# Exploring Volumetric Video & VR on Self-Efficacy for First Aid Training - A Pilot Study

by

Colin Orian

A thesis submitted the the School of
Graduate and Postdoctoral Studies in
partial fulfillment of the requirements for
the degree of

Master of Science in Computer Science

University of Ontario Institute of Technology
(Ontario Tech University)

Supervisor: Dr. Andrew Hogue

December 2023

# Thesis Examination Information

Submitted by: **Colin Kevin James Orian**

**Masters of Science in Computer Science**

Thesis Title:

Exploring Volumetric Video & VR on Self-Efficacy for First Aid Training - A Pilot Study

An oral defense of this thesis took place on December 4, 2023 in front of the following examining committee:

**Examining Committee:**

| | |
|---|---|
| Chair of Examining Committee | Dr. Ying Zhu |
| Research Supervisor | Dr. Andrew Hogue |
| Examining Committee Member | Dr. Alvaro Quevedo |
| Examining Committee Member | Dr. Adam Dubrowski |
| Thesis Examiner | Dr. Faisal Qureshi |

The above committee determined that the thesis is acceptable in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate during an oral examination. A signed copy of the Certificate of Approval is available from the School of Graduate and Postdoctoral Studies.

# Abstract

The health profession is currently in a global crisis due to the lack of health professionals, such as nurses and doctors. In response to this ongoing crisis, extended reality is being investigated as a potential modality for teaching the next generation of health professionals. In addition to extended reality being used for teaching, dynamic recordings of sequential 3-dimensional models, also known as volumetric videos, have been investigated for their use in education. However, there is a limited amount of research on how volumetric videos compare to conventional 2D videos. Therefore, this thesis compares how volumetric videos and 2D videos influence a person's self confidence by having participants learn how to perform head bandaging in virtual reality through watching either video type. A significant difference in self confidence was found after viewing an instructional video on head bandaging. A significant difference in presence between the videos was also found.

**Keywords:** Virtual Reality, Volumetric Video, Presence, Self-Efficacy, Nursing Education

# Author's Declaration

I hereby declare that this thesis consists of original work of which I have authored. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I authorize the University of Ontario Institute of Technology (Ontario Tech University) to lend this thesis to other institutions or individuals for the purpose of scholarly research. I further authorize University of Ontario Institute of Technology (Ontario Tech University) to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research. I understand that my thesis will be made electronically available to the public. The research work in this thesis that was performed in compliance with the regulations of Research Ethics Board under REB Certificate # 17145.

Colin Kevin James Orian

# Statement of Contributions

My supervisor Dr. Andrew Hogue, Dr. Adam Dubrowski, and I determined the research topic of applying volumetric videos to teaching head bandaging in VR. I researched and explored options within the topic, and designed and developed the Unity project. I used Unity packages developed by Soar and Meta within my Unity project. I designed and conducted the study, analyzed the data, wrote the manuscript, and edited it with the aid of guidance and feedback. I have used standard referencing practices to acknowledge ideas, research techniques, or other materials that belong to others.

# Acknowledgements

I would first like to thank God the Father for the honour of exploring His universe as a scientist and the Holy Spirit for guiding my hands over my keyboard during trying times. I would not have been able to complete this thesis without the emotional support from my family. The academic support from my supervisor, Dr Hogue, and my other professors was an invaluable experience that I will take into my future. I would also like to thank Andrea Cope for giving her insight in first aid. I'm thankful for the participants of this study who gave their time to help me. Finally, I would like to thank the doctors, nurses, and first line workers that worked tireless during the Covid-19 pandemic to keep us safe and return the world to pre-pandemic times.

# Contents

# List of Figures

# List of Tables

# List of Abbreviations

**AR** Augmented Reality

**ECG** Electrocardiogram

**HDRP** High Definition Rendering Pipeline

**ICT** Information Communication and Technology

**ITQ** Immersive Tendencies Questionnaire

**MRC** Medical Research Council

**NCSES** Nursing Competence Self-Efficacy Scale

**RGB** Red-Green-Blue

**RGB-D** Red-Green-Blue-Depth

**SUS** System Usability Scale

**TA** Teaching Assistant

**URP** Universal Rendering Pipeline

**VR** Virtual Reality

**VV** Volumetric Video

**WHO** World Health Organization

**WSP** Witmer-Singer Presence

**XR** Extended Reality

**2D** 2-Dimensional

**3D** 3-Dimensional

# Chapter 1

# Introduction

## 1.1 Background

Nearly two decades ago a global nurse shortage was identified that was caused by a higher demand for nurses yet there was a decreased in supply of nurses [40]. The World Health Organization (WHO) further identified a shortage of approximately 17.4 million health professionals in 2013 [27]. This world-wide shortage was only exacerbated during the Covid-19 pandemic due to burnout and the tragic loss of over 100,000 nurses due to Covid-19 as of 2021 [30].

How can this need for new nurses be addressed? An ongoing field of research that may alleviate the shortage of nurses and other health professionals is to integrate digital technology into health professional classrooms [7]. Digital education is a broad field that includes topics such as educational video games (serious games) and enhancing the physical world through technology, known as extended reality (XR) [7, 43].

