Pandemic-Proofing Simulation-Based Education: Development and Evaluation of Interactive Virtual Educational Content for Medical Trainees

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Background: During the global pandemic of 2020, simulation centres were forced to close or significantly curtail activities in an effort to reduce the spread of COVID-19. For 4 months, medical students and residents were unable to participate in simulation-based training that are core to their established curriculum. At the University of Ottawa Skills and Simulation Centre (uOSSC), this resulted in the cancellation of approximately 352 sessions with an estimated loss of 28,000 learning hours. As regions gradually reopen, significant restrictions in group sizes mean that in-person experiential learning will continue to occur at a fraction of pre-pandemic times. When combined with restricted access to clinical environments for learners, this presents an important challenge for the preparation of future and current health care workers, and thus patient safety[1]. Many of the skills learned during hands-on simulation sessions are difficult to recreate trough lectures or small group discussions[1]. The goal of this project is to develop and evaluate virtual reality (VR) simulation modalities for their effectiveness in preparing residents to manage patients in uncertain and time-pressured conditions.

Traditional theatre-based simulation sessions require the physical presence of interdisciplinary groups of learners caring for a physical mannequin-based patient, where social distancing is challenging. However, the rapidly evolving field of virtual reality (VR) applied to healthcare education[2,3] may provide effective physically distanced solutions should another pandemic or second wave impacts our ability to deliver face-to-face educational content. Virtual reality is defined as "*a real or simulated environment in which a perceiver experiences telepresence*", with telepresence defined as "*the experience of presence in an environment by means of a communication medium*".

Imagine a virtual classroom - learners wearing VR headsets in the safety of their home are immersed in a computer-generated simulation centre. Through their avatars, they can interact from a first-person perspective with their environment, colleagues and instructors. The virtual patient has been in a car accident and the learners, by interacting with the virtual trauma bay environment, must work together to perform a primary trauma survey and resuscitate the patient. The ***interactive VR*** environment provides the team with real time information in a realistic environment that includes the uncertainty, noise, and time pressures of a real case. At several key points in the VR video, learners are presented with interactive decision points, and their choices determine how the rest of the video unfolds

Alternatively, imagine a second immersive environment based on high-definition ***360^o video*** obtained from our simulation centre. Single learners, wearing a VR headset, find themselves in the resuscitation room, at the foot of the bed, leading a trauma team through the assessment and resuscitation of a patient in a virtual scenario. An example of a non-interactive VR video developed by our team for the obstetrical curriculum can be found at (https://youtu.be/AqdwmHPeoBY).

In both the interactive VR and 360^o video experiences as well as the pre- and post-test traditional theatre-based simulations, our study will aim to measure participants' heart rate (HR), heart rate variability (HRV) and oxygen saturation levels as markers of arousal and stress responses. These will serve as a physiological indication for: 1) their comfort and change in comfort when leading scenarios and making decisions for critically ill patients in real-time and 2) their emotional engagement in their own learning throughout the immersive experiences.

The properties of VR hypothesized to result in effective learning - over lectures, passive videos or discussion groups - include those of vividness (representational richness with which information is presented to the various senses) and interactivity (the ability to actively modify an environment). Increased vividness and interactivity can lead to greater emotional, motivational and cognitive engagement with learning materials. In turn, this greater engagement can lead to more active learning (analyzing, synthesizing and evaluating information rather than passively receiving it), and thus better knowledge retention and ability to apply this knowledge for subsequent problem solving. To date however, work related to VR has been targeted towards development of the technological resources to permit realistic and immersive experiences. Significant advances have led to this technology being readily affordable and accessible. However, little research has been conducted to determine the educational effectiveness of virtual simulations. Both interactive VR and 360° video provide immersive and interactive components; however, 360° video is arguably more of a passive experience for the learner. We felt that our constructed interactive VR simulation may provide more opportunity for interactivity for the learner and encourage them to participate in more active decision-making, but may increase extraneous cognitive load for the learner given the new environment. Both interactive VR and 360° video techniques require a significant investment of time and resources, but we do not yet know whether these techniques are equivalent in terms of learning or if one significantly differs from the other. There is no evidence to suggest that one method is superior to the other, therefore we chose to do a comparison study to investigate for any significant difference between these simulation experiences.

