



REVIEW

Metaverse: the future of medicine in a virtual world

Metaverso: el futuro de la medicina en un mundo virtual

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ABSTRACT

The metaverse is a virtual space that uses Virtual Reality (VR), Augmented Reality (AR) and Artificial Intelligence (AI) capable of recreating a world parallel to reality, in the health sciences the use of technologies during the last decade has increased dramatically and the benefits for both patients and professionals are countless. After the implementation of quarantine by COVID-19, social isolation led to the emergence of new tools that made health sciences become even more involved in this digital world. The applications of the metaverse in medicine range from data processing, the simulation of environments for the exchange between groups of patients, to the simulation of surgical procedures, diagnostic and experimental processes and the simulation of avatars of doctors or nurses capable of advising patients according to their clinical conditions.

Keywords: Metaverse; Telemedicine; In Silico.

RESUMEN

El metaverso es un espacio virtual que utiliza la Realidad Virtual (RV), la Realidad Aumentada (RA) y la Inteligencia Artificial (IA) capaz de recrear un mundo paralelo a la realidad, en las ciencias de la salud el uso de las tecnologías durante la última década ha aumentado vertiginosamente y los beneficios tanto para los pacientes como para los profesionales son incontables. Tras la implementación de la cuarentena por la COVID-19 el aislamiento social llevó al surgimiento de nuevas herramientas que hicieron que las ciencias de la salud se inmiscuyeran aún más en este mundo digital. Las aplicaciones del metaverso en la medicina van desde el procesamiento de datos, la simulación de ambientes para el intercambio entre grupos de pacientes, hasta la simulación de medios quirúrgicos, procesos diagnósticos, experimentales y la simulación de avatares de médicos o enfermeras capaces de aconsejar a los pacientes según sus condiciones clínicas.

Palabras clave: Metaverso; Telemedicina; In Silico.

INTRODUCTION

The basic principle of medical care has been the doctor-patient relationship for a long time, and this interaction has been considered essential for medicine. After COVID-19 and the worldwide isolation and quarantine policies implementation, it was demonstrated that health services should not always be in the patient's presence in the same space and time as the health professional. This is how telemedicine has taken a significant boom during this time. This new reality triggered a revolutionary acceleration in the adoption of innovative technologies in all sectors of daily life, from social interactions and entertainment to medical

services.^(1,2)

Telemedicine, augmented reality (AR) and virtual reality (VR) have flourished in this unprecedented global health landscape, opening new horizons in health sciences and, more than ever, uniting it with technological advances to achieve care optimum for the patient.⁽³⁾

This technological advance in the use of virtual reality and augmented reality has reached a colossal point of splendor “the metaverse”, which has already taken its first steps in different areas of daily life with very beneficial results for human well-being. The healthcare industry has not lagged in implementing this emerging technological promise, and its applications in the world today are already unimaginable, as well as its prospects.

The metaverse is nothing more than the virtual representation of the natural world in silico. The term was first described in the 1992 science fiction novel *Snow Crash*. Neal Stephenson described an immersive Internet-connected virtual universe as an alternate reality for its participants, calling it “the metaverse”.⁽⁴⁾ Since the Internet expansion, the metaverse reference progressively found its place in the technological lexicon that describes any large-scale virtual environment in the online space that users can be a part of. Simply put, the metaverse is a three-dimensional (3D) digital environment where AR/VR and artificial intelligence (AI) are the primary visual providers and where people can engage in social, financial, and other interactions using personalized digital avatars that mimic experiences of real life. It represents a combination of interconnected digital spaces that allow its users to participate in activities such as shopping, gaming and attending virtual events etc.⁽⁵⁾

The metaverse in medical sciences may cover potential applications such as diagnostics, telemedicine, remote patient care, and monitoring. For example, some of the most important applications are remote monitoring of patients requiring intensive care, access to data, a better understanding of clinical outcomes (such as blood sugar and heart rate monitoring), and COVID-19.⁽⁶⁾ It also extends to the surgery field, improving surgical precision and to other medical areas like radiology, mental health and health personnel’s education and training.^(7,8)

Given the vertiginous development of the metaverse in health, it is necessary to search for information regarding the subject to bring health personnel an update on the main applications of this technology in medicine and the principles of its operation, including the advantages they offer both for the patient and professionals. This article aims to identify the metaverse's main applications in the health field.

DEVELOPMENT

The arrival of the metaverse as a reality applicable to dissimilar fields has generated significant societal debate.⁽⁹⁾ Some experts argue that it is just another of the many ways to industrialize the sector and seek economic benefits.⁽¹⁰⁾ Although it is indeed deniable the high costs of the services, it is also a fact that the multiple applications generate more significant benefits to the field, including greater precision, less waiting time, and more comfort for health personnel and patients. These are some of the advantages listed in multiple studies that will be summarized below.

Applications in disease prevention and control

Primary health care is a fundamental link in patient care. Public health systems invest millions of dollars each year in disease prevention and the promotion of healthy behaviors to avoid risk factors that predispose to disease or to control these and prevent complications.