Virtual Reality (VR) and serious games have been shown to be effective for surgery training [44] and digital technology has been used for remote education. As an example, digital organs models were used instead of physical organs to teach students in response to Covid-19 lockdowns [57]. Furthermore, digital technology can be used to teach a wide range of tasks in the health profession such as surgery or patient recovery [9, 44]. Unlike the traditional 2D videos used in remote education, volumetric videos (VV) are dynamic 3-dimensional (3D) recordings where each frame of the video is a 3D model played sequentially (Figure 1.1) [39].

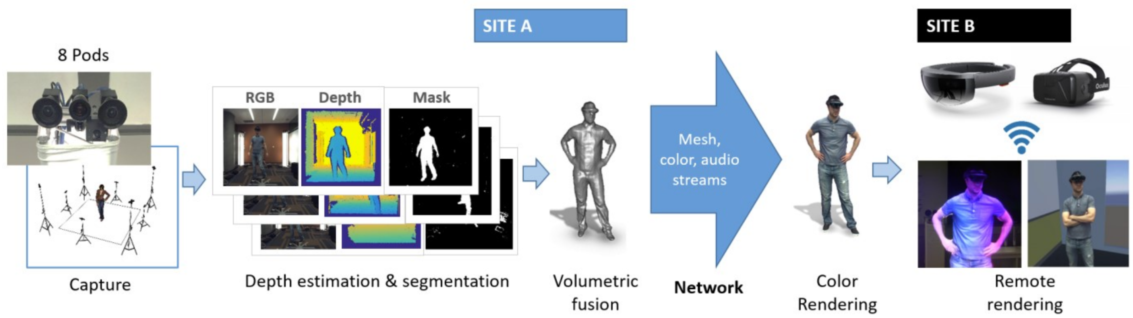


Figure 1.1: The VV pipeline for Orts-Escolano et al.'s holograms [39]. They used eight cameras to generate 3D models that are streamed to a XR device to be viewed remotely.

Figure 1.2: The Meta Quest 2 is a common VR headset that is viable for a consumer to purchase [31]

This thesis will explore how VR can be improved for first aid education by utilizing VVs. For the purpose of this thesis, consider VVs to be dynamic 3D recordings of a subject that can be viewed from any angle interactively (Figure 1.3). They can be generated using multiple synchronized red-green-blue-depth (RGB-D) cameras, such as the Azure Kinect [33], whereby the depth and colour information of each frame recorded video is fused into a 3D volume and a textured mesh extracted [39]. Alternatively, a single consumer RGB camera and artificial intelligence can be used to generate a VV [42, 58]. VV development is limited because of the high monetary cost for both hardware and software [19]. However, advancements by Guo et al. has lowered hardware costs to a level that is accessible for consumers [15].

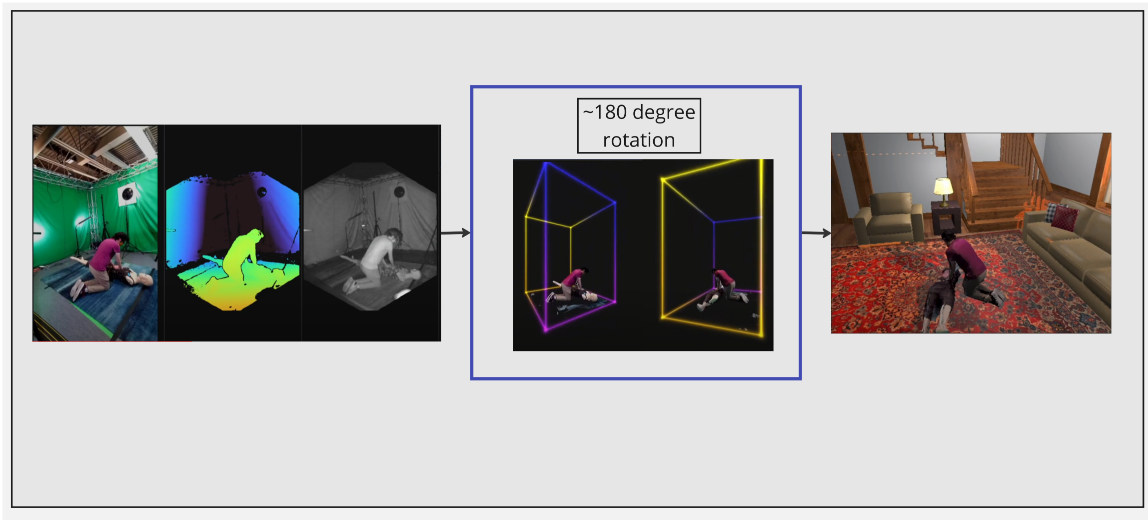


Figure 1.3: Unlike a 2D video, a VV can be rotated to be viewed at different angles. VVs can also be imported into game engines such as Unity.

VVs are already being used in the movie industry. The media production studio Volucap was hired to create VVs of action scenes for the movie *The Matrix Resurrections* [59]. VV has also been used to communicate with astronauts on the International Space Station and has the potential to be used by astronauts for medical conferences [13]. This technology could also be used on solid ground to"transport" experts to places with extreme conditions that would be too difficult to transport physically [13].

