Benefits of Virtual Reality in Medical and Healthcare Training

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Abstract

Recently, virtual reality "VR" has emerged as promising training method for healthcare providers. VR is a simulation event done by the combination of computer-generated software and physical hand devices. It is able to provide an immersive and interactive environment for its users. VR has been introduced in medical and nursing training programs since it offers a highly interactive and realistic learning environment, exceeding the traditional methods. However, the benefits of VR over traditional training methods in medical and healthcare training are still debatable as shown by current evidence. The aim of this review is to explore current evidence discussing the benefits of VR in medical and healthcare training. VR has shown positive outcomes in various medical fields training from the providers' perspective, including emergency medicine training, radiology training, and disaster medicine. It also has shown positive outcomes from patients' perspective, including stress and anxiety relieving training and gait and balance training. However, confirming VR superiority over traditional methods still needs further research. Additionally, VR was associated with nausea, vomiting, and headache which known as "cybersickness".

Keywords: *Virtual Reality, VR, Healthcare Training, Emergency Medicine, Disaster Medicine, Cybersickness.*

Introduction

Healthcare professionals should be adequately trained to guarantee appropriate access to health services and to accomplish global health coverage (1). A worldwide shortage in healthcare professionals has been reported in previous years (1). Inadequacy of medical and healthcare training programs can aggravate this shortage and disproportionate distribution of healthcare professionals globally (2). Thus, it is crucial to create efficient and high-quality strategies and training programs for health workers (1). Digital technology is considered a promising source for efficient healthcare professions education and training programs (3).

Digital education, often referred to as eLearning, involves the use of digital technologies for teaching and learning. It serves as an umbrella term encompassing a wide range of evolving educational methods, concepts, tools, and approaches (4). It includes virtual reality (VR), various online and offline computer-based digital education, virtual patients, massive open online courses, serious gaming and gamification, mobile learning, and psychomotor skills trainers (4).

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Virtual reality is a simulation event done by the combination of computer-generated software and physical hand device (5). It aims to create interactive and immersive environments so artificial reality can be more realistic. To experience VR, individuals have to wear a headset which engages them in a surrounding 3-dimensional environment (5). Various VR systems have been developed that enable the user to interact with the virtual environment through tactile controllers depending on the type of VR system. This in turn allows users to engage in the environment with characters, objects and scenes, inducing a sense of true presence within the immersive environment (5). "This allows users to learn from experiences as they would in real life. This ability to deliver experiences on demand is where the power of VR lies." (6)

Recently, VR has been introduced in medical and nursing training programs since it offers a highly interactive and realistic learning environment, exceeding the traditional methods (7-9) (Figure 1). Traditional training methods showed multiple disadvantages including large space requirement, high-cost, ethical issues in human or animal tissue use, facilitator expertise requirement, and high cost of, or difficulty in, repeating the educational experience; all of which can be avoided by VR (7). However, the benefits of VR over traditional training methods in medical and healthcare training are still debatable as shown by current evidence. The aim of this review is to explore current evidence discussing the benefits of VR in medical and healthcare training from healthcare providers' perspective and patients' perspective and comparing it with traditional training methods. The review also aims to highlight VR adverse effects, and the ethical issues related to its use.
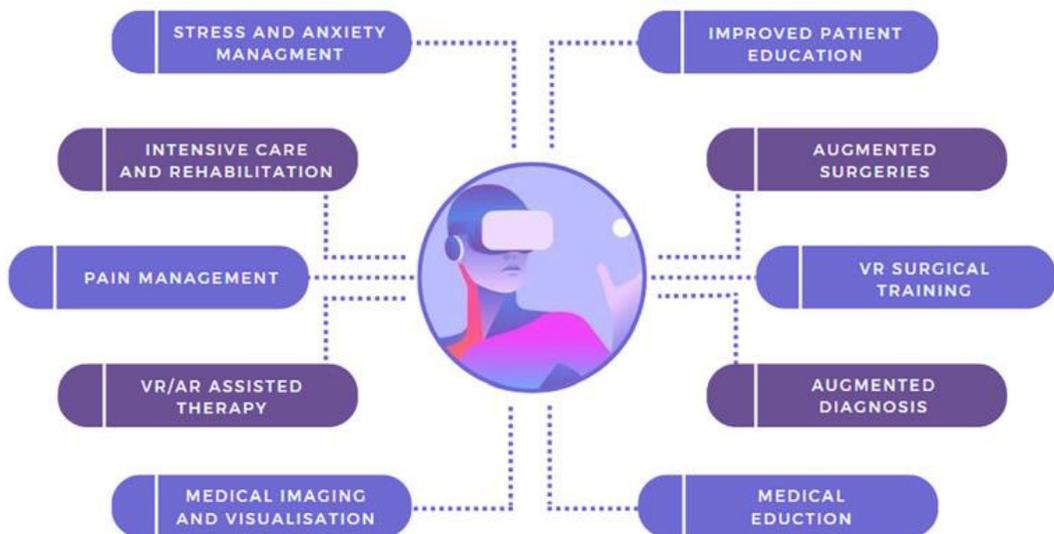

