Virtual reality for medical and nursing training in low- and middle-income countries

Background Paper

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Abstract

This paper reviews the potential for the use of new low-cost Virtual Reality (VR) technology for conducting medical simulation training in low- and middle-income countries (LMICs). VR has been used in medical simulation training for many years but has traditionally been very expensive and requiring large machines that would be difficult to set up and maintain in LMICs. However, new advances in computer technology have enabled a new generation of consumer-focused VR hardware that offers the potential for implementation in LMICs. Our research team based in Oxford and Kenya developed a VR training scenario for the Life Saving Instruction for Emergencies (LIFE) project. We tested LIFE:VR with healthcare workers in Kenya to establish the potential feasibility and acceptability of low-cost VR for medical simulation training. We found that healthcare workers were enthusiastic about the approach but the systems we tested had a number of technical limitations such as requiring powerful laptop computers and the installation of laser tracking base-stations that would limit scale up. However, newly announced hardware from major VR manufacturers appear to address these technical issues and will continue to reduce the costs of devices increasing the potential for wider adoption in LMICs.

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Background

Approximately 1 million children die in their first month of life in low- and middle-income countries (LMICs). The World Health Organization (WHO) estimates that two-thirds of these children could be saved if the healthcare workers who look after them had adequate training and resources [1]. In high-income countries such as the UK, healthcare workers are trained in the management of medical emergencies by conducting simulation training. This involves working in groups in a simulation training 'lab', enacting the step-by-step procedures needed to save a life. Instead of a real patient, trainees use plastic mannequins as patients. However, they use real medical equipment and the lab is often laid out in the same way as a real hospital ward. This type of training is effective at preparing healthcare workers for emergencies, but it is expensive and requires trained personnel, medical equipment and training facilities [2, 3]. To roll out simulation training in LIMCs, even using minimal equipment and low-cost mannequins, would costs millions of pounds every year for each country [4].

To overcome these challenges, virtual reality (VR) has been proposed as a lower-cost alternative to face-to-face simulation training. VR systems create a highly realistic computer-based three-dimensional (3D) environment in which a student can learn. Trainees use a head-mounted display and handheld controllers to allow them to interact with virtual objects [5].

VR has been used in the military and for surgical training for many years [6], but these first-generation VR simulators are very expensive and use large machines that would be difficult to set up and operate in an LMIC context. However, recent innovations developed for the mobile phone industry – such as high-resolution displays and advanced graphics processing units (GPUs) – have enabled a new kind of VR technology that could scale simulation training at much lower costs in LMICs. Using these mobile phone components, companies such as Oculus (acquired by Facebook in 2014) and HTC, have built a new generation of VR headsets that offer significant potential for improving medical simulation training.

This next-generation VR technology was designed primarily for the entertainment industry and, more specifically, for the gaming industry. However, in recent years, research groups and start-up companies have begun to apply this new technology for medical training and clinical practice. The use of VR in medical training has the potential to overcome barriers that exist with traditional face-to-face simulation sessions that require both the learner and trainers to be present in the same room. Using VR over the internet has the potential to connect students who are separated geographically from skilled trainers. This is especially important for places where it is not feasible to travel large distances for the sole purpose of training. It also allows for skilled trainers to mentor and provide support in locations that would have otherwise been impossible to visit.

We know from studies conducted with first-generation VR simulators that using 3D graphics offers an effective learning experience for procedures such as performing surgery or operating a piece of medical equipment [7-9]. However, the expensive simulators used in these studies are housed at training facilities rather than with individuals. This means that healthcare workers have limited opportunities for training, particularly in LMICs and rural areas. Also, these types of simulators most often provide a solitary experience and do not train people to work as a team. Nor do they allow workers training simultaneously to communicate with one another.

Universities in high-income countries are now using next-generation VR headsets to teach students various aspects of clinical medicine. This is often in a partnership between a teaching institution, a hospital and, at times, one of the new VR headset manufacturers such as HTC [10, 11]. To date, the new VR approaches have predominantly been used for surgical training [5]. An example of VR application in surgical education is Surgical Theater.[1] This is a visualisation platform that has been deployed at several academic hospitals. It enables patients and surgeons to step into a VR reconstruction of a patient's anatomy. The National University of Singapore, Yong Loo Lin School of Medicine has been using VR for basic science education. The university has been testing a system called Virtual Interactive Human Anatomy which allows students wearing a VR headset to explore the anatomy of a human body [12].