A widely adopted concept is Health 4.0, which integrates innovative technologies with healthcare.^(11,12) Examples of Health 4.0 are the Internet of Health Things, cyber-physical medical systems, health cloud or fog, big data analytics, machine learning, blockchain, and intelligent algorithms;⁽¹²⁾ but also virtual reality.⁽¹¹⁾ This allows us to monitor the population and educate by involving people in community activities. Digital innovations can be adopted as an alternative care delivery model. Creating avatars allows consultations and personalized care⁽¹³⁾ at home by connecting real life with the virtual world. The follow-up of the clinical appearance and, consequently, of the health of the distant person can be adopted by 12-lead electrocardiograms for the heart, tensiometers evaluating cardiovascular systems, oxygen saturation meters for the cardiorespiratory system and blood glucose calculators; which are ideal for people with diabetes.⁽¹⁴⁾

Related to the evaluation of physical performance, also through the web, heart rate monitors¹⁴ have been widely adopted. Another tool is the smartwatch that integrates heart rate, blood saturation, pedometers, and accelerometers, but also Global Positioning System (GPS) data, allowing monitoring of health status and physical performance, but also chronic disease management.^(15,16,17)

These smartwatches are often connected to the smartphone, which is connected to communities where people can compare their data with other users in real time and accept challenges. The potential of smartwatches in health promotion programs is enormous. In fact, through real-time monitoring, the possibility of being part of an online community and being guided by experts worldwide increases the probability of attending fitness programs and adopting a healthy lifestyle.⁽¹⁸⁾ These smartwatches could be an instrument to bring to life the

person in the metaverse.

Thanks to new technology, these considerations can also be made considering that avatars react realistically in their speech, facial expressions, and body language.⁽¹⁹⁾ Virtual reality could be adopted to create preoperative planning by analyzing the situation in 3D and requesting the opinion of other experts connected to therapies. It is an effective intervention for several medical conditions with advantages in personalization, compliance, cost, accessibility, motivation and convenience.⁽¹¹⁾

One last aspect to consider is the possibility of creating an avatar that can act as a “virtual nurse” to direct and monitor care and interact with the patients, educate them or the staff around them, but also supervise and monitor, in real-time, quality/patient safety surveillance, physician activity, and admission and discharge activities.⁽²⁰⁾

On the other hand, for chronic diseases such as hypertension, diabetes, obesity, and some mental health conditions, virtual care models with group psychological support programs could be a valid intervention, while remote virtual nursing care with robotic delivery units, the end user, could also be of help.⁽²¹⁾

Obviously, people need an environment to carry out the activities, tools and means to fulfil the indicated tasks. Carraro *et al.*⁽²²⁾ and Petrigna *et al.*⁽²³⁾ refer to the use of stationary bicycles, treadmills and other equipment that allow races to be carried out with the simultaneous use of “Pelotón”, a virtual reality application that simulates races and allows the user to exchange with other netizens who carry out the same activity in another part of the world. In addition, the application is capable of recreating dissimilar environments and taking users to races from natural environments to extreme environments such as the International Space Station.

Given the analysis of the benefits offered by this *in silico* tool, the authors of the present review take a particular position in which they do not intend to discourage its use. Still, it is necessary to analyze the possible disadvantages this brings to individual and collective health and environmental health. The indication to patients of aerobic races in the open air is not only intended for the patients to perform the physical exercise for multiple purposes; but also to do so in a “natural” environment in which they manage to find a balance with the environment, in addition to the benefits of breathing fresh air in contact with nature are second to none.

In ophthalmology, this care model has classically been used for diabetic retinopathy screening based on a store-and-forward approach in which fundus photographs are captured in a community clinic and scored remotely later; it is cost-effective and clinically applicable.⁽²⁴⁾

Other eye conditions that have successfully implemented telemedicine programs include glaucoma management and retinopathy of prematurity.⁽²⁵⁾ For glaucoma, countries like the United Kingdom and Singapore have adopted a “virtual glaucoma clinic” system for glaucoma suspects and those with mild to moderate glaucoma.⁽²⁶⁾ Further developments in this area have been explored for detecting and managing age-related macular degeneration,⁽²⁷⁾ diagnosing surgically indicated blepharoptosis in oculoplastics,⁽²⁸⁾ and detecting senile⁽²⁹⁾ and congenital⁽³⁰⁾ cataracts.

The mounted 3D display has proven helpful in assessing visual acuity with the advantage of portability and automated nature. Additionally, virtual reality technology has been used to detect visual field deficits in glaucoma patients correlated with Humphrey's perimeter and to assess visual functions in patients with strabismus and amblyopia. Several studies evaluating AR-based therapy for low vision and visual field loss have shown that AR can improve functional vision for these patients in real-world settings. On the other hand, VR can be used to complement low vision therapy through practical vision training, remapping, and magnification. Also, several studies have demonstrated the effect of VR-based interactive and immersive binocular treatment.⁽³¹⁾

But it is not all good for ophthalmology. Researchers have also found that choroidal thickness increases markedly after wearing a virtual reality headset in young adults aged,^(18,32,33,34,35) which may be due to the consequence of fixed viewing distance combined with accommodation induced by convergence in the virtual environment.⁽³¹⁾

Applications in emergency services

Hospital emergency services are one of the health systems' main care sites. The population's lack of knowledge about what is considered an urgent or medical emergency means that these services often collapse or are overloaded with patients who usually do not have urgent care criteria.