Figure 1. Virtual And Augmented Reality Applications in Healthcare (10).

Methods

Medline (PubMed), Scopus, and Web of Science were used in systematic research till April 8, 2025. To retrieve the synonyms of search strategy, MeSH database was used. Boolean operators according to the Cochrane Handbook for Systematic Reviews of Interventions was used to combine search terms by ("AND" and "OR") as follows: "Virtual Reality" OR "VR" AND "Healthcare Training" OR "Medical Training". Summaries and duplicates of the found studies were exported and removed by EndNoteX8. Any study that discusses benefits of virtual reality

in medical and healthcare training and published in peer-reviewed journals was included. All languages are included. Full-text articles, case series, and abstracts with the related topics are included. Case reports, comments, animal studies and letters were excluded.

Discussion

VR benefits in healthcare training

Surgical skills have been typically learned, for decades, through direct experience in the operating room under the supervision of senior surgeons (11). However, the number of junior doctors and trainees has largely increased along with further restrictions on resident work hours, which in turn have limited opportunities for hands-on practice (10). Therefore, VR was integrated into surgical training since traditional training methods have become inadequate for mastering more advanced surgical skills (12). VR simulations offer a highly interactive and realistic learning environment, exceeding the traditional methods such as e-learning or animal models. The simulations that VR provide feature intuitive 3D visualizations of anatomical structures, enabling trainees to interact with the anatomy and visualize each surgical phase including its dynamic changes (10). In addition, the opportunity to evaluate performance objectively via metrics such as identification of anatomical landmarks, path length, overall satisfaction, and task completion time can improve the training effectiveness and the assessment of psychomotor skills (13).

VR benefits in Emergency Medicine

Delivering effective and safe emergency medical services requires various skills including psychomotor skills, clinical reasoning, and decision-making skills (7, 14). The development of clinical skills is a multifaceted interaction between motor skill development, cognitive ability, and theoretical knowledge (15). For decades, traditional simulations have been the gold-standard of emergency skills training, and recently the number of specialist centers educating emergency skills has been growing significantly (16). These simulations take place in various settings such as purpose-built simulation suite, educational institution, or acute-care settings and typically use wide range of techniques, including cadavers, physical mannequins, table-top exercises, part-task trainers, in-situ techniques, or role-play (7, 17). Although traditional simulation aimed to fill the theoretical-practice gap among various healthcare providers, it still has some disadvantages, including large space requirement, high-cost, ethical issues in human or animal tissue use, facilitator expertise requirement, and high cost of, or difficulty in, repeating the educational experience (18).

Thus, VR was introduced in the emergency skills training field to overcome these advantages. Multiple studies evaluated the effectiveness of VR in emergency training among various healthcare professionals through measuring outcomes such as knowledge, performance, and usability satisfaction (19-24). Knowledge was measured using a pre- and post-intervention written assessment model. Studies demonstrated that VR simulation results in an increase in knowledge (19-22), especially when it was used alone in the training of nurses in multiple clinical fields in comparison with VR alongside didactic education (22). Although two studies reported no difference between VR group and control groups (23, 24), it was stated that VR is likely to result in a positive effect on the knowledge of VR learners (7).

