Virtual and augmented reality in healthcare management mechanisms for maintaining public health: Literature overview

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Abstract. The study aimed to analyse scientific data on the use of virtual and augmented reality technologies in the practical work of doctors. The main results of the study showed that virtual and augmented reality are actively transforming the medical field, offering new opportunities to improve the quality of medical services. In particular, these technologies are effectively used in dentistry for treatment and prosthetics, in ophthalmology for diagnosis and vision training, as well as in psychiatry and psychological assistance for the treatment of phobias, post-traumatic stress disorder (PTSD) and anxiety. In addition, VR and AR technologies have proven effective in the rehabilitation of patients after strokes, traumatic brain injuries, and in the restoration of motor functions after orthopaedic surgery and amputations. Of particular note is the role of VR and AR technologies in planning complex operations, where they can be used by surgeons to pre-model interventions and receive visual cues in real time, reducing the trauma of operations and increasing their effectiveness. In rehabilitation programmes, VR and AR are becoming crucial tools for the physical and cognitive rehabilitation of patients, providing effective methods for restoring motor and cognitive functions. Another relevant aspect is the use of VR and AR for training medical professionals, which can be used to practise in conditions close to real life without risk to patients, thereby improving the level of professional training of doctors. This review not only showed how virtual tools can be used to solve specific problems in medicine, but also encouraged a further analysis of the processes taking place in the healthcare sector under the influence of the latest information and communication developments

Keywords: virtual technologies; non-drug treatment; patient rehabilitation; VR simulators

Introduction

At the beginning of the 21st century, virtual reality (VR) and augmented reality (AR) have become an integral part of the modern digital world, changing approaches to learning, entertainment and professional activities. They create new opportunities for interacting with information, creating intuitive tools for analysis, visualisation and learning. These technologies are substantial in healthcare, where their application improves the quality of diagnosis, treatment, and rehabilitation of patients. Studies demonstrate the high potential of these technologies in medicine. S. Bin *et al.* [1] described in detail the use of VR and AR technologies in various biomedical fields, particularly in surgical practice. For example, when planning operations, VR simulations help surgeons visualise and plan complex surgical procedures; in minimally invasive surgery, AR technologies are used to superimpose images, such as computed tomography (CT) or magnetic resonance imaging (MRI) data, onto the patient's actual body, which improves the surgeon's orientation during the operation. Scientists have described how VR and AR can be used to train medical students. For example, creating realistic virtual simulations can be used to practice surgical skills or diagnostics without risk to the patient.

The demand for such technologies is growing rapidly. According to a report by Fortune Business Insights [2], the global market for virtual reality in healthcare was worth approximately 4.18 billion USD in 2024. The market is projected to reach 46.37 billion USD by 2032, with a

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compound annual growth rate (CAGR) of 35.1%. This information demonstrates significant market growth, confirming the research relevance and the high demand for these technologies in the medical field.

These technologies are key elements of the digital transformation of healthcare systems. They are used to overcome traditional barriers in the training of medical professionals, communication with patients, and the organisation of treatment processes. Virtual and augmented reality technologies are quite effective in projecting relevant digital information (images, videos, text, graphics) outside of device screens and combining relevant virtual objects with the real environment. For instance, D. Oyekunle *et al.* [3], researching the use of AR and VR in simulation training in clinical education, confirmed that these technologies can be used by medical students and practising specialists to gain a realistic experience of operations and clinical scenarios, reducing the likelihood of errors during real procedures. The study noted that VR/AR improve the quality of diagnosis and treatment, enhances interaction between doctors and patients, and contributes to savings in training costs. Studies showed that VR simulations improve information retention using virtual patients and the reproduction of real-life situations, which can be used for practice at any time. The study of augmented reality has been included in the curricula of most medical specialities. Thus, T. Tene *et al.* [4] conducted a review of the literature on this topic and found a trend toward improved educational outcomes when using VR/AR technologies in the training of future doctors, although it was not statistically significant.

B.W. Munzer *et al.* [5] identified significant potential for AR in three areas: user-environment interfaces, telemedicine and pre-hospital care, as well as medical education and training of medical personnel. The study concluded that AR can improve clinical care in various settings (operating rooms, hospitals, and outpatient clinics) and provide effective training, and that further research in this area is crucial for the development of emergency medicine.

Specific examples of VR and AR use in practice confirm their effectiveness. For instance, these technologies are used for preoperative planning and visualisation. Virtual reality can be used by surgeons to create three-dimensional models of a patient's heart based on CT and MRI scans, which improves awareness of complex anatomy before surgery. J.M. Castellanos *et al.* [6] described how VR was used to plan a complex mitral valve replacement procedure, providing a detailed assessment of the anatomy and preparation for surgery. S.V. Inozemtseva & I.O. Malynina [7] described an example of using the AccuVein AR device, which can be used for real-time visualisation of the patient's venous network, reducing the number of venipuncture attempts by 45%. With these tools, surgeons can plan procedures before making the first incision, and AR diagnostic tools can simulate the patient's condition after surgery.

VR and AR are also actively used for neurorehabilitation and cognitive function improvement. D.D. Georgiev *et al.* [8] emphasised the role of VR in the recovery of patients after brain injuries, including after surgical interventions. A.Y. Kafes *et al.* [9] demonstrated the effectiveness of a virtual reality-assisted psychological intervention programme for eliminating traumatic symptoms in people who had survived an earthquake. Their study involved 17 people who underwent a five-stage intervention programme using VR technologies at the stages of rethinking, creating a safe place, and developing problem-oriented coping strategies. The results showed a significant increase in post-traumatic growth and social support seeking, as well as a reduction in trauma levels after the earthquake.

Similar results were obtained by R. Cáceres-Matos *et al.* [10] in an evaluation of the use of VR to reduce pain, fear, and anxiety in children and adolescents during invasive procedures (e.g., injections, blood sampling). The use of VR was found to be statistically significantly associated with a reduction in pain intensity, as confirmed by various assessment scales (Wong-Baker Faces Pain Scale, Visual Analogue Scale/Numerical Rating Scale). VR also showed significant effectiveness in reducing anxiety and fear associated with procedures. The effectiveness of virtual reality is explained by its ability to distract patients' attention from pain stimuli through immersion in an interactive virtual environment that activates several senses.

With VR and AR, healthcare professionals have access to innovative training methods that simulate real clinical situations, improving their skills and increasing their level of professional training. Patients, meanwhile, can receive personalised treatment and rehabilitation that was previously unavailable or ineffective. This makes VR and AR technologies not only useful but also necessary in the context of the rapid digital transformation of healthcare. Therefore, the study aimed to analyse scientific data on the potential use of virtual and augmented reality in medical education and clinical practice.

