological research, and chronic disease management. In contrast to traditional health promotion models, the Metaverse offers active, hands-on educational experiences to improve people's health. Prediction or actual diagnosis of diseases is one area that has benefited from the advances in big data analysis mentioned in previous sections. Here, it is about early indications, new patterns, and trends of diseases. In addition, virtual reality provides realistic scenarios for exercising; therefore, healthcare practitioners can practice realistic emergency approaches rather than demonstrate them. These technologies proved helpful during the pandemic: AI models helped the governments predict the further evolution of COVID-19 and allocate medical supplies; virtual reality helped the healthcare personnel predict the further course of disease transmission. In chronic disease management, AI-driven health monitoring involves patients receiving personalized information and being continuously monitored. Research has also shown the effectiveness of VR-based therapy applications in enhancing compliance with stroke, cardiac, and pain management regimens. In behavior change, applied practices used in public health campaigns within the Metaverse include gamification and artificial intelligence applications utilizing metadata. Innovation has always been a central concept in public health, and employing methods such as Artificial Intelligence and Virtual Reality can open up new possibilities that are crucial for the advancement of the global healthcare system.

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