Performance is another outcome measured to evaluate VR effectiveness in emergency skills training. Methods to measure performance were various throughout the studies with objective and subjective tools in a post-intervention evaluation being the most used methods (7). This was

done with the learner undertaking an activity during a non-VR simulation (20, 23, 24) ,a task trainer (25), during a real life activity (26), in a VR experience (27), or during a traditional Objective Structured Clinical Examination style assessment (21). Studies showed inconsistent results regarding the utilization of VR in emergency skills training, as some studies found that VR improved performance (27-29), while others reported better performance after traditional simulation (30). Despite these inconsistent results, it was stated that VR may improve performance of a skill in a simulated or virtual environment as compared with traditional educational tools or in the absence of a comparator (7).

In recent studies, the utilization of VR in resuscitation training including basic life support and advanced life support was also explored (31). These studies showed mixed results regarding gaining resuscitation knowledge, this is explained by the high heterogeneity in clinical case complexity, type of VR hardware, timing of feedback, amount of exposure to virtual cases, degree of gamification and interactivity, and nature of debriefing. Studies also showed no difference between the VR groups and controls regarding CPR depth, rate, chest recoil and overall CPR performance (32, 33).

VR benefits in Radiology Training

In recent years, the utilization of VR in radiology training has been rising significantly (34). The utilization of VR in radiology training enables learners to practice radiography in a virtual, radiation free environment (35). Furthermore, VR offers effective and repeatable training. This allows trainees to recognize and correct errors as they occur (36). Numerous studies have shown that VR is associated with positive outcomes in radiology training, especially in the context of skill acquisition and development (37-39).

Almost all studies reported that VR training is superior to traditional training methods in improving various areas of radiologic and radiographic skill development except for only one study by Kato et al (38) who showed that VR training is inferior to traditional training. Furthermore, studies demonstrated better results in equipment handling, patient positioning, proficiency, and radiographic techniques among trainees trained using VR (34). These results were explained by the interactive and immersive nature of VR simulations that enabled learners to engage with radiological cases in a dynamic and hands-on way (35).

VR benefits in Disaster Medicine

Virtual reality has been implemented in disaster medicine training in recent years. It can be particularly useful in disaster medicine where low incidence, but high effect events provide little opportunity for real world practice (40). A disaster is described as a disruption that occurs in a community where its capabilities cannot afford the resources required (41). Live training has been considered the gold standard for disaster training that includes mass casualty events simulation. These simulations evaluate emergency management skills such as crisis leadership, control and command, or patient care principles such as hot zone interventions and triage (40). However, live training is associated with time restraints, high costs, and significant resource utilization (42). Thus, VR has been introduced in disaster medicine training to overcome these disadvantages of live training. A recent review by Brown et al. explored current evidence aiming to evaluate the benefits of VR in disaster medicine training (40). They reported a significant variation in the way VR was utilized as both an assessment and/or training tool. They also found that participants showed an elevation in confidence and overall acceptance of VR non-immersive and immersive technology as a training method. In addition, VR was associated with similar or

improved triage accuracy but a more prolonged triage time when compared to other forms of simulation. Overall, the study reported that VR and AR were successful in disaster medicine training (40).

VR benefits in Stress and Anxiety

The overwhelming noise, insufficient information, and loss of personal autonomy associated with the hospital environment prompt patients to perceive the hospital as an "unfriendly" environment (43). Stress and anxiety further worsen the situation, as both are well-known risk factors for numerous mental health conditions—including depression and anxiety disorders—as well as physical illnesses like cardiovascular disease (10). Recently, VR has been consistently utilized to reduce stress and anxiety in hospital patients as it provides straightforward distractions through shifting the patient's focus away from conscious awareness of stressful situations during occupational activity (44).

Multiple studies have examined the impact of VR training on reducing patients' stress and anxiety. A recent study applied a VR preoperative training program aiming to reduce anxiety levels in elective surgery patients and found that VR-based approaches were feasible and effective in reducing preoperative anxiety (45). In addition, various studies utilized VR in chronic and depressed patients and observed that VR led to lower patient's stress and shorter hospital stays among chronic patients (46), as well as lower depression severity and self-degradation among depressed patients while enhancing their overall satisfaction (47).