The material for this study included scientific articles published in peer-reviewed medical and technical journals, as well as conference materials related to virtual and augmented reality in medicine. In addition, publications on specialised news websites and blogs dedicated to medical innovations were analysed to identify current trends and practical implementation cases. The search for scientific literature covered the period from 2008 to 2025 and was conducted using the following electronic search engines and databases: Scopus, Web of Science, and Google Scholar. The following keywords and their combinations in English and Ukrainian were used to form search queries: "Virtual reality in healthcare", "Augmented reality in public health", "VR/AR for health management", "Immersive technologies in medicine", "Telemedicine and VR/AR", "Rehabilitation with VR/AR", "Medical training VR/AR", "Mental health VR/AR". The criteria for selecting literature were publications directly related to the application of virtual or augmented reality in any aspect of healthcare; studies containing empirical data, literature reviews, meta-analyses or systematic reviews; articles available in full-text format; publications in English and Ukrainian. After the initial search, more than

100 potentially relevant sources were identified. After careful screening of titles and abstracts, and then full texts, 58 sources that best met the criteria and covered the topic of the work were included in the detailed analysis. The selected sources were analysed according to the following characteristics: application of VR/AR field of use (diagnosis, treatment, rehabilitation, surgery, training, psychological assistance, public health prevention); description of technologies type of technology used (VR, AR), hardware and software, functional capabilities; target audience categories of patients or healthcare professionals for whom the developments are intended; research results quantitative and qualitative indicators of effectiveness, authors' conclusions.

AR/VR in medicine:
Opportunities and differences

Virtual and augmented reality are key tools for the digital transformation of modern medicine. Despite their close interconnection, these technologies have fundamental differences in their mechanisms of operation and levels of user immersion. AR involves superimposing digital information (images, videos, text, graphics) onto the physical environment using specialised devices (smartphones, tablets or AR glasses) without breaking the connection with the real world. As noted by V. Volynets [11], one of the main advantages of AR is the ability to integrate digital information with data about the user's surrounding reality in real time. By using this method, medicine gains the ability to visualise physical reality, supplemented or enhanced with computer-generated perceptual data such as images, GPS data, audio or video signals. This integration of digital data with the user's environment in real time is particularly valuable in healthcare for visualising clinical data, supporting decision-making and training.

Virtual reality, on the other hand, creates a fully simulated three-dimensional environment that mimics both physical impact and the user's response to it. With the help of VR devices and 360° visualisation, complete separation from physical reality occurs by blocking signals from the outside world, and the person is completely immersed in virtual space, which provides the maximum effect of presence, providing the necessary visual, auditory and other sensations. As emphasised by H. Guan *et al.* [12], this approach can be used to practise medical scenarios without risk to the patient and to effectively use simulation technologies in the educational process. The complete isolation from external stimuli contributes to enhanced learning and the reproduction of clinical situations in a safe environment.

Despite their differences, AR and VR complement each other in the context of medical applications. AR maintains a connection with the real environment while enhancing it by providing adaptive information display. It requires less cumbersome equipment than VR, making it convenient for use in surgery, diagnostics, and telemedicine. For instance, the review article by J. Silva *et al.* [13] provided a detailed overview of the literature exploring new and promising areas of application for virtual reality technology in cardiology. In particular, the authors analysed how VR can extend the scope of the entertainment industry and become a powerful tool for medicine. The study highlighted the significant potential of virtual reality for training medical students and interns. The study demonstrated how VR simulations create realistic 3D models of the heart and vascular system, which can be used for the visualisation of complex pathologies such as congenital heart defects or atherosclerosis. This provides practice for future cardiologists of invasive procedures, such as catheterisation or stenting, in a safe virtual environment, significantly improving their skills before working with real patients. Researchers note that VR is an effective tool for improving communication between doctor and patient. Patients can use a VR headset to view a 3D model of a heart, perceive the nature of their disease, and visualise the treatment process. This not only improves awareness but also increases trust in the doctor and promotes greater patient adherence to recommendations. Therefore, increased demand necessitated a review and the formation of new areas of application for VR and AR in healthcare (Table 1).

Table 1. Main areas of application for VR and AR in healthcare

Area	Description
Diagnostics	Use of VR and AR to visualise internal organs, improve diagnostic accuracy and reduce the risk of errors.
Surgery	Simulation of operations in a virtual environment and use of real-time prompts during operations.
Personalised treatment	Adapting medical procedures to individual patient needs using VR and AR.
Rehabilitation	Physical and cognitive rehabilitation of patients using interactive games and virtual exercises.
Educational simulations for healthcare professionals	Training medical personnel in conditions close to real life, using VR and AR to practise emergencies.

Source: compiled by the author based on O. Kovalchuk *et al.* [14]

Due to the rapid development of technology, augmented reality studies have been included in the curricula of many medical specialties [12]. One of the key aspects is their use for visualising the patient's internal organs, which provides medical professionals with a three-dimensional view of anatomical structures and pathological changes.

Such capabilities significantly improve diagnostic accuracy, reduce the risk of errors, and provide a more detailed analysis of the patient's condition [15]. Thus, AR and VR technologies create new opportunities in healthcare, particularly in the areas of personalised treatment, simulation training, clinical training, and improving the patient experience.

Industry applications of AR and VR in medicine: Surgery, dentistry, ophthalmology

The active introduction of virtual and augmented reality into medical practice demonstrates significant potential in highly specialised areas of healthcare. They not only contribute to improving the accuracy of diagnosis and the effectiveness of treatment, but also shape new approaches to surgery, rehabilitation and care for patients with sensory impairments. This section addressed examples of the successful use of AR and VR in surgery, dentistry and ophthalmology, fields where accuracy, visualisation and modelling are critical to the quality of medical care.

In surgery, VR and AR technologies can provide volumetric and surface visualisation of organs and structures of the body, section boundaries, and display information, so they can be used in minimally invasive intra-abdominal surgery. R. Vávra *et al.* [16] provided a review of the literature on the use of augmented reality in surgery. The study demonstrated that surgeons' interest in the use of AR is growing. This technology has the potential to improve the safety and effectiveness of operations. For instance, the use of AR technologies provides intraoperative guidance to surgeons and can quickly identify hidden objects and critical structures: foreign bodies, neoplasms, organs, nerves, veins, vessels, etc. In addition, VR and AR in surgery are becoming crucial tools for planning and performing complex operations. Thanks to these technologies, surgeons can pre-model surgical interventions, practise them in a virtual environment, and receive visual cues during the operation in real time. This minimises the trauma of interventions, reduces the duration of the operation, and improves treatment outcomes.