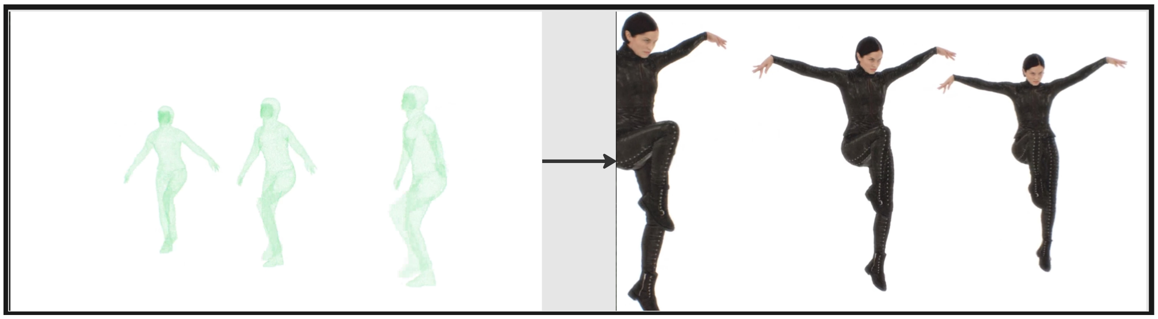

Figure 1.4: Volucap uses many cameras to create VV of actors in the movie *The Matrix Resurrections.* [59]

Researchers are already exploring how VVs can be used for education, including remote education. Several use cases for VVs in education utilize extend reality (XR), such as augmented reality or virtual reality [41, 51]. Studies have found that VVs are well received by participants when used for teaching [41, 50, 51]. However, the evidence for the effectiveness of VVs for educational purposes is limited.

## 1.2 Motivation

The ongoing global health professional shortage crisis must be addressed to prevent the serious impact on the health care needed for every person. The proposed solution of utilizing digital technology to address this crisis holds promise but needs to be explored further to find the ideal modality for digital education. Previous studies on VVs influence on education have received positive feedback such as finding the experience enjoyable by the students [49, 50] however, perceived enjoyment does not necessarily mean that VVs would have a significant impact on learning outcomes. Given the lack of data on VV effect on learning, this thesis probes into how VV can influence nursing education in Canada. We did this by observing the potential differences in student self confidence and student immersion between a VV and a 2D video.

## 1.3 Thesis Contributions

To observe potential differences in student self confidence and immersion between a VV and a 2D video, we made two videos: One was a volumetric video and the other was a 2D video. Both videos are of the same instructor teaching head bandaging. These videos were viewed using a VR headset in a between-subject study where one population watched the instructions in a VV and the other watched the instructions in a 2D video. After the participants watch the video, they practiced head bandaging on a medical mannequin and were recorded. The participant then watched the video of themselves and the instructor in the same format as before in VR to identify potential mistakes in the participant's actions. This study found a significant difference in both realism and presence when comparing a VV and 2D video. There was no evidence of a significant difference in the uncanny valley between the two types of videos. Evidence was found that there is a significant difference in the participant's self efficacy before self-reflection when comparing the two types of videos.

## 1.4 Chapter Overview

The remainder of this thesis describes the process of developing and testing a tool to evaluate the effectiveness of VVs for education. Chapter 2 explores and reviews the related literature that informed the work in this thesis, specifically surrounding the concepts of VV, extended reality and education, and how novel technology aids in medical and nursing education.

Chapter 3 explains the theoretical framework of this thesis. The framework will then lead into the detailed explanation of the methodology of the study and the data points that were collected during the study.

Chapter 4 will cover the results of the study. This will be split into two sections. The first will be the quantitative data that was collected through the study and whether the data supports or negates the study's hypothesis. The second section will contain a discussion on the results, implications of the results and limitations of the study.

Chapter 5 is the conclusion of the thesis. The first section will contain a brief overview of the methodology. The second section is the contributions section and is a brief summary of the results from the study. After the contributions section is the future works section of the conclusion. The future works section contains places of improvements for the study and potential new avenues that future researchers should explore.

# Chapter 2

# Related Work

In this chapter, we delve into the related work and concepts that guided our exploration into the use of VV technology for our intended application. We examine the literature around the terms "presence" and "uncanny valley", explore how digital technology is being used in remote education, focusing especially on the role of 3D digital models in healthcare. Next, we discuss the field of eXtended reality and how it's applied in health education. We then explore VV technology, narrowing our focus to their use in health education. We then discuss self efficacy and system usability and how to measure them because we will be measuring both self efficacy and system usability. Finally, we highlight important research gaps we have identified through our literature review.

## 2.1 Presence & Immersion

Witmer and Singer defined presence as "the subjective experience of being in one place or environment, even when one is physically situated in another"[62]. Witmer and Singer argued that a requirement for a person to experience presence is the ability to focus on a single set of stimuli and ignore other stimuli that are not related to the set.

They also identified that many of the factors that contribute to presence and the factors that enhance learning overlap. Therefore, Witmer and Singer hypothesized that there is a positive relationship between presence and performance [62]. More recent studies have found that the relationship between presence and learning is actually mixed, with presence sometimes leading to better performance, sometimes worse performance, and sometimes an insignificant difference in performance [45]. Parong et al. suspected that presence does have a positive relationship to spatial learning and found evidence to support their hypothesis. Parong et al. found that presence does have a positive impact on knowing an object's location in relationship to other objects in the scene and oneself, also known as survey knowledge [45].

Witmer and Singer also defined immersion as "a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" [62]. Witmer and Singer predicted that a head-mounted display (HMD), such as the Meta Quest 2, would cause a higher sense of immersion in a virtual environment because the user would be isolated from the physical world. On the other hand, experiencing a virtual environment, such as a video game, on a computer screen or TV would have a lower immersion because the the player is exposed to the physical world [62].