The present application is for the development and evaluation of two VR simulations (interactive VR, 360° video) applied to the context of Emergency Medicine. The aim of this pilot study is to develop two VR simulations, and to compare their effectiveness with traditional theatre-based simulations. Given the novelty of both interactive VR and 360° video simulations, our primary objective is to compare knowledge retention and application of knowledge during a paper quiz and traditional theatre-based emergency department simulations following preparation with either 360° video training or interactive VR training. The secondary objectives are to assess the usability and feasibility (resources), as well as the emotional engagement, of the above three modalities.

Methods:

Phase 1: *Creation of Content*: A software engineer with expertise in video-game development will be hired to develop the computer-generated emergency department in collaboration with the educators and clinicians on the team. A theatre-based trauma scenario from the current uOttawa Emergency Department curriculum will be adapted to the ***VR platform***. This virtual environment will allow a team of students to manage a patient simultaneously through their avatars, from a first-person perspective. In parallel, a well-managed depiction of the same scenario will be scripted and recorded using a ***360-degree HD video*** camera. The recording will be made using the investigators as actors, with additional interprofessional volunteers recruited as needed. These videos will be edited and then converted to an application that can be uploaded to the Oculus© platform. Both platforms will undergo piloting for content and usability. The amount of time, money and other resources required to develop each of these scenarios will be calculated.

Phase 2: *Evaluating the intervention*:

Participants: 40 residents and medical students will be recruited to participate in the evaluation of the VR modules. Participants will be randomized to one of two groups (20 participants per group) – interactive VR or 360° video education. See Figure 1.

Pre-Test: Prior to participating in one of the two educational interventions (360°-video or interactive VR), participants will complete a pre-test of their content-specific knowledge and knowledge application with respect to basic presentations to the emergency department. All participants will complete a video-recorded simulation of an emergency department case, half will complete Case A while the remaining half will complete Case B. These cases will be counter-balanced at post-test in order to account for any possible differences in case difficulty. All participants will also complete a knowledge test which will consist of approximately 20 multiple-choice questions with a mark out of 20 for a minimum score of 0 and maximum score of 20. Questions will be based on Advanced Cardiac Life Support (ACLS) guidelines and algorithms. Team performance will be recorded for subsequent scoring (see measures and analysis section below). During the traditional theatre-based simulation sessions, we will measure the learners' HR and HRV with the use of a Polar H10™ chest belt linked with a commercial capture and analysis software (EliteHRV™) program on an iPad. This will allow us to measure both arousal and stress responses, as physiological indication of the learners' emotional engagement.

Intervention: Following the pre-test, participants will either participate in the interactive VR or the 360° educational video. In each condition, the scenarios will be matched for duration, and will be followed by a debriefing session focused on the learners' comprehension of the case, their rationales for decisions, as well as closing any observed gaps in performance. UOSSC-affiliated instructors with formalized simulation and debriefing training will lead the debriefing. The learners' HR and HRV will be captured during the simulation and the debriefing sessions as a measure of engagement during the activity.

Post-Test: Two weeks after the education session, all participants will complete a post-test of their knowledge and knowledge application (matched in difficulty with pre-test), as well as lead a theatre-based simulated case. Participants who completed Case A will now complete Case B and vice versa. The sessions will be videotaped for subsequent rating of clinical and team performance. We will also capture their HR and HRV again as measures of physiological arousal and stress.

Measures and Analyses:

This will be an equivalency study which hypothesizes that there will not be a difference in learning between 360-VR or interactive VR. The primary outcome measures for this study will be changes in knowledge and in clinical performance from pre-test to post-test. Two experienced simulation instructors will view and score the videos, blinded to the group allocation and whether the scenario is pre or post the intervention. The raters will evaluate the learners using the Ottawa GRS scale as well as a checklist of expected actions for the scenario. The raters will independently rate the videos, and their level of agreement will be calculated using an intra-class correlations coefficient. The averaged scores, as well as scores on the knowledge tests, will be submitted to separate mixed-design analyses of variance (ANOVA) with time (pre, post) as a repeated-measure and groups (interactive VR, 360° video) as a between-subject variable. Post-hoc analyses will be conducted with relevant paired or unpaired t-tests.

The secondary outcomes measures are arousal and stress responses during pre and post theatre-based simulation sessions, educational sessions, and debriefing sessions. Mean and peak HR and HRV (rMSSD, pNN50) will be submitted to separate ANOVAs, with time (pre-test, debriefing, post-test) as a repeated measure and group (interactive VR, 360º video, theatre-based) as a between-subject variable. Post-hoc analyses will be conducted with relevant paired/unpaired t-tests.