In addition, these technologies contribute to the improvement of minimally invasive surgery methods, which is particularly relevant in the context of modern requirements for the quality of medical care. Thus, S. Bernhardt *et al.* [17] analysed laparoscopy (minimally invasive surgery), where AR is considered a particularly promising technology. The study authors addressed various aspects, from technical implementations to clinical trials. The study concluded that AR technology can be used by surgeons to superimpose preoperative 3D models of organs, tumours, blood vessels or nerves onto live video images from a laparoscope. This significantly improves the visualisation and awareness of the patient's anatomy, especially in the case of complex structures that are difficult to distinguish on a 2D screen. The studies reviewed in the review showed that AR can help surgeons reduce errors, shorten surgery time, and increase the accuracy of interventions. For example, one study showed that AR navigation can significantly reduce the error of tumour localisation in a phantom model of the liver.

The Remote Interactive Surgery Platform (RISP), which uses Microsoft HoloLens 2 glasses, was described by Y. Kalbas *et al.* [18]. It can be used by a remote consultant to observe the field of view of the operating surgeon and provide advice using 3D annotations, medical images, and voice communication. E.L. Wisotzky *et al.* [19]

described the implementation of a scalable remote solution called TeleSTAR (Telepresence for Surgical Assistance and Training using Augmented Reality). The study explained in detail how the system, which uses a digital surgical microscope, enables surgical training and assistance in the operating theatre. The low-latency of TeleSTAR 3D video transmission, which can be used to observe the same view as the surgeon and use AR tools for annotations and measurements, was noted.

Several software solutions can be used to perform the necessary remote consultations in real time using a standard Internet connection, helping surgeons who are performing the operation. The core concept of these systems is the use of an AR headset (such as Microsoft HoloLens) or cameras installed in the operating theatre to broadcast live video from the surgeon's field of view to a remote consultant. The remote expert can view the operation, overlay annotations, pointers, and 3D models of organs on the image, and provide voice instructions. For example, Y.S. Shpryakha *et al.* [20], analysing the application of augmented reality technologies in training programmes for surgeons in Ukraine, mentioned the following software solutions and platforms:

◉ Touch Surgery and Proximie are simulation platforms that combine augmented reality and artificial intelligence technologies with real-time video streaming. They feature a virtual operating theatre where surgeons can virtually "scrub in" (join the operation) to provide expert support and relevant advice. They are used in the United States;

◉ HoloMed is a local initiative for modelling simple surgical procedures;

◉ Medivis SurgicalAR is a tool that provides real-time visualisation of anatomical structures;

◉ Anatomy is a tool designed for interactive anatomy learning;

◉ Augmedix is a medical student training system developed in Italy.

These platforms make it possible to bridge the gap between medical theory and practice and provide high-quality services in local medical institutions. AR visualisation facilitates the planning of surgical procedures, reducing the duration of operations and patient recovery time. They provide the ability to safely simulate procedures and improve learning of anatomy through interactivity. These platforms make modern education accessible not only in leading medical centres but also in local educational institutions. They help surgeons operate with greater confidence and students learn more effectively, creating conditions for safer and higher-quality medicine. Thus, VR and AR technologies are gradually becoming key tools in modern surgery, providing not only improved visualisation and intraoperative guidance, but also new opportunities for remote consultations and training.

The main area of application for AR technologies in dentistry is maxillofacial surgery and oral surgery. Most often, such technologies are used during specific procedures, in particular, the installation of dental implants, orthognathic surgery, etc. AR technology is also increasingly used

in such areas of dentistry as endodontics, restorative dentistry, and orthodontics. For instance, V. Faus-Matoses *et al.* [21] compared the accuracy of endodontic access formation using an AR device with the traditional technique. The results showed that AR systems can be used to perform this procedure more safely and accurately. D. Dolega-Dolegowski *et al.* [22] described the development of a holographic AR system using HoloLens 2 glasses to study the anatomy of root canals. This demonstrated how AR can be an efficient teaching tool for students. S. Fahim *et al.* [23] described the potential of AR and VR in various fields, including restorative dentistry; in particular, how AR can improve communication with patients by visualising the expected results of treatment (e.g., smile design or prosthetics) directly on the patient's teeth. As noted by E. Roy *et al.* [24], traditional teaching methods in dentistry, which rely on phantom models and mannequins, have certain shortcomings that VR simulators can effectively address. For example, traditional phantom classes cannot always fully reproduce the anatomical features and complexity of real clinical cases. In addition, they do not support real-time tracking of student progress and do not provide instant feedback on the procedures performed. Instead, according to the study, VR simulators can eliminate these shortcomings. They provide training for complex procedures without risking damage to real patient tissue; they can adapt the level of difficulty, ensuring accessibility for students with different levels of training to learn at desired pace; they can automatically analyse student movements, the force of instrument pressure and the accuracy of actions, providing detailed reports for skill improvement. In addition, thanks to haptic feedback, VR simulators can mimic the sensation of tissue resistance, making training as close as possible to a real clinical situation. The authors conclude that the introduction of VR simulators is a substantial step towards improving the quality of dental education. This does not mean a complete abandonment of traditional methods, but VR can significantly complement them, providing further mastery of anatomy and practice of the skills necessary for successful clinical practice.

VR and AR are significant assistance to people with visual impairments. Augmented reality glasses improve the ability to view everyday objects and enhance visual function using 3D recognition software, as demonstrated by M. Iskander *et al.* [25]. Such glasses assist individuals with vision loss and patients with severe visual impairments in locating lost items, recognising people, and easily navigating their surroundings. However, the use of VR and AR in ophthalmology does not replace traditional methods of treatment and rehabilitation but can only be an additional tool for ophthalmologists to improve the quality of medical care. For example, D.L. Fortenbacher *et al.* [26] analysed how VR can be an effective addition to traditional methods of treating visual impairments. In contrast to conventional therapy, VR games and simulations make the process more engaging and motivating for patients, especially children. The publication emphasised the concept of dichoptic training, which involves showing different images to each eye. This stimulates both eyes to work together, which is key in treating conditions such as amblyopia (lazy eye) and strabismus (crossed eyes). The study highlighted a specific VR system called "Vivid Vision", which uses a virtual reality headset to conduct training. The system is designed to help specialists personalise exercises for each patient and objectively track progress, which is a big advantage over traditional methods.