Presence and immersion can be experienced through multiple forms of media, such as books or movies, or even a person's own imagination through daydreaming. Developers and researchers that create immersive experiences, such as conventional video games or XR experiences for training, are invested in understanding the presence and immersion of their application so they can improve the experience for the user. Therefore, Witmer and Singer created two questionnaires related to presence. The first questionnaire is the Immersive Tendencies Questionnaire (ITQ) which measures an individual's tendency to experience presence. On the other hand, Witmer and Singer also developed the Presence Questionnaire, which measures how much presence an individual experiences in response to specific and virtual environments [62].

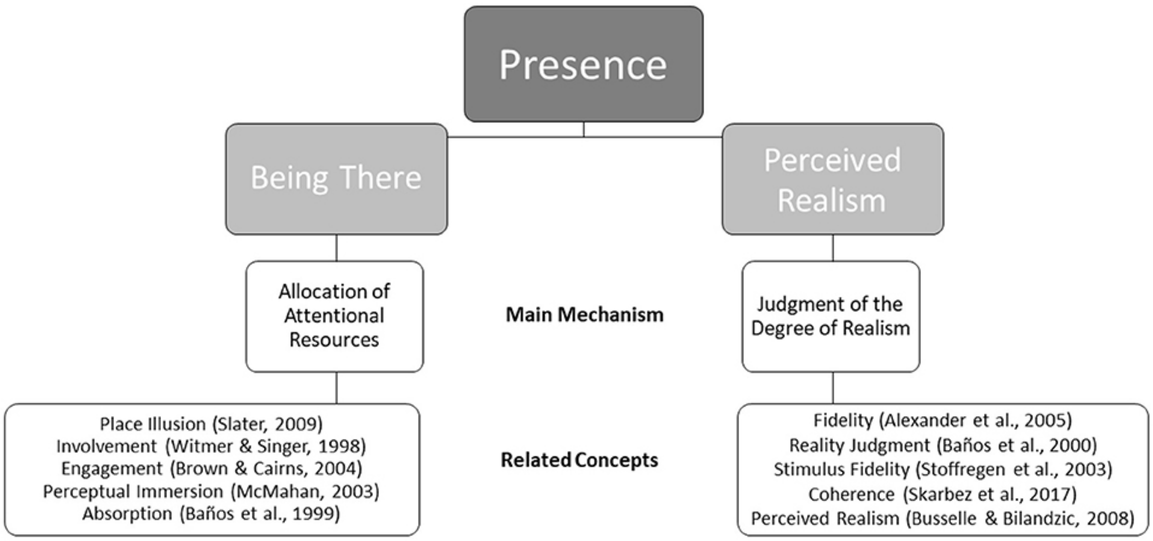


Figure 2.1: Presence defined by [60].

The uncanny valley is an uncomfortable feeling that can occur when a person views a somewhat realistic representation of a human and is caused by subtle differences between the representation of a human and an actual human [4]. The uncomfortable feeling when viewing an artificial human poses a challenge for human-robot interaction because a person would be less satisfied with a robot if the robot falls into the uncanny valley. Therefore, Bartneck et. al developed a 5-point Likert scale questionnaire called the Godspeed index to aid technical developers in avoiding the uncanny valley by giving developers a tool to measure the uncanny valley [4]. The uncanny valley can also be experienced with virtual humans and developers should consider the uncanny valley when creating photorelastic characters [18].

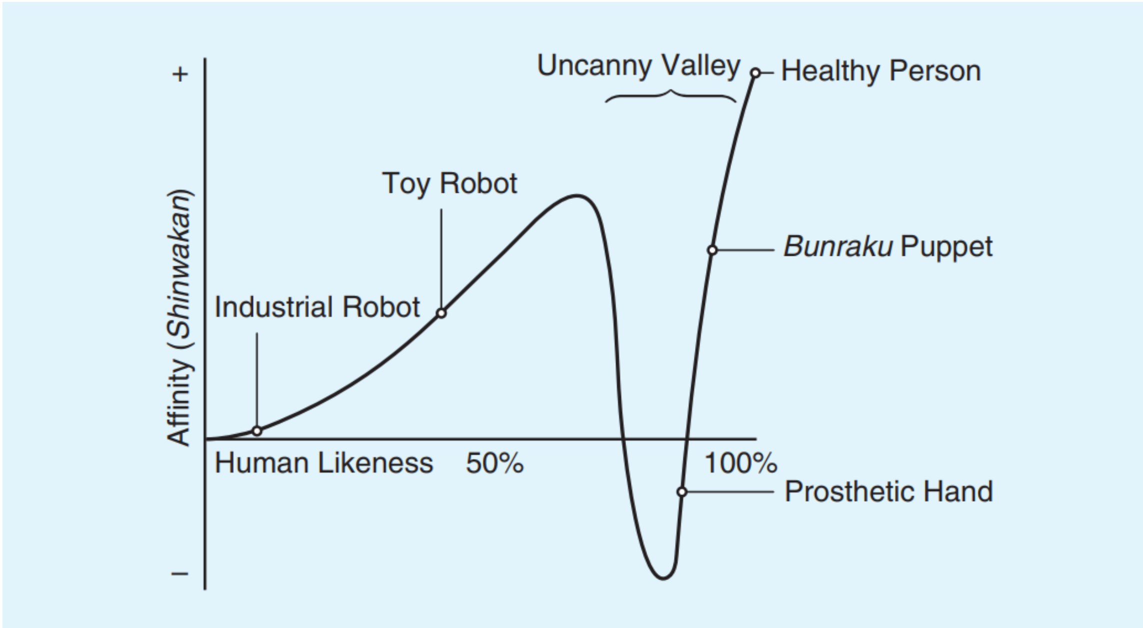


Figure 2.2: The closer an object looks like a human, the more likely it will fall into the uncanny valley [36].