Next-generation VR is also being used in LMIC settings. In Zambia, a project proposes to compare traditional versus virtual simulation enhanced training for surgical training [13]. To do this, the project set up a VR simulation of a surgical procedure to pre-train surgical trainees. It allowed them to acquire the psychomotor skills, sensory acuity and, to a lesser extent, cognitive planning required to achieve the surgical dexterity necessary to perform cervical cancer surgery. The project is now in field testing after beta testing in laboratory conditions.

[1] See www.surgicaltheater.net

Life-saving Instruction for Emergencies (LIFE)

Our research group, based in Oxford and Kenya, has also begun to explore using low-cost VR for healthcare worker education. We developed Life-saving Instruction for Emergencies (LIFE) to allow more health workers access to high-quality training and to overcome the challenge of dispersed medical and nursing training across Kenya. We have developed a mobile and VR platform to teach health workers how to manage medical emergencies – initially to provide training in caring for very sick newborn babies and children. LIFE evolves the scenario-based teaching model that is used in a face-to-face training approach (Emergency Triage, Assessment and Treatment plus admission care, ETAT+ [14, 15]). ETAT+ has already been used to train more than 5,000 healthcare workers and 2,000 medical students across Kenya, Uganda, Rwanda, Zimbabwe, Zambia, Malawi, Tanzania, Sierra Leone and Myanmar. It is now part of the undergraduate medical training curriculum in medical schools in Nairobi, Kampala and Kigali [16]. The ETAT+ training is usually delivered over a period of between three and five days.

The LIFE platform uses the concept of 'serious gaming' or 'educational gaming' to deliver training to health workers. Serious games are video games with a specific applied purpose other than entertainment – such as trying to improve health outcomes [17]. The rationale for using serious gaming is that emergency care training should enable health workers to follow highly structured care pathways (or algorithms) that are similar to the structure of computer games. Key pieces of information (cues) sought at each step determine the correct actions to perform. Executing cue-response sequences perfectly, rapidly and automatically demonstrates mastery and supports effective care. However, the frequent rehearsal this requires is difficult and expensive to achieve in face-to-face training. Using a gaming approach aims to make the repetition of the training more enjoyable and engaging than is possible using more straightforward quizzes, videos or textual information.

LIFE:Mobile

The initial version of the LIFE platform was not designed for VR. It uses Android and iOS smartphones and comprises a scenario-based 3D mobile game that is highly interactive. The first LIFE scenario for LIFE:Mobile was developed to help train health workers to manage neonatal resuscitation. It is currently being rolled out in Kenya.

LIFE:VR

LIFE:VR was developed in partnership with VR Education and uses the Engage platform, a digital education and corporate training platform with the core objective to provide students, educators and corporate trainers globally with an alternative to typical physical institutes or expensive on-site simulated training. The Engage platform enables meetings, classes, private lessons and presentations with people from all around the world in a safe virtual multi-user environment. VR Education achieves this by partnering with educational institutes and corporate trainers and VR and augmented reality (AR) hardware manufacturers to package tailor-made solutions for corporate and simulated training such as safety and medical training.

LIFE:VR was established through an informal partnership with VR Education, University of Oxford and HTC. A neonatal resuscitation module was developed based on ETAT+ training that is already being used to train health workers in developing countries. The neonatal resuscitation training module is available through the Engage education platform and can be downloaded for free. HTC provided the LIFE project with VR equipment that comprises a HTC Vive™ VR headset, hand controllers and base stations to enable users in Kenya to test the module.