The use of AR and VR in surgery, dentistry, and ophthalmology demonstrates a high level of effectiveness, safety, and technological feasibility. These innovations not only improve clinical outcomes but also expand the capabilities of physicians in planning, performing, and monitoring medical interventions. Thus, the use of AR/VR is becoming an essential component of modern personalised medicine, contributing to the transformation of the traditional healthcare system.

Virtual and augmented reality in psychiatry

In psychiatry, virtual reality is used to simulate the subjective experiences of patients to increase empathy and awareness on the part of specialists and relatives. A study by E. Vass *et al.* [27] emphasises that VR can be efficient for improving cognitive skills in patients with schizophrenia. Although the study addressed therapy, its findings support the idea that VR can simulate social interactions, which is key to the research of mental states. Their study confirmed that VR interventions can help patients better recognise and interpret emotions, which in turn also contributes to the awareness of their condition by both specialists and loved ones.

VR is also used in exposure therapy to create virtual environments that can simulate real-life situations that cause fear and difficulty for patients. Exposure therapy is one of the most effective methods of treating anxiety disorders, and virtual reality is a safe and controlled way to show patients their fears. For example. I.H. Bell *et al.* [28] noted that VR is a promising technology that can improve assessment and therapy in mental health. It can be used to immerse people in interactive virtual worlds that are completely controlled by the researcher or clinician. This ability is key to the use of VR in both the assessment and treatment of mental disorders. The article also discusses the use of virtual reality to create controlled environments, which is the basic principle of exposure therapy. In this context, VR systems can be used by clinicians to immerse patients in simulated situations to help them overcome phobias, anxiety or post-traumatic stress disorder (PTSD), which is the essence of exposure therapy.

At the same time, meditation programmes that use augmented reality have become efficient in reducing stress and anxiety levels. AR integrates virtual elements into the real world, allocating focus to deep relaxation and meditation techniques in a familiar environment. This approach stimulates psychosocial adaptation and improves overall psycho-emotional state, helping to reduce symptoms of anxiety disorders and alleviate psycho-emotional stress.

This practice is called relaxation therapy. A.I. Iqbal *et al.* [29] confirmed that VR and AR technologies significantly improve the patient experience and the quality of medical education by creating engaging and interactive environments for learning and practice. For instance, VR is used for pain management, anxiety reduction, and surgical simulation. The study also notes that "relaxation and meditation in various VR applications are becoming increasingly common for treating patients at home or in hospitals". VR can be effective in creating a calm environment and applying relaxation techniques to significantly reduce stress in intensive care units (ICUs). The study also discussed the use of VR for pain relief, which is closely related to relaxation. In particular, the use of VR games has proven effective in reducing acute pain, for example, in patients with burns. The combination of VR with hypnosis (known as virtual hypnosis, or VRH) is also mentioned, which has shown promise in reducing pain and anxiety. Therefore, the authors of the article conclude that VR is efficient for relaxation therapy.

Meditation programmes using augmented reality can create interactive visual and audio stimuli that reduce distractions and increase concentration on relaxation processes. The integration of virtual elements into the real environment helps patients immerse themselves more deeply in meditative practices, which reduce stress and anxiety more efficiently. This technology is particularly relevant for people who are unable to practise traditional meditation due to external factors or concentration difficulties. AR can be used to create customised meditation sessions that increase the effectiveness of treatment, as the programmes are tailored to the user's personal preferences and needs. For example, R. Jackson *et al.* [30] compared the effect of a mobile AR meditation app with a "point-to-point" distraction technique on 37 participants. The results showed that the group using AR had a more significant anxiety reduction and perceived stress compared to the distraction group. This confirmed that short AR meditation practice can improve aspects of negative mental health.

In addition, virtual reality can be used to treat phobias. The main method of treating phobias is exposure therapy. It involves the patient gradually confronting their fear under the supervision of a therapist. VR makes this process safe, controlled and accessible. In contrast to the real world, where circumstances are unpredictable (for example, it is not always possible to "accidentally" reach a height or be near a spider), in VR simulation, the psychotherapist has complete control over the situation. They can adjust the level of "scariness" of the situation, starting with the least alarming stimuli and gradually increasing them. The patient recognises the safety of the situation, even if the brain reacts to the virtual stimulus as if it were real. This is used to learn emotion and physiological control (heart rate, breathing) without any real threat to health. In addition, the simulation can be repeated as many times as necessary, which is impossible in real life. For example, for a patient with aerophobia (fear of flying), an unlimited number of "virtual flights" can be created, which accelerates the process of desensitisation (reducing sensitivity to the stimulus).

Numerous studies confirm that VR exposure therapy is as effective as or even more effective than traditional exposure. A study by G. Albakri *et al.* [31] reviewed data from various studies that used virtual and augmented reality technologies to overcome common fears such as acrophobia (fear of heights), arachnophobia (fear of spiders), aerophobia, and claustrophobia (fear of enclosed spaces). The main method discussed in the article is exposure therapy. The authors considered three types of exposure therapy: classical exposure therapy (*in vivo*) involves controlled, gradual contact between the patient and the object of their fear in real life; VR exposure therapy (VRET) uses virtual reality to create a simulated environment, in which patients can interact with their fear in a safe, controlled environment, which can be used to customise and avoid unpredictable factors of the intensity level; AR exposure therapy uses augmented reality, where virtual elements are superimposed on the real environment (e.g., a virtual spider on a real table), which can also be used for control of the process. The study concluded that VR and AR are effective tools for conducting exposure therapy to treat most phobias.

Some medical start-ups propose using VR technologies to help elderly people improve their memory and cognitive functions, facilitate rehabilitation, and increase their social activity. For instance, the research protocol by E. Gambella *et al.* [32] described the evaluation of the effectiveness of a combined approach to the treatment of Alzheimer's disease. The evaluation addressed the efficiency of an integrated intervention that included computerised cognitive training and aerobic physical exercise using virtual reality, in people with early-stage Alzheimer's disease, as well as to investigate whether such a combined therapy, combining cognitive and physical exercises, can provide greater stability of cognitive functions, improved mood and quality of life compared to physical exercise alone. The study involved 78 patients with mild Alzheimer's dementia. The experimental group underwent cognitive training using Brainer software on a tablet and aerobic training using the jDome® BikeAround™ system. This system combines an exercise bike with a dome-shaped projector and Google Street View technology, providing virtual bike rides through places from their memories. The control group underwent cognitive training using Brainer software on a tablet and aerobic training on a standard exercise bike. The intervention consisted of 16 sessions of 60 minutes each, twice a week for 8 weeks. Each session included 30 minutes of cognitive training and 30 minutes of physical exercise. The study believes that their intervention, which combines virtual reality with physical and cognitive exercises, will be effective in combating Alzheimer's disease, leading to improved cognitive function and quality of life for patients.