## 2.2 Effectiveness of Remote Education

Remote education can be divided into two separate groups; the first being synchronous and the second being asynchronous [10]. Synchronous education often involves instant transfer of information between student and teacher through technology such as teleconferencing or instant messaging. Asynchronous education, on the other hand, relies on non-instantaneous communication between student and teacher through technology such as pre-recorded lectures or email. Both synchronous and asynchronous remote education is of interest to this study due to the utilization of 2D videos (either live or pre-recorded) to teach students. A meta-study in 2004 found that there was little difference in effectiveness between remote education and the traditional forms of education and also found little difference between synchronous and asynchronous remote education [1]. If remote education has little difference effectiveness compared in-person education, educators should consider what remote education provides that in-person education can not. For example. the meta-study found that courses teaching foreign languages did have an advantage when using remote education because remote education allowed students to communicate with native speakers. Likewise, the authors also found that remote education provides greater access to education due to communication technology [1].

A more recent study found similar results in regards to synchronous and asynchronous remote education in courses [21]. Fabriz et al. found conflicting evidence that synchronous education outperformed asynchronous education but stressed that asynchronous education still has value that should not be neglected such as increased skills in autonomous learning [10]. These studies, however, were conducted on courses that had to be quickly turned into remote courses because of emergency lockdowns due Covid-19. If an educator had more time to prepare for the course the results of these studies may be different.

The study conducted by Attradi and Rogers investigated the differences between remote education and in-person education in the early 2010s because of the high enrollment count of a human anatomy course and therefore were not under the extraordinary circumstances of Covid-19 [3]. The study's course had its lectures conducted in-person for the in-person students with the lecture streamed and archived for the remote students. The labs were also done in-person and remote for the respective groups. Attradi and Rogers found that student performance was dependent on the student's grades from the previous year and not on whether the student was in the remote class or in-person class [3]. A later study conducted in 2021 by Attradi et al. interviewed professors and teaching assistants (TAs) of the same course to evaluate the course subjectively [2]. The TAs expressed software difficulties when teaching the remote group due to lag and quality of the 3D anatomy software used to teach the remote group. Both the professors and TAs expressed concerns about the limited student-teacher social relationship in the remote group and how the lack of non-verbal social cues (such as body language) prevented the teachers from understanding if the students were understanding the concepts. However, a TA noted that students in the remote group could ask questions anonymously without the fear of being judged by the other students [2]. Previous studies in remote education have stated similar results about the social impact of remote education [1].

## 2.3 Physical and Digital 3D Models in the Health Profession

3D digital models have been used extensively for several decades to aid in patient diagnosis through 3D ultrasounds and provides benefits in many medical areas ranging from fetal cardiac areas to prostate assessment [38]. 3D ultrasounds allow health professionals to view anatomy in orientations that would be too difficult to view in a 2D format and therefore provide a deeper understand of a patient's anatomy. 3D ultrasound imaging being non-invasive means that a patient will experience limited discomfort during the imaging process [38]. Phelps et al. explored how 3D medical imaging can aid in patient understanding diagnosis by using 3D images, 2D images, or no images when providing diagnosis. They found that patients had greater satisfaction, understanding, and trust in the diagnosis when any type of image was used to explain the diagnosis compared to no images used to explain the diagnosis. Phelps et al. also found that there may be a slightly better benefit when using 3D images compared 2D images [48]. The patients in the study, however, were healthy patients that volunteered for the experiment and the results may be different for a patient actually seeking medical attention [48].

Dehabadi et al. investigated how simulations are used in learning laparoscopic surgery skills through a literature review and identified three types of simulators: Video-scopic, computer-enhanced, and virtual reality [35]. Video-scopic simulations are physical simulations that allow trainees to utilize actual surgery tools during a simulation and provides haptic feedback to the trainee but requires a person to manually collect performance metrics. Computer enhanced simulators are video-scopic simulators that have automatic performance collection. Finally, virtual reality is a completely virtual environment that can automatically collect performance metrics. Dehabadi et al. found that simulators are effective at teaching laparoscopic skills and allows trainees to learn new skills without potentially harming a patient. They did not find that one specific simulators was better than the others but did find video-scoptic surgery tools are the cheapest to acquire and VR simulators are expensive. Although VR simulators are expensive, they allow trainees to be more self-sufficient due to automatic feedback [35]. Khayruddeen et al. utilized digital 3D models as an alternative to a physical fetal skull in an anatomy course [25] (Figure 2.3). Participants provided feedback on the system and the 3D model of the skull, with the feedback being overall positive [25]. Khayruddeen et al. noted that the digital skull could be annotated which was impossible to do on the physical skull. The physical skull was also very fragile and couldn't be handled but the digital skull could be handled without fear of breaking the skull. Tóth et al created a 3D digital model of a cadaver so that medical students could study the cadaver on the students' computers during the closures due to Covid-19 [57]. All the students recommended the digital model for remote education but less than half believed it should fully replace in-person examinations. The researchers also found that creating the digital model did not add significant amount of extra work to the autopsy process [57]. Petriceks et al. found similar results when creating 3D digital models of human organs that students could study through an iPad [47] (Figure 2.4). Once again, the tool was received well by the students. The faculty enjoyed the tool but did mention that the digital models should not replace cross-sectional information. These 3D models could be a good temporary solution when students are unable to travel to class, such as unsafe driving conditions or could be used when the physical organ is not available, such as outside of a lab setting.