During the COVID-19 pandemic, in which emergency medical services were dedicated almost 100 % to the care of critically ill COVID-19 patients, access to hospitals was made impossible. That is why multiple computer developers created teleconsultation platforms to facilitate patients' self-care with professional advice.

Telemedicine has proven helpful for emergency department consultations in triaging the urgency of referrals or providing ophthalmic first aid remotely. In London, Moorfields Eye Hospital launched an emergency video-consultation service to alleviate the burden of vision victims in physical facilities during the pandemic and has been shown to prevent more than 70 % of potential in-person encounters. In Paris, emergency teleconsultation of ophthalmology reduced unnecessary physical consultations by 73 %. Similarly, real-time video consultations

can also be applied to ophthalmology outpatient visits. Using an inbound funnel model, a remote provider (i.e., an ophthalmic technician or optometrist) would transmit clinical parameters and photos over a secure network to the doctor for teleconsultation. General ophthalmology clinics in Hong Kong could maintain 80 % of their outpatient load during the pandemic.⁽²⁰⁾ While a tertiary eye care hospital in Singapore reported high specificity and sensitivity using this method to assess chronic blurred vision. Subspecialties such as oculoplastics,⁽²²⁾ pediatric ophthalmology, and strabismus have also employed video-based teleconsultation with good feedback from clinicians and patients.⁽³¹⁾

Applications in surgical services

Surgical postgraduate training is one of the most extensive training programs in the medical sector. Most surgical training programs need five to six years of postgraduate education to qualify. Usually, this is followed by one or two years of fellowship study in a subspecialty. During the last 20 to 30 years, there have been no significant changes in this situation. The rapid transformation of surgical practice is attributed to advances in medical technology.⁽³²⁾

Some of the most prominent applications of surgical training are the use of virtual reality simulations in training orthopedic surgery residents in arthroplasty (a surgical procedure to restore function to a joint) such as training in total hip, glenoid (part of the shoulder joint) exposure in training shoulder arthroplasty and knee arthroscopy, spinal pedicle screw placement, tibial shaft fracture fixation, fracture carving before surgery, and dynamic hip screw placement.⁽³²⁾

Johns Hopkins neurosurgeons have performed augmented reality surgeries on living patients, beginning with spinal fusion surgery to fuse three vertebrae to relieve excruciating, chronic back pain and the removal of a malignant tumor.⁽³³⁾

AccuVein overlays a map of the patient's veins onto the skin using projection techniques, potentially aiding intravenous injections.⁽³⁴⁾

Sridhar et al. used virtual reality techniques to alleviate anxiety during first-trimester dilation and curettage surgical procedures in pregnant patients.⁽³⁵⁾

In reconstructive surgery, HoloLens overlays a 3D holographic image of the donor's anatomy onto the recipient's face, allowing the recipient to verify alignment and adjust their facial surgery plan accordingly. This technology will enable clinicians to walk around the holographic image and analyze the anatomy effectively. Patient-specific images for the transplant candidate are created from their scan data and mapped onto their face using markers, allowing surgeons to view the data set overlaid on the patient's face as a complete representation in 3D images.⁽³²⁾

Undoubtedly, in the surgical field, the development of these technologies would considerably increase the precision of surgical interventions while substantially reducing the patient's recovery time and postoperative discomfort.

Applications to mental health

Concerning mental health, the metaverse can create ideal spaces for the comfortable work of psychologists and psychiatrists and create favorable environments for therapies without leaving the room to share stories and problems with professionals.

Anxiety and stress have negative medical, biological, mental and behavioral repercussions on the mother and her child during pregnancy. During labor, a pregnant woman's heart rate and blood pressure increase, reducing uterine blood flow. Anxiety can also increase the amount of pain. After childbirth, as well as the risk of postpartum depression. Metaverse technology, as a non-pharmacological technique, can create a virtual world and divert patients' attention from pain signals during pregnancy to something else.⁽³⁶⁾

The metaverse or its early version, i.e. virtual reality, has been proposed for use in treating attention-deficit/hyperactivity disorder, autism spectrum disorder, post-traumatic stress disorder, anxiety, and specific phobias, borderline personality, various forms of psychosis, as well as rehabilitating offenders, improving empathic skills, cultivating prosocial behavior, and helping to overcome personal problems in life.⁽³⁷⁾

CONCLUSIONS

With the isolation implementation due to the pandemic, it became necessary to rapidly widen the range of metaverse applications and implement hundreds of in silico tools in all health branches. In that sense, it highlights the simulation of surgical means, favorable environments, image processing tools, values and processes, and health professionals' avatars.

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