Portuguese scientists J. Oliveira *et al.* [33] suggested using appropriate training for people with moderate Alzheimer's disease, linked to the development of basic skills. Patients with this disease struggle with skills such as

morning hygiene, cooking, going to the shop or pharmacy, etc. However, with the help of modern technology, these patients can train or even "relearn" actions that were once familiar to them. Patients perform all manipulations within the virtual apartment and city.

Post-traumatic stress disorder (PTSD) is a type of nervous disorder that affects millions of people worldwide. This disorder can arise for various reasons, such as war, acute conflict, etc. VR can be used to create specially designed environments that simulate real-life situations, helping patients to gradually confront their fears or traumatic memories in a controlled setting. This approach reduces the intensity of symptoms and helps patients develop coping mechanisms.

Since 1997, the University of Southern California's Institute for Creative Technologies has been using virtual reality technology to treat PTSD. Various simulations, mainly based on military scenarios, are used to help most veterans successfully overcome the symptoms of the disorder. For instance, O.D. Kothgassner et al. [34] evaluated the effectiveness of VRET in comparison with control groups (waiting in line) and active comparators (other treatment methods). The study conducted a literature search that identified nine controlled studies involving 296 participants. The primary outcomes were assessed by the severity of PTSD symptoms, as well as secondary outcomes such as symptoms of depression and anxiety. VRET showed significantly better results in reducing PTSD symptoms and depressive symptoms, indicating that virtual reality therapy is more effective than no treatment. However, no statistically significant difference was found between VRET and other active treatments (e.g., traditional exposure therapy) in reducing PTSD and depression symptoms, suggesting that the effectiveness of VRET is comparable to other recognised therapies.

The experience of Ukrainian scientists also shows positive changes in reducing the symptoms of PTSD and depression when using virtual reality in treatment. For instance, K.A. Kosenko et al. [35] studied and summarised modern innovative approaches to the diagnosis, therapy and rehabilitation of patients with post-traumatic stress disorder, especially among military personnel who participated in combat operations. In the context of the ongoing military conflict in Ukraine, this problem is particularly relevant. The study described traditional and innovative methods of treating PTSD. Traditionally, PTSD treatment includes psychotherapeutic approaches such as cognitive behavioural therapy (CBT) and pharmacological intervention. The study emphasised that pharmacological intervention cannot cure PTSD, but it increases the effectiveness of psychotherapy, especially in patients from risk groups. At the same time, the study noted that modern technologies, such as virtual reality, which is used to simulate stressful scenarios, are substantial in treatment, helping patients gradually process traumatic events in a safe, controlled environment.

B.V. Kichak et al. [36] investigated the potential of video games and virtual reality technologies as innovative tools in the treatment and rehabilitation of patients with post-traumatic stress disorder, especially in the context of military conflicts. The study emphasised the need to introduce new, accessible methods to help victims. The study discusses several substantial aspects of the application of gaming technologies:

⦾ controlled exposure VR content developers can create simulated environments that are used to relieve patients of traumatic memories in a safe and controlled setting. This helps to lessen their emotional impact in the future;

⦾ a combination of CBT video games and VR technology should be used as a supplement to traditional methods. This combined approach helps patients overcome negative thoughts, develop coping strategies, and gradually desensitise themselves to triggers;

⦾ regulation of physiological responses: the game format can be used to help patients learn to control physiological responses such as heart rate and breathing, which is particularly useful for managing anxiety and stress associated with PTSD;

⦾ social support – the authors emphasise the importance of communicating with people who have had similar experiences. Multiplayer games and online communities can be used as a platform for creating support networks where patients can help each other and share their thoughts.

The researchers concluded that although game therapy cannot replace traditional approaches such as psychotherapy and medication, its implementation can significantly improve the effectiveness of PTSD treatment. Continuous technological developments and new research open new opportunities for the further application of computer games in this field. Thus, the use of VR for the treatment of anxiety and PTSD has a wide range of advantages, including the creation of a safe and controlled environment for patients, which can be used for exposure therapy without the need for real-life physical situations. Thanks to deep immersion in the virtual environment, patients can gradually adapt to stressful or traumatic situations, which reduces fear and anxiety levels. Virtual reality can also be adjusted by doctors in real time to change the intensity and complexity of situations, which helps tailor treatment to each patient's individual needs.

Possibilities for using VR and AR during rehabilitation

Rehabilitation is a crucial stage in restoring health after injuries, illnesses, or surgical interventions. Physical and cognitive rehabilitation programmes are designed to restore bodily functions and improve patients' quality of life. Physical rehabilitation includes a set of exercises that help restore motor functions, increase physical endurance and improve overall well-being. Cognitive rehabilitation focuses on restoring memory, attention, language and cognitive functions that are critical for normal functioning in everyday life. Games that can stimulate both motor and brain activity are essential components of rehabilitation programmes.

The use of games in rehabilitation programmes not only restores physical abilities but also activates cognitive processes, contributing to comprehensive health recovery. Games designed to develop motor skills and brain activity can be used to improve coordination, memory, concentration, and other cognitive functions. For example, K.E. Laver *et al.* [37] studied the effectiveness of virtual reality and interactive video games in the rehabilitation of stroke patients. The authors analysed 72 randomised controlled trials. The study compared groups of patients who received rehabilitation using VR with groups who underwent traditional therapy. The study emphasised that virtual reality has potential, especially as a supplement to standard therapy, to help increase the total rehabilitation time. However, further research is needed to draw more conclusive conclusions and to clearly identify which types of VR interventions are most effective and for which patient groups. In turn, N. Ahmadpour *et al.* [38] examined the potential of VR as a non-pharmacological treatment for acute and chronic pain. The study argued that virtual reality is an effective complementary or even alternative method of pain relief that does not require medication. Its effect is based on distracting the patient's attention from pain sensations by immersing them in an immersive virtual environment. In their opinion, VR demonstrates high effectiveness in cases of acute pain arising during medical procedures. For example, burn wound care (VR games such as SnowWorld can be used to distract patients from pain during dressing changes), dental procedures, and pre- and post-operative procedures (VR helps reduce anxiety and pain). The study also believes that VR has substantial potential for treating chronic pain.