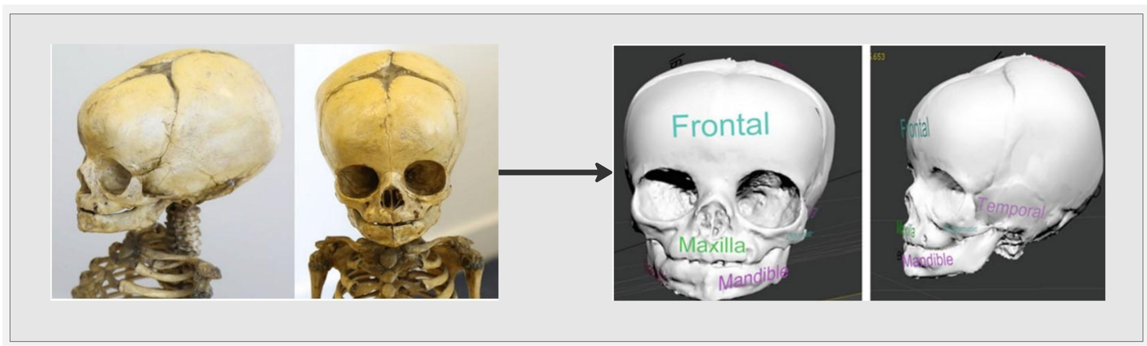


Figure 2.3: A physical skull was used to create a digital 3D skull that was later annotated [25].

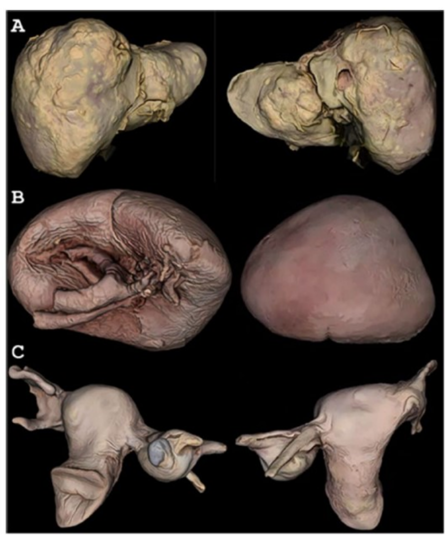


Figure 2.4: 3D digital organs generated by Petriecks et al. [47]

A reoccurring pattern in using 3D digital models in teaching health professionals is that the digital models are not significantly better than physical models and students would still benefit from using physical models, but digital models are able to provide benefits that a physical object can simply not provide such as portability. Therefore, we suspect that a mixed approach that utilizes both 3D models and physical models should be considered when developing courses for the digital age.

## 2.4 Extended Reality (XR)

For the purpose of this thesis, we define Extended Reality (XR) as the catch-all term for using technology to enhance the physical world and includes multiple forms of technology [43]. XR is a spectrum with the physical world on the far end of the spectrum and the virtual world on the other end of the spectrum (Figure 2.5). Stationary extensions are desktop computers and are very close to the physical world [43]. Augmented Reality (AR) is when the virtual world is layered on top of the physical world. Virtual Reality (VR) is a computer generated virtual environment that utilizes hardware so a user's senses are only activated by the computer-simulated environment and the user can interact with the virtual environment [43]. VVs are not constrained to a specific section of the XR spectrum; therefore, VVs have been used for both AR and VR [50, 52]. Throughout this thesis, XR will be used as an umbrella term encompassing AR and VR.

XR has a wide range of use cases and one of these use cases is entertainment through video games. The exercise game *Pokemon Go* uses AR to overlay virtual creatures onto the physical world (Figure 2.6) and the video game *No Man's Sky* can be played with a VR headset to allow the user to be "inside" the cockpit of a spaceship (Figure 2.7) [8, 12]. XR has more productive use cases than video games and it can be used for telecommunication technology. *Mozilla Hubs* is an example of XR telecommunication that is available to consumers [37]. XR has also been used

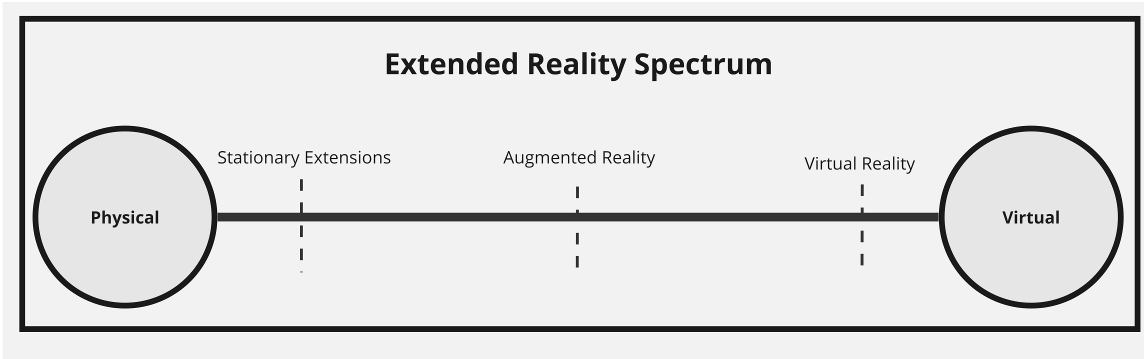


Figure 2.5: Spectrum of Extended Reality. Devices are closer to the physical world the closer they are to the left and closer to the virtual world the closer they are to the right.

with movable a platform to allow a person in VR to move around an area while others can see the user's avatar using AR [22].

