

Virtual Reality Training for Health-Care Professionals

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ABSTRACT

Emerging changes in health-care delivery are having a significant impact on the structure of health-care professionals' education. Today it is recognized that medical knowledge doubles every 6–8 years, with new medical procedures emerging everyday. While the half-life of medical information is so short, the average physician practices 30 years and the average nurse 40 years. Continuing education thus represents an important challenge to face. Recent advances in educational technology are offering an increasing number of innovative learning tools. Among these, Virtual Reality represents a promising area with high potential of enhancing the training of health-care professionals. Virtual Reality Training can provide a rich, interactive, engaging educational context, thus supporting experiential learning-by-doing; it can, in fact, contribute to raise interest and motivation in trainees and to effectively support skills acquisition and transfer, since the learning process can be settled within an experiential framework. Current virtual training applications for health-care differ a lot as to both their technological/multimedia sophistication and to the types of skills trained, varying for example from telesurgical applications to interactive simulations of human body and brain, to virtual worlds for emergency training. Other interesting applications include the development of immersive 3D environments for training psychiatrists and psychologists in the treatment of mental disorders. This paper has the main aim of discussing the rationale and main benefits for the use of virtual reality in health-care education and training. Significant research and projects carried out in this field will also be presented, followed by discussion on key issues concerning current limitations and future development directions.

INTRODUCTION

EMERGING CHANGES in health-care delivery are having a significant impact on the structure of health-care professionals' education in many ways. As Kaufman¹ points out, "medicine has gone through major changes over the last 50 years. Today it is recognized that medical knowledge doubles every 6–8 years, with new medical procedures emerging everyday." While the half-life of medical information is so short, the average physician practices 30 years and the average nurse 40 years.² Continuing education thus represents an important

challenge to face. All this implies restructuring of curricular content, the teaching process, performance evaluation strategies, and faculty infrastructure of the academic department. According to Gorman,² the education of these health-care professionals, both present and future, is largely mired in the 100-year-old apprenticeship model best exemplified by the phrase "see one, do one, teach one." Apart from the limited moments of real apprenticeship, for years lectures and films have formed the basis of health-care training.³ Recent advances in educational and training technology are offering an increasing number of innovative and promising

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learning tools. These include three-dimensional and two-dimensional virtual worlds as well as computer simulations, which can provide an opportunity to enhance the training of health-care professionals through experience in virtual environments. As Bonk and colleagues⁴ point out, “recent technological developments have converged to dramatically alter conception of teaching and learning process.” As suggested by several authors,⁵⁻⁷ virtual reality (VR) represents a promising area with high potential of enhancing and modifying the learning experience: virtual environments (VEs) can provide a rich, interactive, engaging educational context, supporting experiential learning. As Bruner underlined,⁸ performing the task enhances the learning process; VR can provide a medium to learn by doing, through first-person experience.

Current use of VEs extends to a wide range of activities, from training people to acting in dangerous environments (e.g., training for emergency interventions) to experiencing contexts that in physical reality would be too expensive or impossible to access (e.g., “traveling” inside a molecule). The use of VR gradually broadened from teaching simple tasks to the acquisition of complex skills, such as abstract reasoning, visualization and management of complex information spaces.⁹

This paper has the main aim of discussing the rationale and main benefits for the use of VR in health-care education and training. Significant research and projects carried out in this field will also be presented, followed by discussion on key issues concerning current limitations and future development directions.

RATIONALE AND BENEFITS FOR THE USE OF VIRTUAL REALITY IN EDUCATION AND TRAINING

What is VR? And how can its use enhance the learning process? Gaddis¹⁰ defined VR as follows: “a computer-generated simulation of the real or imagined environment or world.” According to Fitzgerald and Riva,¹¹ “the basis for the *Virtual Reality* idea is that a computer can synthesize a three-dimensional (3D) graphical environment from numerical data. Using visual and auditory output devices, the human operator can experience the environment as if it were part of the world. This computer generated world may be either a model of a real-world object, such as a house; or an abstract world that doesn’t exist in a real sense but is understood by humans, such as a chemical molecule or a represen-

tation of a set of data; or it might be in a completely imaginary science fiction world.”

A key feature of the VR experience is also the possibility to actively interact with the created environment; this is allowed by the use of external input devices (mouse, joystick or typical VR peripherals such as Dataglove) responding to the user’s reactions and motions.