LIFE:VR neonatal resuscitation scenario

The neonatal resuscitation scenario begins with a newborn baby that is not breathing. The baby is placed on a Resuscitaire® (a baby warmer) in a ward that depicts a typical delivery room in a low- and middle-income setting. All the necessary equipment is placed within reach of the student. There is a virtual teacher in the room who asks the student to perform tasks to help the baby breathe. In the scenario, the baby needs basic resuscitation. The learner uses a bag and mask device and is expected to follow the steps required for a simple resuscitation. If they perform a step incorrectly, the virtual trainer gives them appropriate feedback before allowing them to proceed to the next action. If a task is performed correctly, the learner receives positive feedback and proceeds to the next step. On successful resuscitation, the learner can see the newborn baby start to move and cry. The resuscitation scenario is timed to emphasise to the learner that time is of essence. The scenario provides a risk-free environment for a learner to practise the steps required to resuscitate a newborn baby.

LIFE:VR in Kenya

The LIFE team set out to collect views from users in Kenya while evaluating the LIFE platform. Users were asked to try out the LIFE:VR neonatal resuscitation module and to give their views on the module and how it might fit in with the teaching landscape in Kenya. We gathered these views informally and observed how the users interacted with the equipment and the training session. Views were collected from paediatricians, pre-service and in-service nurses and lecturers in universities in Nairobi, Kenya.

Feedback from users

LIFE:VR neonatal resuscitation was received with a lot of excitement from both practising and teaching paediatric trainers and students. The educators felt that the VR set-up provided a realistic environment where students can learn practical skills. The learners felt that this would give them an opportunity to practise their skills. They also gave feedback on how the scenario could be improved – for example, by expanding the scenario to include more steps (such as preparing the room), using the timer for reinforcing specific actions at appropriate times, and proving additional visual feedback, such as the rate the user is providing ventilation breaths to enable real-time correction of their technique.

Challenges

The introduction of any new equipment or technology is often faced with challenges. Table 1 highlights some of the challenges encountered.

Table 1:

	Challenge	Discussion
VR hand controllers	Some learners' resuscitation of the baby was affected by their ability to use the hand controllers and interact with the virtual equipment.	Repeat users were able to resuscitate the baby on the second attempt. This points to the fact that, once a learner has been able to acclimatise to the equipment, they are able to go through the module successfully.
Physiological issues	A very near-sighted participant found it very difficult to use the headset. The individual could not complete the module because of nausea or headache experienced when wearing the headset.	This is a well-documented problem on the use of VR equipment and it is expected that this problem can be overcome with improvements in technology [18].
Set-up favours right-handed users	During the tests, it was discovered that the set-up favoured right-handed users more than left-handed users.	While this was not the developer's intention, it only emerged when left-handed users found it more difficult to interact with the equipment - they were forced to use their less-dominant right hand to perform the ventilation task.
Cost of equipment	Users were concerned about the cost of equipment and the type of technical support required for a VR set-up within a teaching institution in the longer term. The current set-up requires powerful computer and VR equipment.	The cost of headsets is decreasing. Availability of new stand-alone headsets might drive down this cost by eliminating the need for a computer or laptop.
Internet requirement	The current set-up requires a reliable internet connection. This is most likely available in most urban areas in Kenya. So far, we have not encountered difficulties in setting up the VR scenario at training institutions or conferences in Kenya.	This challenge will become more apparent when attempts are made to connect more remote training centres with urban ones, or across continents. Advances in internet infrastructure and penetration will improve the situation.

Conclusion

Our experience in developing and testing LIFE:VR has demonstrated that VR is a feasible and attractive option for clinical education in LMICs. Our beta testers showed a high level of engagement with the technology and were keen to see more content made available. However, there were significant challenges that need to be overcome before VR could be used on a wider scale.

Even though the next-generation headsets are more affordable than first-generation VR systems, the early versions of next-generation VR devices we used require connections to powerful computers and wall-mounted laser tracking systems. However, the latest iterations of these devices, such as HTC VIVE Focus™ and the Oculus Go™, are fully integrated stand-alone headsets that do not require any additional computers or training. There is the potential for learning institutions to transition from the traditional VR technology to adopt stand-alone VR headsets. These headsets are pre-programmed with training modules; learners simply wear the headset and use the hand controller as a pointer to interact with the training scenarios.

As VR technology continues to become more affordable and portable, its potential for adoption in LMICs for clinical education may be significant. Our research team is now investigating how stand-alone VR headsets could be adopted by training institutions. We are continuing to work on new and expanded training scenarios for the LIFE platform that will be able to use these technologies to deliver high-quality simulation training at scale in LMICs.

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