Virtual reality in residents training

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Abstract: Training in residency programs is highly competitive, it requires the formation of competent physicians that achieve the performance standards that were declared for their technical skills, attitudes and interpersonal abilities. The use of simulation and technology on the medical education has increased considerably. Particularly in ophthalmology the simulators used are: live models from animal or cadavers, mannequins, wet laboratories, simulated patients, part-task moles, laser or surgical models, and more recently, virtual reality (VR). VR places a person in a simulated environment that has a specific sense of self-location, where the participant interacts with the objects within the setting. Teaching with VR refers to the use of the available resources in technology and visualization of structures to improve the educational experience of medical students, residents and physicians in professional continuous development programs. Several authors highlight the benefits of assessing trainees with the tools, they argue that the key contribution of this model is in the formative assessment. Rather than evaluating and putting a score on student's grades, VR provides a powerful experience for the acquisition of skills. A conclusion is the need to develop studies to document the effects that it has on knowledge, skills and behaviors, and to patient related outcomes.

Keywords: Virtual reality (VR); ophthalmology training; educational technology; educational innovation

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Ophthalmology training

Training in residency programs is highly competitive, it requires the formation of competent physicians that achieve the performance standards that were declared for their technical skills, attitudes and interpersonal abilities (1). Studies report that 30–50% of major complications from general surgical procedures are potentially avoidable by improving skills development (2).

The goals of any residency program describe three needs: best care for the patient, honor the demands of employers and society, and contribute to job satisfaction (3). This responsibility with the patient outcomes fuels the assessment of competences in training programs. The best care of the patient depends of the acquisition of surgical skills that can be considered more complex than mastering basic motor skills (2).

Sadideen *et al.* (2) describe the domain of skills in residency, such as: psychomotor skills, memory and deep learning. The Royal College of Physicians and Surgeons of Canada (4) recommends the CanMeds model which identifies and describes the skills required by a physician to meet the health needs of the public it serves. They describe seven roles: medical expert, communicator, collaborator, leader, advocate, academic, and professional. In addition to the roles, the Royal College of Physicians and Surgeons of Canada established entrustable professional activities (EPA). This frame of reference translates the traditionally theoretical competency model into a real vision of medical practice where the definition of tasks is specific to a field, specialty or subspecialty (5).

Traditionally, the model for training is based on a

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supervision structure where medical students report to junior residents, they report to senior residents which report to attending physicians. This model requires that the students gain skills and independence until, gradually, they can be responsible of the patient. Although, ideally training should provide sufficient practice opportunities for all students, this is time and resource constricted (6).

According to Valdez-García and Uscanga (7), learning that takes place on the clinical setting is highly influenced by several changes on the clinical care, such as the diminution of patients, cost optimization, and a reduction of the length of stay in hospitals. Medical specialties should adapt to those changes, and they would have to reorient their efforts to still prepare the physicians in their residency.

The use of simulation and technology on medical education has increased considerably. Ting *et al.* (8) argue that it is due to the formal studies that have documented the effects that it has on knowledge, skills and behaviors, and that some are even able to link it to patient related outcomes. Particularly in ophthalmology the simulators used are: live models from animal or cadavers, mannequins, wet laboratories, simulated patients, part-task moles, laser or surgical models, and more recently virtual reality (VR).

VR

The term VR was originally invented in 1987 by Garb when referring to the representation or simulation of the world through symbols or figures (9). VR is defined as an alternative environment that is composed of scenes and objects that replace reality, commonly incorporating headsets and visors attachments to recreate these immersive environments. Therefore, the elements that comprise a VR setting are:

- ❖ Simulated environment;
- ❖ Googles and headsets displays;
- ❖ Software.

According to Sherman and Craig (10) this immersion can occur in two ways: mental or sensory, in order to create a personal experience through the use of devices and sensors that complement the scenario. Choi *et al.* (9) assure that this immersion must provide the illusion of a virtual world that responds to the interaction where the user has some kind of control of the perspective and points of view of the environment.

Psotka (11) affirms that VR place a person in a simulated environment that has a specific sense of self-location, where the participant can move the head and explore it, can feel the space surrounding him or her, and can interact with the objects within the setting. The objects then must have a feel as the real one, can be picked up, bumped into, heard or explored as natural as the senses would interact with them. These rules of engagement then lead to the development of haptic responses to interact with the environments.