According to Winn,⁵ the real added value of VR consists of in the possibility for students, by the means of interaction and immersion, to learn through first-person experience. First-person experiences play a central role in our activity in the world and our learning about it: immigrant environments allow constructing knowledge from direct experience by giving the participants the “perceptual illusion of nonmediation”¹² between them and the computer. VR technology provides trainers with the possibility to reflect and get a deeper understanding of the process through which a person can reach knowledge of the world.

The possibilities provided by the use Virtual Environments, such as 3D immersion, multiple perspectives and multisensory cues⁹ offer a number of potential benefits to health-care education and training^{13,14}:

- *Experiential and active learning.* VR provides experience with new technologies through actual use: learning in VEs requires interaction, thus encouraging active participation rather than passivity. Students and trainees assimilate knowledge more effectively when they have the freedom to move and engage in self-directed activities within their learning context. Finding and structuring content autonomously, they invest mental effort for the construction of conceptual models that are both consistent with what they already understand and with the new content presented. According to McGuire,¹⁵ this active process allows students to reach understanding of the world through an “ongoing process of making sense out of new information- by creating their own version of reality instead of simply receiving the author’s view.” The effective adaptation of old knowledge to new one leads to understanding and, when the students are in charge of this process of “accommodation,” success is also intrinsically motivating. Simulation of the real world provided by VR offer students the opportunity to learn while they are situated in the context where what they learn is to be applied; this results in more meaningful and effective learning, as compared with learning out of context.^{16,17} Nicaise and Crane¹⁸ point out how,

within constructivist perspective, physical engagement with material is central in the learning process. Students reach an understanding of the material under study through object manipulation and building of physical artifacts. To the extent that “immersion in a virtual world allows the same kind of natural interaction with objects that participants engage in the real world,”⁵ action in VEs can support this process of knowledge construction.

- *Visualization and reification.* VEs can be an alternate method for presentation of material, new forms and methods of visualization. Its use can be very important in domains where information visualization is needed, such as manipulating and rearranging information using graphic symbols; it is useful also when it is needed to make perceptible the imperceptible (e.g., as a means to teach abstract physics and biological concepts which are part of health-care professionals *curricula*). For example, researchers at George Mason University and the University of Houston¹⁹ developed “NewtonWorld” and “MaxwellWorld.” These systems provide immersive learning environment in which students may explore the kinematics and dynamics of motion, electrostatic forces, and other physical concepts.
- *Learning in contexts impossible or difficult to experience in real life.* Virtual reality allows observation and examination of areas and events unavailable or impossible (e.g., “traveling” inside human body, moving among molecules) by other means. Furthermore, it allows extreme close-up examination of an object, as well as observation from a great distance. VEs can also be a good solution when teaching or training using the real thing is dangerous (e.g., there is risk of injury to the patient), or for logistic reasons (e.g., the possibility of training without moving from the laboratory or the clinic). VR can furthermore provide effective training in situations requiring the use of equipment prohibitively expensive or impossible to obtain otherwise.
- *Motivation enhancement.* Interacting with a VR model can be as motivating or more motivating than interacting with the real thing, for example, using a game format. It can be a good solution to make learning more interesting and fun, for example, when working with boring material.
- *Collaboration fostering.* Shared VR can encourage collaboration and foster the learning of skills that can be better developed through shared experiences of a group in a common environment. It is most useful when the experience of creating

a simulated environment, or model is important to the learning objective.

- *Adaptability.* VR learning offers the possibility to be tailored to learner’s characteristics and needs (different students are characterized by different learning rates and styles). Learners are allowed to proceed through an experience at their own pace, and during a broad time period not fixed by a regular class schedule. Furthermore, well-designed VEs can flexibly present trainees a broader, deeper set of experiences than those that can be found in the “standard” educational environment.
- *Evaluation and assessment.* VR itself offer a great potential as a tool for evaluation, since every session in the virtual environment can be easily monitored and recorded by trainers and teachers, thus facilitating assessment tasks.²⁰

VR TRAINING APPLICATIONS FOR HEALTH-CARE PROFESSIONALS

In recent years, a number of VR platforms were designed and implemented to support education and training in different learning domains. Identifying the situations where learning in VEs can represent a real added value to traditional education and understanding how to use and adapt virtual reality to support the learning of different concepts and skills has represented (and actually still represents) a challenge involving educators and developers at the same time.