Rehabilitation is not only a medical but also a social process that includes supporting patients in restoring their ties with society, family and workplace. Successful rehabilitation requires an interdisciplinary approach that involves various specialists, including doctors, physiotherapists, psychologists and social workers. A substantial aspect is an individual approach to each patient, considering their physical condition, psychological characteristics, age factors, and social conditions. Psychological support and motivation of patients are essential for achieving high rehabilitation results, as without proper emotional support, the recovery process can be significantly slowed down. In this context, the role of cognitive rehabilitation, which contributes to the improvement of intellectual abilities and neuropsychological functions, cannot be overestimated. Programmes that address memory, language skills, and cognitive abilities help patients adapt to changes caused by disease or injury, which is crucial for their social functioning.

As such, H. Bateni *et al.* [39] considered virtual reality as an innovative and promising tool for rehabilitation. This technology can create immersive and motivating environments that help patients do physical exercises, which can be boring in traditional settings. The cited studies confirm that VR improves motor function, balance, and coordination. In addition to treatment, VR is also considered a valuable diagnostic tool. With VR systems, therapists can objectively assess a patient's movements and functionality in a controlled virtual environment; measure key indicators such as reaction time, movement accuracy and range of motion, which is difficult in traditional clinical practice; create realistic scenarios to assess how a patient responds to different situations, which is relevant for determining fall risks and planning rehabilitation. The study discusses the use of VR in the rehabilitation of patients with various conditions, including Parkinson's disease, stroke, and other neuromuscular disorders. The study emphasised that VR can be beneficial for patients who have lost the ability to perform certain tasks independently, as the virtual environment facilitates safe and fear-free training.

V.V. Kormiltsev & A.M. Chyhyrynskyi [40] systematised the experience of foreign studies on the use of virtual reality technologies in physical therapy for patients after an acute cerebrovascular accident (CVA), or stroke. The study believes that the use of VR in physical therapy for patients after ACIS has led to statistically significant improvements. Improvements in upper limb motor function, range of motion, muscle strength, and independence in daily activities were noted, and VR training has a positive effect on patients' ability to walk. VR-based rehabilitation also has a positive effect on neural plasticity. This includes improved interhemispheric balance, enhanced cortical connectivity, and activation of areas in the frontal cortex, which correlates with improved behaviour. The study noted that VR systems are divided into specialised and commercial game consoles that can be adapted for clinical practice. In Ukraine, there are also VR trainers, such as VR NOW, which are designed based on clinical experience to restore movement and overcome complications.

T. Rutledge *et al.* [41] described the development and initial results of research on the use of VR for the treatment of phantom limb pain. Phantom limb pain (PLP) is a common and debilitating condition that is difficult to treat. It occurs in people who have undergone amputation and is felt as pain in the missing part of the body. The study developed a new VR programme to help reduce PLE and conducted a pilot study to assess its viability, i.e. its feasibility and safety. Ten patients with lower limb amputations who suffered from phantom pain participated in the experiment. The VR intervention was based on the principle of mirror therapy, but instead of a physical mirror, a virtual reflection was used. Patients saw a virtual version of their missing leg moving along with their healthy leg. Participants underwent 10 sessions of VR therapy over 5 weeks. This study showed a positive trend towards a reduction in the intensity of phantom pain in most participants.

The gaming methods used in rehabilitation can include both traditional board games that stimulate cognitive activity and interactive computer programmes that use virtual exercises and tasks to train various mental and physical functions. The use of such methods improves motor skills, perception and concentration, which contributes to

the restoration of nervous system functions and facilitates the adaptation of patients to new living conditions [42]. In turn, the integration of such games into a comprehensive rehabilitation programme reduces stress levels, promoting psycho-emotional recovery [43], which is a substantial component of successful rehabilitation (Table 2).

Table 2. The role of VR and AR in rehabilitation

Type of rehabilitation	Description
Physical rehabilitation	Exercises to restore motor functions and improve endurance.
Cognitive rehabilitation	Exercises to restore memory, attention, language and cognitive functions.
Motor functions development games	Use of interactive games to improve coordination and motor function development.
Cognitive activity games	Stimulation of cognitive processes through games to improve concentration and memory.

Source: compiled by the author based on L. Atukunda [44]

It is worth noting that the use of VR in the rehabilitation of patients with cerebral palsy (CP) demonstrates a high level of effectiveness. The main clinical manifestations of this disease are movement disorders (paresis, paralysis), impaired muscle tone, and poor coordination of movements. The main goal of rehabilitation therapy for patients with CP is to correct these motor disorders. Thus, D.K. Ravi et al. [45] provided evidence of the effectiveness of VR rehabilitation in improving sensory and motor skills in children with CP. The analysis covered 31 studies with a total of 369 participants. The study showed that VR rehabilitation is a promising intervention for improving balance and overall motor development in children and adolescents with CP. The authors emphasised that virtual reality, especially in the form of games, increases children's motivation and engagement in therapy, which is a key factor in achieving better results. This makes the rehabilitation process more enjoyable and less monotonous.

Notably, scientists have convincingly demonstrated the potential of virtual reality and computer games in the rehabilitation of patients with cerebral palsy (CP). For instance, an experimental study by F.R.C. Machado et al. [46] found that the targeted use of computer games as a therapeutic tool significantly increases activity and improves the functionality of the upper limbs in children with paretic CP. This indicates the promise of interactive approaches in the restoration of motor functions. In addition, S.S. Korney et al. [47] emphasise that virtual reality is a valuable technique for expanding the range of motor tasks for the upper limbs. It can be effectively used in both clinical and home settings, as well as in educational institutions, providing flexibility and accessibility of rehabilitation. In general, as shown by the research of J.H. Do et al. [48], interactive virtual reality programmes have proven effective in improving hand dexterity and coordination in children diagnosed with hemiplegic CP, creating new opportunities for their adaptation and improving their quality of life.

Although the main application of virtual reality in rehabilitation is the correction of motor disorders, its potential is not limited to this. Immersion in immersive virtual environments also demonstrates high effectiveness in relieving pain syndrome, which creates new prospects for non-drug treatment. An example of this is the development of a VR product with an analgesic effect. G. Hoffman et al. [49] described an experiment in which patients with burns were immersed in a virtual winter wonderland, where they had the opportunity to shoot snowballs at snowmen. According to the data obtained, this significantly reduced pain during dressing changes and was more effective than opioid analgesics.