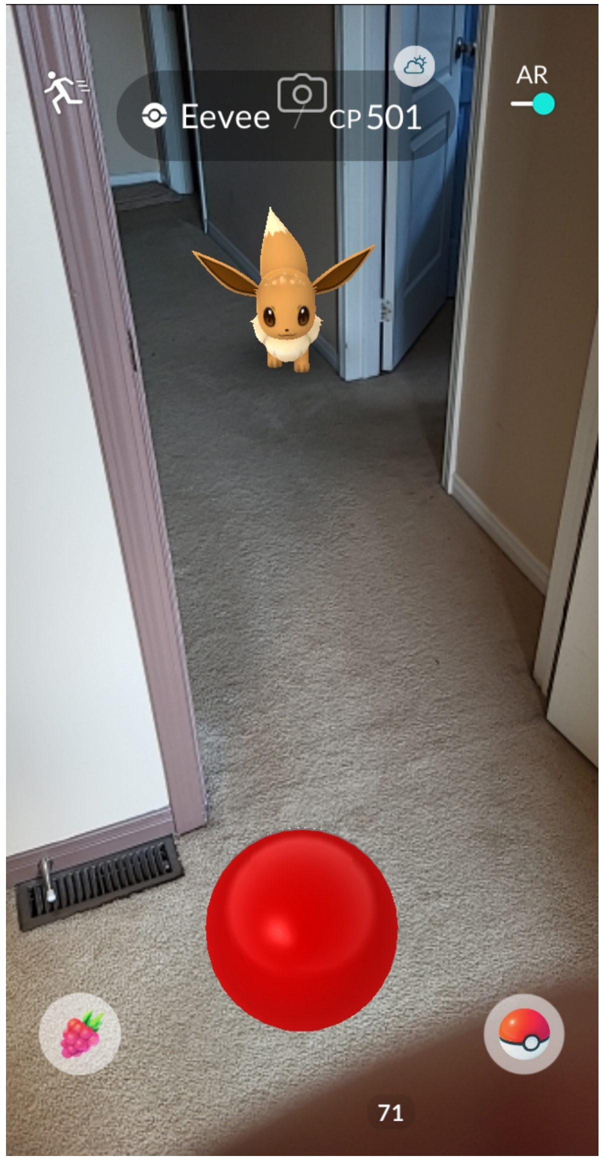


Figure 2.6: Screenshot from the video game *Pokemon Go*. The player can use AR to project virtual creatures into the physical world [8].


Figure 2.7: The video game *No Man's Sky* allows players to fly a space ship in VR [12].

Figure 2.8: *Mozilla Hubs* allows users to join a virtual meeting using a computer or VR headset [37].

Hamad and Jia recently performed an extensive literary review on the applications and limitations of VR [17].Through their literary review, they found that VR is limited by the current technology and the lack of a standardization. The current hardware means that VR headsets are often heavy and cause physical strain on users. Lag between user input and visual feedback can also cause VR-motion sickness, also known as "cybersickness". Cybersickness is major barrier to VR usage because users may not utilize VR if cybersickness persists. VR's long term effects on eyesight is currently unknown. Finally, the price of a VR headset is another barrier to entry and some VR headsets also require high-end computers to run VR applications therefore increasing the price barrier even more.

### 2.4.1 Extended Reality in Health Education

Tang et al. performed a systematic literature review of literature published from 2000 to 2021 to find trends with immersive technology and medical training. Tang et al. found that surgeon students trained with VR had significantly higher surgical procedure skills and had a significantly lower operation time when performing surgery. The literature review also found that XR applications can be a useful alternative instead of a cadaver because of the ethical and monetary restrictions of using a cadaver. XR applications can also automatically record a student's performance instead of instructors recording the performance manually [56].

Tang et al. found several limitations in how XR is being used in medical training. XR tends to be used for a short duration because XR is often used in a research setting instead of a classroom setting. In practice, learning is a long process so short use of XR may not generalize into an classroom setting. Utilizing XR may also cause simulation sickness in some people and therefore reduce the quality or accessibility of education for some people. Tang et al. also stressed the importance of governmental aid in training teachers because of the cost of immersive technology and the time to train the teachers with the new technology [56]. Tang et al. also discovered that XR is predominately used to train doctors and is predominately used to train for surgery [56]. XR research being focused on training doctors and for surgery means that other health professionals are not gaining the potential benefits of XR and future studies should explore this gap in XR research.

