The Viability of a Virtual Reality Preanesthetic Checkout Simulation

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A Pilot Study

A pre-anesthesia machine checkout is a checklist-based review of the anesthesia machine performed to ensure that the machine is operating normally and is safe to use with a patient. The goal of the checkout is to prevent patient injuries due to preventable equipment malfunction.

Early studies of preventable anesthetic injury demonstrated that equipment faults alone accounted for 4% of all anesthetic-related patient injuries or deaths with 51% of them related to components of the anesthesia machine (Cooper et al, 1984).

"33% of all equipment-related anesthetic mishaps could have been prevented by a proper preanesthetic checkout"

Moreover, studies reveal that between 11% and 33% of all equipment-related anesthetic mishaps could have been prevented by a proper preanesthetic checkout (Craig et al, 1981; Fasting and Gisvold, 2002).

Multiple studies have demonstrated that experienced clinicians find less than half of the equipment faults in anesthesia machines (Buffington et al, 1984; Armstrong-Brown et al, 2000). It is important to note that the incidence of missed steps in the preanesthetic checkout increases significantly as the case load increases (Demaria, Blasius, and Neustein, 2011).

With the many difficulties in gaining access to clinical training for anesthesia providers worldwide due to Covid-19 (Sneyd et al, 2020), the need for an alternative means of gaining experience with the anesthesia machine is crucial.

Virtual Reality in Other Healthcare Professions

It Works There, Why Not Here?

The transfer of healthcare skills from virtual reality (VR) training to the real-world operating room has been documented thoroughly, particularly in the field of surgery. Studies in which learners practiced laparoscopic surgical procedures in virtual reality prior to a real-world test have demonstrated that VR training increases the learners' self-efficacy scores (Francis et al, 2020), laparoscopic performance scores (Guedes et al, 2019) and a 29-32% decrease in procedure time (Hagelsteen et al, 2017; Muralha et al, 2017; Seymour et al, 2002).

Orthopedic training in VR is associated with a 50% increase in procedure speed and a nearly 400% decrease in training time in addition to higher performance scores and a higher enjoyment of learning (Lohre, Athwal, and Goel 2020; Lohre, Bois, Pollock et al, 2020).

"…training in VR is associated with a 50% increase in procedure speed and a nearly 400% decrease in training time…"

VR training for cataract surgery has been shown to result in increased self-confidence levels (Pulijala et al, 2018) and greater improvements in technical skill for novices and intermediate-level surgeons (Thomsen, Bach-Holm, Kjaerbo et al, 2017). Virtual reality training has been shown to improve respiratory assessment skills in medical students (Zackoff et al, 2020), higher posttest scores in fire safety training (Rossler and Duvall, 2019), and higher learning satisfaction scores in nursing students (Smith et al, 2018). It would seem logical that the educational advantages of VR training demonstrated in other healthcare professions would hold true in anesthesia as well.

Virtual Reality Sickness

The Achilles Heel of VR

A consistent difficulty associated with the use of immersive virtual reality is a form of motion sickness known as virtual reality sickness (also called cybersickness). Studies have demonstrated that as many as 40% of VR participants will experience some degree of discomfort with symptoms such as headache, nausea, blurred vision, double vision, and disorientation (Moro et al, 2017). More than 15% of participants abandon VR learning experiences early due to the symptoms of VR sickness (Saredakis, 2020). Studies demonstrate that an average of 30 minutes of training time is lost just in recovering from the symptoms of VR sickness (Tanaka & Takagi, 2004).

"More than 15% of participants will abandon VR learning experiences early due to the symptoms of cybersickness"

Hardware-related factors contributing to an increased incidence of VR sickness include an increased field of view (Fernandez & Feiner, 2016) and the use of controllers for locomotion (Chance et al, 1998). Other factors are significant contributors as well. Interactive gaming content produces a higher incidence of VR sickness than 360-degree videos or scenic content (Saredakis, 2020), and longer exposure times in VR increase the incidence of VR sickness (Stanney et al, 2003) with the peak incidence occurring at ten minutes of simulation (Moss & Muth, 2011).

The prevalence of VR sickness is a tremendous barrier to the widespread adoption of immersive VR in healthcare. This pilot study will employ four concomitant VR methods demonstrated independently in other literature to be effective at mitigating the effects of VR sickness: 1) teleportation locomotion (Moghadam et al, 2020), 2) viewpoint snapping (Farmani & Teather, 2018), 3) dynamic field-of-view reduction (Fernandes & Feiner, 2016), and 4) visual guides (Seok et al, 2020).

Methods

Simvana, a virtual operating room environment developed by Torch Technologies (Huntsville, Alabama) was selected for the test scenario. The features of a real operating room were replicated in close detail, and the performance of the anesthesia machine was simulated mathematically to match the pressures, gas sources, vacuum levels, and other characteristics of a real-world anesthesia machine.