H. Deng et al. [50] also confirmed the distraction theory. The study used near-infrared functional spectroscopy to assess brain activity and found that VR reduces pain perception by modulating cortical processing of pain signals. When the brain is busy processing visual and cognitive tasks in a virtual environment, it has fewer resources to process pain impulses. R. Gopalan et al. [51] confirmed that distraction was the most effective mechanism for pain relief using VR, which was proven in 86.9% of the studies they examined. According to these scientists, VR outperforms other non-pharmacological methods (such as watching television) due to its high immersiveness, which completely captures the patient's attention. The review indicated that VR offers an innovative way to manage acute pain while minimising the side effects and risks associated with traditional pharmacological approaches, such as nausea, addiction or even overdose.

In conclusion, VR and AR are key innovative instruments of modern rehabilitation programmes, as they offer an effective complement to traditional therapy methods. These technologies help restore physical and cognitive functions after strokes, injuries, neuromuscular disorders, and cerebral palsy. Due to their immersive nature, VR technologies provide high patient motivation and increase their engagement in training, which is critical for achieving positive results. In addition, VR is effectively used as a non-pharmacological means of pain relief, as it distracts the brain from pain sensations. Studies also confirm that VR systems are valuable diagnostic tools that can be used for objective assessment of patients' conditions, contributing to comprehensive health recovery and social adaptation.

Features of training medical professionals to work with VR and AR

The process of training medical professionals using VR is crucial. For example, A. Alaraj et al. [52] described the development and evaluation of the usefulness of a new virtual reality simulator with tactile feedback for training neurosurgeons to clip aneurysms. The study created a simulator for clipping aneurysms of the middle cerebral artery using

the ImmersiveTouch platform, which provides realistic 3D images and tactile sensations, simulating mechanical impact on virtual tissues. A study involving scientists from three institutions (the University of Illinois at Chicago, the University of Chicago, Weill Cornell Medical College, USA), showed that the simulator is a useful tool for preparing for real operations, improving knowledge of anatomy and assisting in the planning of surgical approaches. As a result, a virtual reality room was created at Weill Cornell Medical College (New York, USA), where simulators for surgeons were installed. The system was equipped not only with the appropriate graphics headset but also with tactile feedback devices. Doctors could feel the mechanical impact on the relevant organs of the "patient". With the help of such a simulator, it is possible to acquire the necessary skills for successful operations at a much lower cost. The work also highlighted the potential of such VR systems to improve patient safety and the effectiveness of neurosurgical training.

D. Mistry *et al.* [53] emphasised that VR provides unique learning opportunities, offering students and healthcare professionals an immersive, safe and controlled environment for practising their skills. Therefore, it is possible to train without risk to real patients and increase the confidence of future specialists. The study covered a wide range of VR applications, including clinical skills training (the ability to practise diagnostic procedures, manipulations and communication with patients), surgical training (the ability to practise complex surgical procedures, improving motor skills and decision-making), studying anatomy and physiology (interactive 3D models for further awareness of the human body), interpersonal skills and empathy (the ability to simulate complex scenarios of interaction with patients and develop empathy). The study highlighted existing barriers and challenges to the implementation of VR in medical education. These include the high cost of equipment, the need for specialised content, possible motion sickness in users, and the need to integrate VR programmes into existing curricula. Future directions for the development of VR technologies and their potential for further transformation of medical education were also analysed, including hardware improvements, the development of more realistic simulations, and wider accessibility.

C. Cao & R.J. Cerfolio [54] addressed the use of virtual and augmented reality to improve surgical education and planning. The study investigated the use of VR simulators for practising surgical skills, including visualisation of anatomy, planning access trajectories, and simulating complex procedures. This improves the skills of novice and experienced surgeons in a safe and controlled virtual environment. The study discussed the possibilities of AR overlaying digital information onto the real world, which can be used for more intuitive learning, such as displaying anatomical structures or step-by-step instructions during simulation. The study emphasised that VR and AR can be used by surgeons to visualise complex patient anatomy in 3D, based on real medical images (e.g., CT, MRI).

This improves analysis of the pathology, planning of the optimal surgical approach, and prediction of possible complications. AR and VR technologies can also be used to "rehearse" the operation, which can be used by surgeons virtually practice all stages of the procedure, increasing the accuracy and efficiency of the actual operation.

S. Patil *et al.* [55] analysed the effectiveness of devices with tactile (haptic) feedback in the preclinical training of dental students. The study conducted a systematic search of several large databases (PubMed, Embase, Web of Science, Scopus) and found that tactile devices significantly improve the psychomotor and manual skills of dental students. The use of such devices increases students' confidence in performing procedures. Tactile feedback systems help develop more precise movements and a greater awareness of how instruments interact with tissues, which is fundamental to dental practice. Tactile feedback makes simulation more realistic and immersive, which contributes to more effective learning. The study noted that these simulators let students repeat procedures many times and get instant feedback, which significantly reduces the number of mistakes in real-life situations.

In 2008-2009, a series of studies on virtual reality simulation and local anaesthesia was conducted at the University of Aachen (Germany). For example, a study by S. Ullrich *et al.* [56] described a virtual reality-based medical training application for local anaesthesia procedures, which includes simulation of electrical impulse transmission to activate the motor response of nerves. O. Grottke *et al.* [57] developed a VR simulator for local anaesthesia that considers the individual anatomy of the patient, which is relevant for realistic training.

Educational simulations for healthcare professionals are essential tools for improving qualifications and practical skills in conditions that are close to real life. The use of virtual environments can be used for practice of healthcare professionals in a variety of situations that require quick and accurate decisions, without risk to patients. Such simulations can be used by medical staff to improve their skills in managing emergencies, developing the ability to adapt quickly under stressful conditions [1, 44]. Such training in virtual reality can provide experience that is difficult or even impossible to obtain in real-life situations due to the rarity of certain emergencies or limitations in training resources. They also help reduce stress levels during real incidents, as medical professionals can deal with potentially traumatic situations in a safe environment, which significantly increases their confidence in their actions [4, 3].

Thus, the integration of virtual simulations into training programmes for medical professionals, particularly in emergencies, achieves high training effectiveness. This approach maintains high-quality medical services even when practical experience in real-life situations is limited or insufficiently available. A key aspect is that virtual simulations can be used for training not only technical skills, but also cognitive and emotional responses to stressful situations, which are necessary for quick decision-making in

extreme conditions. Training through virtual simulations has great potential to improve the quality of medical practice, particularly in emergencies where accuracy and speed of action are relevant. It maintains skills at a high level and prepares medical professionals for any challenges in the real world.

Benefits and drawbacks of using VR and AR in medicine

The introduction of virtual and augmented reality technologies into medicine faces several challenges and limitations, among which financial costs, technical limitations, and ethical issues are substantial. Thus, the financial costs of introducing VR and AR into medical practice can be significant. The cost of technological equipment, software, and training medical staff to use these tools effectively requires significant investment. Most medical institutions, especially in countries with limited financial resources, may face difficulties in securing the necessary funding to implement such technologies.