VR benefits in Gait and Balance

The preferred treatment for Parkinson's disease (PD) currently is drug therapy; however, it can be effective only for the first years after drug onset and some symptoms do not subside after drug treatment (48). Furthermore, deep brain stimulation is another treatment used in PD; however, improper intraoperative electrode placement or incorrect stimulation parameters can not only compromise the therapeutic effect but also inadvertently stimulate peripheral nerve bundles, leading to a range of motor and sensory symptoms, as well as other adverse reactions (49).

Long-term rehabilitation may improve the motor and cognitive functions in patients with PD (50); however, clinically, long-term rehabilitation highly requires skilled rehabilitation therapists, adequate financial resources of patients, adequate safety of patients, and training places, all of which are difficult to obtain by PD patients.

VR has recently been investigated as a therapeutic tool in neurorehabilitation research (51). It was stated that VR can enhance stroke (52), quality of life, and cognitive function in the elderly (53). Additionally, VR can improve daily life activities and balance function of patients with PD. A recent Systematic Review by Lei et al. assessed the effectiveness of rehabilitation training based on VR in PD patients and compared it with traditional training methods. The study reported that VR rehabilitation training showed more effectiveness than traditional training methods in improving neuropsychiatric symptoms, step and stride length, quality of life, and balance function mobility in PD patients (54).

VR side effects

Various side effects associated with VR in medical and healthcare training were reported in recent studies (8). Most frequently reported side effects are nausea, vomiting, and headache, which is described as "cybersickness" that can be linked to motion sickness (55). During VR a

"vergence accommodation conflict" may occur contributing to this cybersickness. It occurs due to an imbalance between the focal point of the virtual simulated world the user gazes at ("vergence") and the physical surface of the screen ("accommodation") and this imbalance results in nausea, headache, and discomfort. Furthermore, it was found that these side effects vary among different gender and age groups (56); however, this relation is not yet fully understood and requires further investigation. Currently, multiple solutions are being evaluated to overcome vergence accommodation conflict that potentially hinders the broad application of VR in medical and healthcare training (57).

VR ethical perspective

Some ethical concerns have emerged regarding the use of VR in vulnerable patient groups, including critically ill patients, which prompted Kellermeyer et al. to establish three core principles regarding the use of VR (58):

1. A human-to-human interaction is preferred ("therapeutic alternativism") over human-to-machine interaction (no "technological solutionism"), if there is a choice.

2. VR technology should be centred around "critical human values," such as autonomy and dignity ("humanoriented value alignment").

3. VR systems should also be centered around the patient; and not centered on the needs of professional customers ("patient-centered design").

Bruno et al. has reported that these principles are of pivotal importance (8). VR has to improve the real-world patient-provider relationship and should not be a tool to replace it. Furthermore, a new medical specialty has been proposed by some researchers which is the "virtualist". The "virtualist" is the person who undergoes thorough medical and technical; and has a deep comprehension of the ethical implications of VR technologies (59).

Future Research

The implementation of VR in medical training and education requires a worldwide accepted framework that highlights crucial components within a learner-centric model. The framework must identify core standards and remain able to adapt to technological enhancements and insights from educational psychology (60). Currently, research focuses on embedding VR in medical training, aiming to improve learner engagement and personalize learning. However, future studies ought to also identify ethical issues, including handling simulated patient data and utilization of VR for evaluations, to uphold ethical standards and confidentiality. Furthermore, existing VR applications should be evaluated comprehensively to verify their effectiveness and adjust them to specific educational goals (60). A well-documented database of best practices and effective technologies will play a key role in guiding educators and institutions to effectively integrate VR into medical training.

Conclusion

Virtual reality has emerged as a transformative tool in medical education and healthcare training, offering immersive, flexible, and repeatable learning environments across a variety of specialties. While current evidence highlights numerous benefits, including enhanced skill acquisition, increased learner engagement, and reduced training costs, findings also underscore the need for standardized frameworks, ethical guidelines, and deeper investigations into its long-term efficacy. As VR continues to evolve, future research must focus on refining its integration

into curricula, personalizing learner experiences, and addressing potential side effects and ethical implications to fully harness its potential for improving medical education and patient care.

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