A convenience sample of 12 first-year nurse anesthesia students were enrolled in the pilot. After a brief orientation to the environment, locomotion methods, and object manipulation, they were instructed to complete the scenario at their own pace. A virtual tablet guided the subjects step-by-step through the American Society of Anesthesiologists' 2008 machine checkout procedure (ASA, 2008). Following completion of the scenario, each participant completed a survey aimed at discerning the effectiveness of locomotion and manipulation controls, their sense of presence, identification of symptoms consistent with VR sickness (nausea, disorientation, or visual disturbances), and their feelings towards the potential of VR as a learning tool for anesthesia.

Results

Effectiveness of Locomotion and Object Manipulation

The orientation to locomotion and object manipulation was performed by that author while the participants were in VR and took approximately two minutes. Despite the fact that 75% of the subjects had never experienced VR before, all of the participants either agreed or strongly agreed that the navigation controls were easy to use and that they could maneuver through the environment with ease. Ninety percent of participants strongly agreed that the visual hints appearing over objects to indicate the appropriate controller action to manipulate them were helpful.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Avg Score
The navigation controls in the simulation were easy to use	0.0%	0.0%	0.0%	33.3%	66.7%	4.67
Once oriented to the controls, I found it easy to maneuver through the environment.	0.0%	0.0%	0.0%	25.0%	75.0%	4.75
The directions and hints were helpful in understanding what I needed to at each step.	0.0%	0.0%	8.3%	0.0%	91.7%	4.83

Sense of Presence

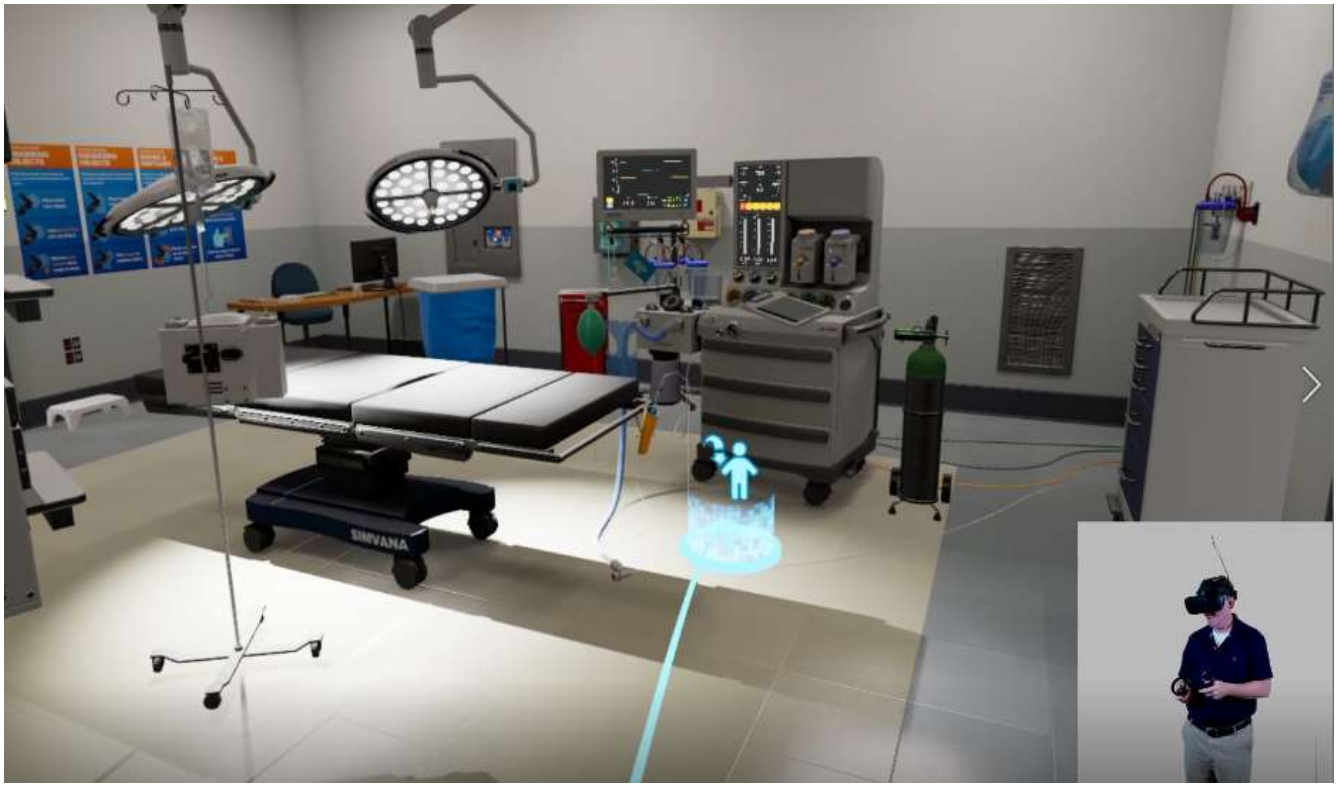
Sense of presence refers to the state of consciousness in which the participant feels as if he or she is within the virtual environment despite knowing that it doesn't exist (Iachini, 2019). The Simvana environment was constructed to replicate the operating room environment with significant detail attention to shadows, lighting, object appearance, and ambient audio. The goal of this section of the survey was to determine if the design characteristics of the virtual operating room was convincing enough to generate a sense of presence. All 12 participants either agreed or strongly agreed that the operating room, anesthesia machine, and sounds seemed realistic, and 83% of participants strongly agreed that they felt as if they were in the operating room.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Avg Score
The operating room environment seemed realistic.	0.0%	0.0%	0.0%	8.3%	91.7%	4.92
The anesthesia machine seemed realistic.	0.0%	0.0%	0.0%	8.3%	91.7%	4.92
I felt like I was in the operating room.	0.0%	0.0%	0.0%	16.7%	83.3%	4.83
The audio and background sounds seemed realistic.	0.0%	0.0%	0.0%	16.7%	83.3%	4.83