In addition, the high hardware requirements for VR and AR, the need to constantly update equipment to support new software versions and improve technologies can be a barrier to the widespread use of these technologies in medical institutions. Furthermore, ensuring proper compatibility with existing medical systems and databases can also require significant technical effort. Systems must not only be functional but also safe for patients, which requires thorough testing and verification. Insufficient accuracy, data errors, or delays in real-time can have substantial consequences, increasing the risk of using these technologies.

Ethical issues related to the use of VR and AR in medical practice are a crucial part of this process. In particular, the use of these technologies for patient treatment, research, or training may raise questions about the security and confidentiality of patients' personal data. It is necessary to determine in which cases the use of VR/AR is ethically justified, whether these technologies can be relied upon in the treatment process, and what potential risks exist for patients who require special attention in terms of psycho-emotional impact. In addition, the issue of technology accessibility for the general population is also necessary. On the one hand, the use of VR and AR can improve the quality of medical services and make them more accessible, especially for patients in remote or hard-to-reach regions. However, on the other hand, the high cost of such technologies may create inequality in access to modern medical services. This could lead to a gap between patients who can afford VR/AR treatment and those who cannot.

In addition to the aspects listed above, there are other challenges that need to be addressed when implementing VR and AR in medical practice. One of these is the need for medical professionals to adapt to new technologies. This requires significant efforts in staff training, as the use of modern technologies requires specific knowledge and skills. In addition, training must be integrated into existing medical programmes, which can be difficult due to changes in educational standards and programme materials [3, 58].

Another aspect is patient acceptance of new technologies. Not all patients are ready to accept and trust treatment or diagnostic methods based on virtual or augmented realities. This is true for older people or those with limited experience with technology. Problems with trust in new treatment methods can lead to delays in the implementation of such innovations.

Conclusions

Virtual and augmented reality are actively changing the medical field, offering fundamentally new and unprecedented opportunities to improve the quality of medical services at all stages, from diagnosis to rehabilitation. Their use has led to significant improvements in the diagnosis, treatment and rehabilitation of patients, creating new horizons for personalised medicine and increasing the effectiveness of therapeutic interventions. The key role of VR and AR technologies in planning complex surgical operations should be highlighted. These innovative systems can be used not only to pre-model interventions with high accuracy, but also to receive visual cues and holographic projections in real time, directly during the operation. This significantly reduces the trauma of operations, minimises the risk of errors and significantly increases their overall effectiveness and safety for the patient. The ability to study the patient's anatomical features in detail in 3D format before the operation can be used for the development of an optimal strategy and preparation for any unexpected situations.

In rehabilitation programmes, VR and AR are becoming crucial tools for the physical and cognitive rehabilitation of patients. These technologies provide effective methods for restoring motor and cognitive functions by offering patients interactive and engaging exercises. Thanks to gamification and simulations integrated into these technologies, patients are actively encouraged to engage in daily training and recovery, which is relevant not only from a medical but also from a social point of view, as it promotes faster reintegration of patients into society by increasing their motivation and self-esteem.

The use of VR and AR to support mental health deserves special attention. Modern technologies can create safe and fully controlled virtual environments for treating various disorders, including anxiety disorders, phobias, and PTSD. Thanks to virtual reality exposure therapy, patients can gradually adapt to stressful situations, overcoming their fears and anxiety in a safe environment, which reduces anxiety levels and improves overall emotional well-being.

Another relevant aspect is the use of these technologies for training and improving the skills of medical professionals. They can be used for training in conditions that are as close as possible to real clinical situations, but without any risk to real patients. This applies to both learning new surgical techniques and practising skills for interacting with patients and making quick decisions in crises. Thus, VR/AR significantly improve the level of professional training and competence of doctors and all medical personnel, which is a guarantee of high-quality medical services in the future.

At the same time, augmented/virtual reality requires further study by scientists, researchers, experimenters, and inventors, because the fast-paced world of modern post-information space on a global scale will only accelerate its progress, and the world of new technologies will continue to develop at the fastest possible pace. Particular attention should be paid to the development of adaptive VR and AR interfaces for different age groups and people with special needs, the assessment of the long-term impact of their use on cognitive functions and psychological state, as well as the study of the ethical aspects of data collection and use in these technologies to ensure user privacy and security. Equally crucial is the improvement of methods for integrating virtual/augmented reality with existing medical information systems and the development of standards for data exchange, which will ensure the effective implementation of these technologies in healthcare practice.

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Віртуальна та доповнена реальність в механізмах управління охорони здоров'я щодо підтримання громадського здоров'я: огляд літератури

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Анотація. Метою даного дослідження було проведення аналізу наукових відомостей щодо використання віртуальних технологій та технологій доповненої реальності в практичній діяльності лікарів. Основні результати дослідження показали, що віртуальна та доповнена реальність активно трансформують медичну сферу, пропонуючи нові можливості для покращення якості надання медичних послуг. Зокрема, ці технології ефективно застосовуються в стоматології для лікування і протезування, в офтальмології – для діагностики та тренування зору, а також в психіатрії та психологічній допомозі – для терапії фобій, посттравматичних стресових розладів (ПТСР) та боротьби з тривогою. Крім того, технології VR та AR довели свою ефективність в реабілітації пацієнтів після інсультів, черепно-мозкових травм, а також при відновленні рухових функцій після ортопедичних операцій та ампутацій. Особливо слід виділити роль VR та AR технологій у плануванні складних операцій, де вони дозволяють хірургам попередньо моделювати втручання та отримувати візуальні підказки в реальному часі, знижуючи травматичність операцій і підвищуючи їх ефективність. У реабілітаційних програмах VR та AR стають незамінними інструментами для фізичної та когнітивної реабілітації пацієнтів, забезпечуючи ефективні методи відновлення рухових і пізнавальних функцій. Важливим аспектом є також використання VR та AR для навчання медичних працівників, що дозволяє тренуватися в умовах, наближених до реальних, без ризику для пацієнтів, тим самим підвищуючи рівень професійної підготовки лікарів. Проведений огляд не тільки показав, як віртуальні інструменти можна використовувати для розв'язання конкретних проблем у медицині, а й спонукає до глибшого проникнення у сутність процесів, які відбуваються в сфері охорони здоров'я під впливом новітніх інформаційно-комунікаційних розробок

Ключові слова: : віртуальні технології; немедикаментозне лікування; реабілітація пацієнтів; VR-тренажери