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The use of Virtual Reality in Medical Training

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ABSTRACT

Virtual reality (VR) has become an increasingly important tool in medical training, offering immersive, interactive environments that provide unique opportunities for skill acquisition, education, and patient safety. Traditionally, medical education has relied on real-patient interactions, which can sometimes pose ethical challenges and risks. VR enables learners to practice clinical procedures in risk-free environments, enhancing skills such as surgery, anatomy recognition, and diagnostic interpretation. This paper investigates the history of VR in medical training, its benefits, challenges, and limitations, alongside examples of successful VR applications in healthcare education. As VR technology continues to advance, its potential to transform medical education is significant, offering a safe, affordable, and flexible method for improving healthcare outcomes.

Keywords: Virtual reality, medical training, simulation, medical education, clinical skills, patient safety.

INTRODUCTION

The use of computer-generated simulations of a three-dimensional environment in which an individual may interact in a seemingly real or physical way using special electronic equipment is the definition of virtual reality. Virtual reality immerses the user in a simulated environment that provides a perception of being there. This technology is widely used across several applications such as entertainment, gaming, education, and training. More recently, virtual reality has been adopted in the medical field for training purposes [1]. Medical ethics require that learners must not adversely affect patients, meaning that clinical skills must be learned in settings other than real patients. Traditionally, it is with the supervision of mentors that clinical training has taken place. This apprenticeship model of medical education has served well for many years, and the healthcare system has relied upon it. However, it has limitations. There is an imbalance between training opportunities and patient needs, difficulties in skill demonstration, lack of practice, and an unfair distribution of mentor burden, among others. Furthermore, novice performance may not be good enough to avoid patient harm, and with increasing specialization, there is concern that training is taking place on the most vulnerable patients [2]. Concerns about patient safety have led to calls for alternatives to the apprenticeship model of learning. Simulation is one of the directions in which medical education is moving. Medical simulators are devices or techniques to deliver and assess healthcare tasks safely, outside of real patients. They allow for rehearsal and refining of skills, and for the initial stages of skill learning, training is contained within the non-threatening realm of a simulator. Training can be progressed at the pace of the learner [3].

HISTORY OF VIRTUAL REALITY IN MEDICAL TRAINING

Although virtual reality (VR) technology has only recently gained prominence, its contributions to simulations and applications in medicine began over 250 years ago. The first simulator was created in 1775 by a surgeon named Philip Sarrazin to teach tracheostomy techniques using wax and cork. This early simulation served as a prototype for similar devices employed to instruct generations of surgeons in the performance of more advanced procedures. During the late 1950s, Morton Heilig developed the

Sensorama, often regarded as the foremost VR device. This technology consisted of a stand-in motorcycle seat outfitted with fans, scents, and monitors to provide the user with the illusion of being a motorcycle driver through the streets of Brooklyn. A few years later, Heilig created the first head-mounted display (HMD) system for television viewing called the "Telesphere Mask." The development of such systems coincided with growing fears in the U.S. about the loss of the space race to the Soviet Union. In August 1965, scientist Ivan Sutherland, a computer graphics pioneer, finished designing the first fully operational head-mounted display system for computer-generated graphics. This device received the nickname "Sword of Damocles" due to its large size, susceptibility to falling, and thick wires that resembled a sword hanging over a user's head. In the early 1970s, the first VR applications were developed while Columbia University Medical Center's Department of Psychiatry conducted research aimed at utilizing computer graphics to create visual stimuli for people suffering from psychiatric disorders. During the same era, MIT and NASA cooperated on a Multi-Sensory Flight Simulator. In the 1980s, Californian developers of flight simulators began creating immersive virtual environments. Later, in 1989, machines capable of 3D rendering designed by an ex-NASA engineer were purchased by the U.S. government and provided to various institutions, universities, and research centers. As a result, VR applications rapidly expanded in the fields of defense, aerospace, and scientific modeling. In the mid-1990s, commercial headsets and immersive games appeared on the market. Medical applications of VR began in the late 1980s when a company started creating virtual and augmented environments. VR devices and full-fledged VR setups were operated by various institutions worldwide. In particular, in 1993, scientists built a VR-based system to treat acrophobia, later known as "Virtual Reality Exposure Therapy" (VRET). In 1990, a pioneering group of researchers developed a program that provided a VR-based exposition of traumatic memories [4].