Current virtual training applications for health-care differ a lot as to both their technological/multimedia sophistication and to the types of skills trained, varying for example from telesurgical applications²¹ to interactive simulations of human body and brain (for the acquisition of physio-anatomical knowledge), to virtual worlds for emergency training (to empower coping skills in critical situations).²² Other interesting applications include the development of immersive 3D environments for training psychiatrists and psychologists in the treatment of schizophrenia (presentation of visual and auditory hallucinations to deepen therapists’ understanding of the disease).

Medical and surgical training

Satava and Jones²¹ presented a possible categorization of virtual environments in (medical) education and training based upon application and distinguished individual training, medical crisis

training, and medical virtual prototyping. According to the authors, individual training systems represent at the moment the majority of VR medical applications. These task-specific individual medical trainers, which are also referred to as “partial trainers,” seek to train a single (or a limited) set of skills within a simulation that is highly realistic and anatomically correct. Kaufman and Bell¹ discuss the potential of VR-based partial trainers for teaching and assessing task-specific clinical skills. It is a promising area, which is being addressed by researchers working in a number of different clinical areas. Common to all such partial trainers is their focus on a specific task and anatomical region: VR-based training system for debridement of a gunshot wound,²³ simulator for temporal bone dissection,²⁴ virtual endoscopy simulator,²⁵ trainer for arthroscopic knee surgery,^{26,27} and simulation for training palpation of subsurface breast tumors.²⁸

More recent examples include VR orthopedic surgery,²⁹ mastoidectomy simulation,³⁰ an open surgery simulation system developed by Bielser and colleagues,³¹ a VR system for training and pre-treatment planning of interventional neuroradiology procedures,³² a VE for esophageal intubation training,³³ and VR training and assessment of laparoscopic skills.³⁴

Emergency training systems

Medical crisis training systems focus on complex training tasks in which the individual must act directly and manually on the environment and in which the responses to an action may be very subtle (such as a change in skin color). Doing so requires the design and implementation of several interaction and simulation methodologies, from distributed-system support for high-fidelity simulations to the development of clinically realistic virtual patients and, perhaps most importantly, to the creation of techniques that permit a user to act naturalistically upon the virtual environment. Stansfield and colleagues⁶ developed BioSimMER, a fully immersive distributed virtual reality platform developed to train medical emergency-response personnel. Small and his team²² presented an emergency medical trainer similar a flight simulator: a customizable mannequin with realistic anatomical features represents the patient, whom users act upon using physical instruments that interface the mannequin to a computer control system that drives the appropriate clinical state and response. Other researchers^{35–37} developed the entire training scenario via software, with dynamic virtual patients presenting changing physical condition and

responding to the clinician/trainee, who interacts with the system via a series of menus.

Freeman and colleagues³⁸ recently developed a virtual reality patient simulation system for teaching emergency response skills to U.S. Navy medical providers. Rapid and effective medical intervention in response to civil and military-related disasters is crucial for saving lives and limiting long-term disability.

All these systems are focused on training professionals to act when faced with limited supplies and the demands of stabilizing casualties not generally encountered in the comparatively resource-rich hospital setting. As suggested by Freeman,³⁸ “this experiential, problem-based training approach engages the user in a stress-filled, high fidelity world, providing multiple learning opportunities within a compressed period of time and without risk.”

VR training for mental-disease professionals

An interesting VR training application was recently presented at the 155th Annual Meeting of the American Psychiatric Association: attendees “saw” what happens inside the mind of a person with schizophrenia. The realistic virtual-reality experience puts participants on a city bus and surrounds them with the sights and sounds seen and heard by a person with schizophrenia.

Janssen LP created the simulation to educate psychiatrists and other healthcare professionals on what it is like to have a severe mental illness. Called “The Bus Ride,” the experience uses specially choreographed sound and video footage—broadcast on a wrap-around screen in a simulated bus—to take riders into the world of schizophrenia. The experience was created based on the descriptions of audio and visual hallucinations provided by both persons with the illness and their physicians.