Mitigation of VR Sickness

Teleportation

This pilot study oriented participants to teleportation as the preferred mechanism of locomotion. Teleportation allows the user to select a location in the operating room using a hand controller and 'jump' to it instead of sliding to the desired position. It was noted that many learners would teleport to the general location they desired and then slide a few inches to position themselves accurately. This hybrid form of movement was not anticipated but resulted in highly accurate positioning while reducing the amount of sliding locomotion motion required.



Teleportation allows the learner to 'jump' to a selected location to reduce the effects of VR sickness

Viewport Snapping

Viewport snapping was used as the preferred method of rotation. Instead of using a controller to rotate continuously (a maneuver known to produce motion sickness), the user rotates in degree increments. Although the amount of rotation in a single snap is adjustable, each user in this pilot was set to turn 10 degrees at a time.

Dynamic FOV Reduction and Visual Reference Guides

Whenever the learner is in continuous motion, a gray vignette appears around the periphery of the screen to reduce the field of view. In addition, a transparent white grid appears in the direction of motion to provide additional visual cues as to the vector of motion. It should be noted that the degree to which the vignetting and reference grid appear on screen correlates with the speed of the motion.

Vignetting and the appearance of a reference grid in the direction of motion reduces the incidence of VR sickness

VR Sickness Mitigation Results

Despite the fact that 70% of participants indicated they were prone to motion sickness at least occasionally, no subjects indicated that they definitively experienced any symptoms of VR sickness including motion sickness, visual discomfort, or disorientation.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Avg Score
I felt discomfort due to motion sickness during the training program.	75.00%	16.67%	8.33%	0.00%	0.00%	1.33
I felt discomfort due to visual problems during the training program.	75.00%	25.00%	0.00%	0.00%	0.00%	1.25
I felt discomfort due to disorientation during the training program.	66.67%	25.00%	8.33%	0.00%	0.00%	1.42

The Viability of VR As An Adjunct to Clinical Anesthesia Training

Five of the survey questions focused on the participant's impression of virtual reality as a viable method of augmenting traditional training. All of the respondents agreed or strongly agreed that virtual reality is a viable alternative to a real-world anesthesia machine for learning the preanesthetic machine checkout. In addition, all respondents agreed or strongly agreed that virtual reality would be beneficial for student training and could be a viable alternative for learning other aspects of anesthesia. Over 90% of respondents indicated that they would undergo anesthesia training for simulated surgical scenarios.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree	Avg Score
Virtual reality is a viable alternative to a real-world anesthesia machine for learning the preanesthetic machine checkout procedure.	0.00%	0.00%	0.00%	50.00%	50.00%	4.5
I see virtual reality as a viable alternative to learning other aspects of anesthesia when an operating room is not available.	0.00%	0.00%	0.00%	50.00%	50.00%	4.5
I would undergo anesthesia training in virtual reality for simulated surgical scenarios.	0.00%	8.33%	0.00%	25.00%	66.67%	4.5
This training program would enhance a student's understanding of how to perform a complete anesthesia machine checkout.	0.00%	0.00%	0.00%	25.00%	75.00%	4.75
This type of virtual training would be beneficial for students before they begin their clinical anesthesia rotations.	0.00%	0.00%	0.00%	41.67%	58.33%	4.58

Discussion

This pilot project sought to evaluate the viability of virtual reality as an alternative to a real-world anesthesia machine for learning the preanesthetic machine checkout procedure. The results demonstrated that the participants felt comfortable with the locomotion and manipulation controls, felt a strong sense of presence within an operating room, experienced no VR sickness, and believed that the experience was a viable alternative for the anesthesia machine checkout and potentially other scenarios. It is the feeling of this author that the results of this study warrant further investigation with a more rigorous approach. In particular, the complete mitigation of VR sickness by the methods implemented in this pilot offers a significant opportunity for investigation by more sophisticated methods such as random participant assignment to a control or experimental group, larger sample sizes, and the use of a validated questionnaire for the accurate assessment of VR sickness.

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