BENEFITS OF VIRTUAL REALITY IN MEDICAL TRAINING

Virtual Reality (VR) technology provides immersive 3D environments that allow users to engage in simulations using sensor-controlled controllers, often involving goggles and headphones. In medicine, VR is emerging as a promising tool to improve medical training and education, offering benefits such as flexibility, affordability, risk avoidance, and the opportunity for repetitive practice. In medical education, the use of VR is still in its infancy but offers several means for achievement. VR medical training tools can be used to improve students' handling of instruments and surgical skills and enhance the ability to recognize anatomy, case diagnosis, measurement and interpretation of images, and interpretation of medical symptoms. VR has many benefits for medical training, including expert time savings, human resources savings due to standardization of training, uniform experience for all students, motivation improvement through simulation of exotic training and testing environments, and the possibility of using telerobotics and telementoring allowing 24-hour advanced expert presence in remote locations [3]. VR medical training simulators are designed to minimize risk to patients and healthcare workers during imitation of high-risk procedures, enabling trainers to recover costs caused by training accident events. Cost reduction can arise from fewer accidents, injuries, and medical errors. Simulation-based training of healthcare workers reflects the overall tendency of various industries, providing a safe, repeatable, inexpensive environment for skill acquisition, improving performance, reducing errors, and leading to an overall saving of costs and lives. The objective quality assessment of performance on VR training simulators can help avoid many costs resulting from human error, as well as fatal, irreversible consequences. Due to recent advances in computing power and visual realism, immersive training with a 2D display does not match reality, whether it is the impression of moving through a corridor or flying an airplane. VR technology currently enables the creation of highly realistic immersive simulation worlds with 3D environments that surprise even experts in simulation. To ensure paradigm shifts in training, matchmaking of the training task and VR technology capabilities is crucial [5].

CHALLENGES AND LIMITATIONS

Despite the potential of virtual reality (VR) to revolutionize medical training, several challenges and limitations must be addressed to fully realize its benefits. One significant concern is the lack of proficiency in VR technology among medical faculty. As with any emerging technology, there is often a technology gap. Since the application of immersive VR in the field is relatively new, not many medical faculty have expertise in this area. It may take years for medical faculty to become proficient in advanced VR technologies. This concern poses another barrier to the expanding usage of VR in the medical education setting [6]. Although many medical schools have purchased or developed VR headsets and training systems, they may not have the necessary staff to operate or create them. VR systems require trained specialists for effective use, unlike other technologies that can be operated by junior staff with no technical background. Until staff become familiar with the newly acquired systems, focus groups, help desks, or demonstrational events can be organized to assure users of their value. Another challenge is the need for advanced knowledge of composition in VR. While 3D modeling tools have simplified the building process, there is still a gap between 2D and 3D media compositions. Elements in VR space must be carefully placed and rendering may require longer tasks or trouble-free file transfers. In one-person perspective VR sessions, the user cannot see anything outside of the VR space, limiting the use of preconceived backgrounds or components used in flat-screen productions. Budgets must be considered and efforts to collaborate and maximize the benefits of VR should be made. Common focus groups can generate open-source ideas for systems, software development, or medical education. Consortiums of institutions can also help achieve objectives, such as assessments for students or materials for licensure tests [7].

CASE STUDIES AND EXAMPLES

The use of VR in medical training has advanced worldwide. Many medical schools and organizations have integrated VR into their education programs. One notable example is the University of Alberta, where a VR environment for studying cadaver dissection was developed. A study on nursing students found that the VR environment was effective and easy to use, leading to improved learning outcomes. Participants appreciated the opportunity to study at their own pace and recommended VR for studying anatomy [8]. HoloAnatomy at Case Western Reserve University utilizes augmented reality headsets and holographic anatomy platforms to learn anatomy. It has significantly improved anatomy examination performance and garnered positive feedback on learning and interest in anatomy courses. The program integrates augmented reality modules, faculty development, and training resources to promote technology adoption. Student simulation and perfusion of donor hearts were developed using 3D printing, and computer simulations were used to core arteries. VR heart models allowed visualization and presentation of pathologies. Faculty received technology training for support. The program encourages institutional investment in 3D printing and augmented/virtual reality in education. VR enhancement of medical imaging courses at UCLA improved student interactions with 3D objects through virtual and augmented reality features. Students could engage with 3D CT data sets of various body parts and MRI brain real-time data using augmented reality headsets. These features were incorporated into lectures and lab activities for first-year medical students. Survey results indicated positive ratings for the VR and AR experience and their effectiveness in explaining medical imaging [9].

FUTURE DIRECTIONS AND INNOVATIONS

Virtual reality technology is transforming medical training. It offers numerous opportunities for application and has the potential to revolutionize complex procedures. This will improve patient outcomes and reduce costs. VR simulators provide practice spaces for surgeons to develop skills away from the operating room. Trainees can practice procedures repetitively and at their own pace, improving confidence and skill. Metrics can assess engagement and track skill progression for educators and employers [10]. Simulations go beyond simple tasks like knot tying. Virtual environments allow complex anatomy modeling, simulating effects of motion and forces, obstructions, and multi-surgeon teams. They also support research, development, and training improvements. Step-by-step training modules ensure correct skill acquisition. Bridging academia and industry needs guarantees tailored applications and continuous user-developer interaction for valuable insights. Unique information or techniques can lead to patents and competitive advantages [11].

CONCLUSION

Virtual reality offers a revolutionary approach to medical training by providing an immersive, interactive, and risk-free environment for learners to acquire and refine clinical skills. The historical development of VR technology has set the foundation for its current applications in medical education, where it offers numerous benefits, including enhanced training outcomes, patient safety, and cost savings. While there are challenges such as the need for specialized training and system accessibility, the potential of VR in transforming medical education remains promising. With continuous technological advancements, VR is poised to become a key tool in the future of healthcare training, enabling both students and professionals to master complex procedures and improve patient care.

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