VR training for clinician-patient relationship

As suggested by Letterie’s review,³⁹ VR has been successfully used to simulate person-to-person interactions for training in psychiatry and the social sciences in a variety of circumstances by using real-time simulations of personal interactions, and to launch three-dimensional trainers for surgical simulation. This indicates that VR could be useful not only to support the acquisition of technical skills, but also to enhance a complex set of skills including the personal aspects of patient care. The author focuses for example on the possible use of VR as an educational modality in obstetrics and gynecology both for surgical skills acquisition and for teaching

essential elements of counseling (from routine pre-operative informed consent to intervention in more acute circumstances such as domestic violence or rape).

CONCLUSION

Technological advances have made available to health-care professionals a wide set of innovative training tools. Among these, VR seems to have a great potential to enhance the learning process.^{9,13}

First of all, VEs can provide modes of experiential learning; to the extent that VR provides high-level interaction with the learning content, it can foster active engagement by students and trainees. This contributes to raise motivation and interest, conditions that are recognized as crucial in the learning process. VR learning also allows entirely new capabilities and experiences that would be too difficult, too costly or simply impossible to have in the real world. Finally, VR environments can be tailored to individual learning and performance style. They are highly flexible and programmable, thus enabling the teacher or the trainer to present a wide variety of controlled stimuli and to measure and monitor a wide variety of responses made by the user.

The considered VR systems differ a lot according to many technological components, such as hardware and software configurations (obviously with different costs and usability issues), interaction modes, the use of the Internet, support of single/multi-user interaction, multimedia components embedded in the 3D worlds. These components influence many VR features such as the levels of immersion, graphic fidelity and interactivity, multi-sensory cues, possibility of collaboration, number and complexity of tasks supported,

How well these features are conducive to learning and instruction depends a lot on the quality and sophistication of the VE design. In fact, features of a learning environment do not act in isolation. Elements such as the concepts to be learned, individual characteristics, the learning experience and the interaction experience all play a role in shaping the learning process and learning outcomes, teaching style.⁹

When looking at the current use and integration of VR tools in educational and training contexts, we can see how a number of problems limit their actual application and effectiveness. These problems represent challenges for future development of learning VEs and include pedagogical, technological, institutional, cultural, economical, management, interface design issues.

At the moment, *costs* surely represent one important limit to VR penetration into educational context. Although some attempts have been made to use PC-based VR systems (and current efforts in this direction are encouraging), most of the existing VEs are based on VR systems such as CAVEs or high-end platforms (such as Onyx Silicon Graphics) whose cost is beyond the reach of the average university, clinic, not to talk about single students. It should also be considered that initially the implementation of VR training systems might be more expensive as compared to using other traditional teaching tools, thus requiring an important ongoing financial support.

Furthermore, almost all applications in this sector can be considered "one-off" creations tied to a proprietary hardware and software, which have been tuned by a process of trial and error. This makes them difficult to use in contexts other than those in which they were developed. Furthermore, this lack of reference standards does not only concerns technological aspects but extends to the lack of common reference framework in design, implementation, evaluation and assessment.

As far as *changes in educational culture* are concerned, 3-D graphics technology is not intended to entirely replace conventional classroom teaching techniques; nevertheless, as Dean and colleagues⁴⁰ point out, "properly implemented virtual environments can serve as valuable supplemental teaching and learning resources to augment and reinforce traditional methods." Anyway, good design and implementation are surely not enough to ensure effective results: the learning potential of the actual VR experience must be constantly integrated and managed by the teachers within the actual educational context. Teachers themselves must develop specific expertise and sufficient practical experience of VR learning in order to effectively support learning process in 3D environments. As considered by Barker,⁴¹ academic and training institutions should understand the advantages of using VR simulations and be committed to developing the procedures and teaching modules and evaluating their effectiveness; simulations are another teaching tool and not a substitute for the teacher.

Another crucial issue for integrating VR into educational curricula is safety: some users have experienced side effects during and after exposure to immersive VR environments,⁴² collectively referred to as "simulator sickness"⁴³: ocular problems (e.g., eyestrain, blurred vision, and fatigue), disorientation and balance disturbances, and nausea. Though the latest VR tools seem to have minor or no side effects, future researchers have to confirm these results.

Finally, system usability represents a key requirement: this is surely not an easy task, seen the multi-dimensional nature of learning process and the complexity and novelty of VR technology. Interface experts stress the value of involving end-users in the development of computer technology during the design phase. Further research is required, both on technological side and on VR issues such as transfer of learning, appropriate curriculum implementation, elements of effective VR design, and the psychological and social impact of the technology use.

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