Another secondary outcome measure will be the cost-effectiveness of the education interventions, based on Levin's cost effectiveness model[4] applied to simulation-based education[5]. The cost categories will include equipment and materials (e.g. market price of equipment, maintenance cost), personnel costs (e.g. staff salary, volunteer time), facility costs (e.g. facility rental fee, facility maintenance), required client inputs (e.g. learner costs, opportunity costs), and other program costs (e.g. communications fees, servers for storage and retrieval of information). These will be summed into a dollar estimation for each modality, and compared using a one-way between-subject ANOVA, with group (interactive VR, 360º video) as the between variable.

Outcome: After six months, we will have developed interactive, virtual educational content for training medical students and residents in emergency medicine using two different VR modalities. These modalities will be easily scalable to other programs across the Faculty of Medicine. In addition, the evaluation phase will result in data to help support decisions regarding which virtual modalities are best suited to distanced simulation, in terms of educational effectiveness (knowledge, clinical performance and emotional engagement) and required costs. The calculations of costs associated with each modality will also allow for fact-based estimations of future investments in virtual-reality education.

Budget Request: $50,000 for 1 year

Budget Justification:

Item	Price	Total
Computer Engineer	80,000/year, for 6 mos.	$40,000
Research Assistant	5 hrs/week for 6 mos. X $40.hr	$7,200
Oculus Quest headset		$800
Insta360 ONE X camera bundle with tripod		$600
InstaVR app VR platform	$199 USD/month = 270 CDN x 5 mos.	$1350
		$49,950

Computer Engineer: A software engineer, with expertise in computer-generation of environments for virtual platforms, will be hired on a full-time basis for a period of 6 months. During this period of time, the individual will work with the team to create an interactive VR trauma bay scenario (that can subsequently be adapted to other clinical content), as well as develop the 360º video based on recordings made by the team.

Research Assistant: The research assistant will support the team in the recruitment, scheduling, data collection, and data entry and analysis elements of the project. We will contract a skilled research assistant from DIME's Research Support Unit, at their standard rate of $40/hr

References

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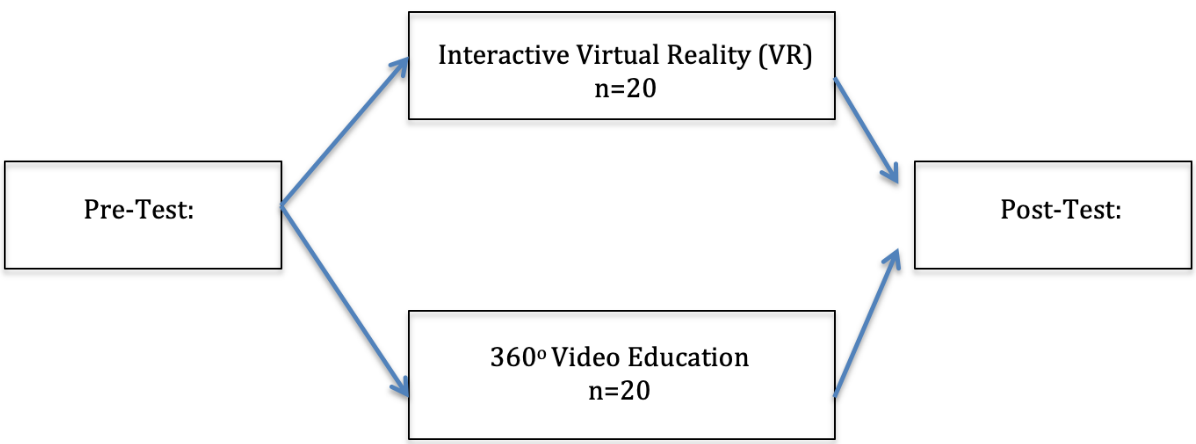
[5] Zendejas, B., Wang, A. T., Brydges, R., Hamstra, S. J., & Cook, D. A. (2013). Cost: the missing outcome in simulation-based medical education research: a systematic review. *Surgery*, *153*(2), 160-176.

Figure 1: Study Design



Measures:
Knowledge (Pre-Test Quiz)
Knowledge Application
Clinical performance sim (A or B)
Physiological Stress response

Measures:
Costs
Required resources
(equipment, HR)

Measures:
Knowledge (Post-Test Quiz)
Knowledge Application
Clinical performance sim (A or B)
Physiological Stress response