In recent years, this technology has led to new educational applications and learning environments (12). Helsel (13) even says that VR allows educators to act as gods that create new realities and magical worlds with educational utopias. Psotka (11) argues that VR distinguishes from all preceding technology by these senses of immediacy created by the immersion itself. The sensation of presence created by the movement of head and eyes, supports the development of programs that build upon active learning methodologies and innovative environments.

This innovative experience has the potential to transfer from abstract pedagogy principles that build on the theoretical knowledge, to a more experiential visual representation. For Psotka (11), the emphasis on the effectiveness of VR for education lies in the transfer of skills to the real world.

When it started, technology was costly due to the specialized equipment that had to be included, and little development of specific applications for education was made. Recently, different companies have developed services and solutions for training and the practice of specific clinical skills.

The use of these environments for visualization and training can provide students with views of anatomical structures and the understanding of spatial relationships that trigger involvement and motivation in the participants (14). Training programs have increasingly incorporated the use of technological resources, this application of VR in education has been perceived by students as a pleasant and stimulating experience. Some studies report the direct impact on student motivation or enthusiasm; however, it is clear that the use of a technology by itself will not have an impact on student learning. Educators should rely on instructional design principles and guidelines to develop and apply VR models in a novel way based on academic gain. In engineering, some studies have assessed the impact on the development of competencies regarding the understanding, perception, and the description of spatial relationship, as well as the projection with adjacent structures and objects (15).

In medicine, some authors have evaluated the impact of technologies for the improvement of three-dimensional

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visualization for the teaching of anatomy, or specifically for organs segmentation (16). Other studies have shown the benefits in surgical education and training using sophisticated laparoscopic simulators (17).

Particularly in ophthalmology residency programs, high-fidelity VR simulation is gaining popularity as universities and hospitals look for new methods to rain residents while maintaining patient safety (18). In that controlled environment, students are able to personalize their training and define their own learning goals.

Khalifa *et al.* (19) argue that although VR models have push training in surgical programs, there is still a struggle to find viable methods for assessing and documenting the acquisition of skills in training. Li *et al.* (20) argue that the potential to be an important teaching modality for ophthalmology training programs, has been shadowed by the lack of evidence.

VR simulators for ophthalmology training

Teaching with VR refers to the use of the available resources in technology and visualization of structures to improve the educational experience of medical students, residents and physicians in professional continuous development programs. Several studies have analyzed the benefits to design training programs supported by VR experiences

Sikder *et al.* (21) conducted a review of the research studies involving VR for ophthalmology training. Three VR surgery simulators were identified: Eyesi VR simulator from VRmagic developers, Immersive Sim from Immersive touch, and the PhacoVision from Melerit Medical. These surgery simulators have developed model for: anti-tremor, forceps, capsulorhexis, hydromanoeuvres, phaco, phacoemulsification, navigation, and cracking and chopping. Capsulorhexis and phacoemulsification are considered to be one of the most difficult steps for trainees to master when they are starting to develop skills as new cataract surgeons (22).

Although the authors agree that the virtual simulators are a safe and effective tool to assess performance, the studies included only had a small sample of participants, with samples varying from 12 to 35 students (21). New studies would incorporate longitudinal assessment of trainees to track progress as they advance in the program, as well as a bigger population to use a wider range of statistics to support findings. But more importantly, these research should focus on demonstrating the impact on a significant reduction in complication rates, because the costs and the benefits of these programs will still remain uncertain (18).

Eyesi VR simulator

It is a high-end simulator that provides: realistic instrumentation, and life-like tissue behavior. They have several modules, one dedicated to cataract and the other to vitreoretinal surgery. The cataract module is divided in introductory, beginners, intermediate and advanced courses. The introductory material focuses on anterior chamber navigation, intracapsular navigation, bimanual navigation, and instrument handling. The beginner level course focuses on navigation and instruments, capsulorhexis, intracapsular tissue, stop and chop, and IOL insertion. The intermediate courses cover capsulorhexis, divide and conquer, copping, irrigation/aspiration, and toric IOLs. The advance modules focus on capsulorhexis errant tear, weak zonules and capsules, white cataracts, capsular plaques, and varying cases (23).

The vitreoretinal surgery training is divided in introductory, beginners, and advanced courses. The introductory is made of navigation and instruments, the non-dominant hand, and bimanual navigation. The beginner courses are made of navigation and instruments, the non-dominant hand, bimanual navigation, posterior hyaloid detachments, epiretinal membranes, and the internal limiting membrane. The advanced courses are made of navigation and instruments, posterior hyaloid detachments, epiretinal membranes, the internal limiting membrane, retinal detachments, and the non-dominant hand.

One of the differentiae factors of this simulator is that it provides immediate feedback for trainees. The score sheet that they received is a detailed performance analysis highlighting instrument and microscope handling, surgical efficiency and tissue treatment. The score is presented in a 1–100 scale, and provides replay and time lapse of the videos of student's performance. The resulting video could be exported to a USB flash drive for students or faculty analysis.

ImmersiveSim

The Immersive Touch team developed several training solutions to be implemented as well for surgical planning. They integrate the use of AR and VR simulations in their platform. Through the incorporation of specialized glasses, the user can interact with a 3D environment. Their design is compatible with HTC Vive and Oculus systems, and they also added a pen stylus to replicate the sensation of using various surgical tools (24).

One of the advantages of this simulator is that the virtual head and instruments is adjustable and provides haptic responses (21).

PhacoVision

This simulator developed by Melerit offers a training module in cataract surgery using the phacoemulsification method including the capsulorhexis and the phacoemulsification part (25). The participant interacts with the environment and the input of his movements is replicated on the screen in the lens, iris, capsule and cornea models. The user interacts through hardware elements that represent the instruments, microscope, and headpieces of real operations.

Data is collected through the participation of the trainee, and performance information is presented at the end of each session. The progress of the trainee is tracked and full analysis can be presented afterwards.

Studies and validation of VR simulators

Saleh *et al.* (26) designed a VR training program for ophthalmology using a VR simulator. Their study was conducted at Moorfields Eye Hospital with the support of the Simulation and Technology-enhanced Learning Initiative (STeLI), the London Deanery School of Ophthalmology and the International Forum of Ophthalmic Simulation (IFOS). Research focused on 18 subject that performed five cataracts specific and generic tasks. They performed continuous curvilinear capsulorhexis, cracking and chopping, cataract navigation, bimanual cataract training, anti-tremor. Physicians were assessed using on three attempts to test for repeatability and reliability. The authors report no significate difference in scores at the first attempt, but they were able to prove that the assessment was sensitive enough to differentiate the complexity of some procedures, for example in the capsulorhexis. To validate the construct, researchers compared novice and senior surgical groups, and as they had more experience the performance was better.

Selvander and Asman (22) used a VR simulator for cataract surgery with senior specialist and new trainees. Every participation was recorded using the video clips in the simulator to be assessed with a validated instrument. The instrument that they used for the assessment was the Objective Structured Assessment of Cataract Surgical Skills (OSACSS) and a modified Objective Assessment of Surgical Skills (OSATS), and two experienced cataract surgeons analyzed the video performance in the simulator. Participants performed the cataract modules in a 60-minute session:

- ❖ Capsulorhexis module where the trainee injected viscoelastics into the anterior chamber, created a flap with a cystotome and then pulled the flap and performed a capsulorhexis with forceps;
- ❖ Hydro-maneuvers module where the trainee performed a hydrodissection of the lens and moved the nucleus around to evidentiate that the dissection was completed;
- ❖ Phaco divide and conquer module where trainee had to dived the nucleus in four quadrants, and remove and emulsify those quadrants with the phaco probe;
- ❖ Manipulation modules where the trainee had to hold the tip of an instrument in spheres that were mobile within the anterior chamber, and move the cataract forceps to pick triangles from the top of the lens to a special region in the middle of the anterior chamber.

la Cour *et al.* (27) did a study about the operating room performance after a VR training in cataract surgery. They asked participants to complete abstract and procedural task. The abstract task consisted of aiming at objects within the capsule with the tip of the instrument, following a circular path on the capsule, and collecting objects in the anterior chamber with the forceps and two other instruments. The procedural tasks consisted of performing a continuous curvilinear capsulorhexis and a phacoemulsification on a medium-hard lens. The technical performance was measured using an OSACSS. Their findings indicate that VR can improve surgical performance in both novice and surgeons on an intermediate level, regarding technical skills.

Conclusions

One agreeable conclusion among the different studies is the need to prepare participants on the use of the simulator itself. It is not particular for VR settings, but for medical simulation in general. Participants may exhibit nervousness, anxiety or rejection to their first encounters with simulation or about the medical procedure itself (28).

Although the authors highlight some of the benefits of assessing trainees with the tools, they argue that the key contribution of this model is in the formative assessment. Rather than evaluating and putting a score on student's grades, VR provides a powerful experience for the acquisition of skills.

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Footnote

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