Buyego et al. explored the feasibility of using VR to teach infection prevention and control procedures for Covid-19 in Uganda. The medical education system that Buyego et al. investigated was comparatively less-endowed and had lower technology exposure. The first phase used an online VR platform called Enduvo. The trainees watched a collection of VR videos and answered multiple choice questions after each video. The second phase involved the trainees navigating a VR lab and practiced infection prevention and control within the lab. The trainees could not proceed onto the next section of the experience until they succeeded on the current section. It was found that VR had a significantly higher score in knowledge and skill acquisition compared to an classroom approach. The authors suspect the system would be accepted by healthcare workers because the system received high qualitative assessments. The researchers also found that younger participants were more receptive to the VR training [46]. Buyego et al.'s research shows that XR technology still contributes to medical education in a low-resource environment instead of only high-resource environments.

Surgeons need to develop psychomotor skills for their work. Papagiannakis et al. developed a VR surgery system so surgeons can practice hand movements for a joint replacement surgery. However, the authors did not test the system to determine if the system provided benefits for the user [44]. The authors' hypothesis is that psychomotor skills through VR should be transferable to a real surgery. This hypothesis may generalize outside of joint replacement surgery and should be explored in other medical interventions.


Figure 2.9: A simulated joint surgery allows a student to develop pyschomotor skills instead of practicing during an actual human [44].

VR has also been used to aid stroke patients to regain balance and mobility. Darekar et al. conducted a scoping review over the topic and found that VR intervention does aid stroke patients in improving gait speed and quality. They also found that training duration is not the only variable that improves benefits. There are a few limitations to their study however. Many of the interventions were like video games and may influence the motivation of patients. Most studies did not analyze the entertainment value of interventions and therefore could not determine the benefit of game like training. In addition, Darekar et al. included some video games that are very close to the physical world on the XR spectrum and do not fall into the VR or AR portion of the XR spectrum [9].

## 2.5 Volumetric Video

Volumetric Videos being dynamic 3D recordings allows a user to view the recorded subject from any angle interactively. For example, VVs can be used for historical reenactment (Figure 2.11) or can be used artistic expression (Figure 2.12) [23, 41]. The process of creating a volumetric capture is usually the following [39]:

1. Multiple RGB-Depth (RGBD) cameras are placed around a central area. This area is the scene that is intended to be recorded.

2. Fuse the data from the cameras together to create an untextured 3D model. This can be done through a variety of ways. One way is to create a point cloud out of the images. This point cloud can then be converted into the mesh.

3. Project camera images onto the mesh to generate a realistic texture of the captured subject(s).

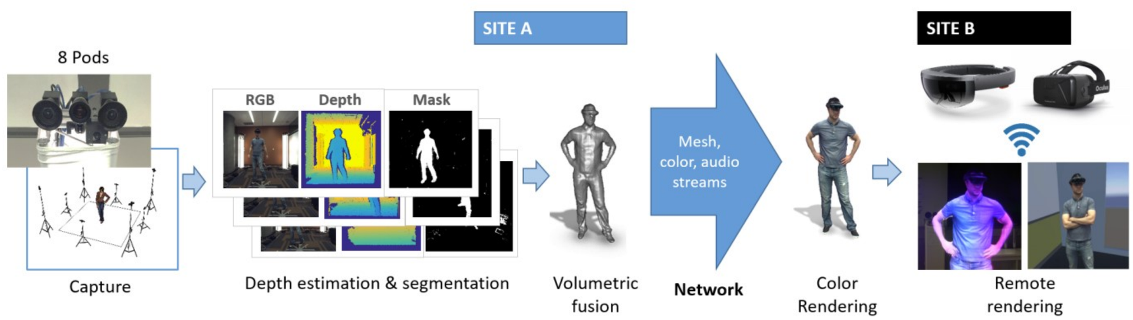


Figure 2.10: Orts-Escolano et al's pipeline for "holoporting" a person to another location. A VV is generated in real time and then streamed to a XR headset worn by a remote viewer [39].

Figure 2.11: VVs have been used to create a comedic performance to teach tourists about Trinity College's Library [41].

Figure 2.12: Kelly et al. used VVs to create an opera performance in AR [23].

The hardware required to create a VV is often bulky and require extensive time to set up therefore limiting VV recordings to a specialized studio [55]. These studios can have hundreds of cameras and are therefore prohibitively expensive for the general population to use [19]. For example, the company Metastage can produces very high quality VVs because the VVs are recorded with 106 4K cameras but the cost to produce a VV is prohibitively expensive (greater than $50,000) for a consumer or researchers to use [19, 32]. An alternative to expensive studios is using consumer grade RGBD cameras. A setup using these devices has a much cheaper price range (between 1k and 10k dollars). The company Volograms created a cloud-based machine learning tool to hopefully reduce the monetary cost as a barrier of entry by allow users to make VVs using a consumer smart phone and is relatively inexpensive compared to other volumetric capture technology [19, 42, 58]. Since a consumer smart phone can be used to create volumetric videos through volograms' tool, the general population can explore volumetric capture for entertainment or for learning about volumetric capture.

Kowalski et al. developed an open source[1] server/client system to generate VVs called LiveScan [26]. They used a server / client system because of technical limitations of the hardware and software at the time prevented multiple Azure Kinects cameras streaming to a single computer.The server computer was connected to the clients through Ethernet to provide instructions to the clients. The clients were connected to the Azure Kinects cameras to calibrated the cameras and then record the videos. Streaming the videos in real-time to the server computer is limited by bandwidth so the videos were only streamed to the server once the recordings were completed and the server computer processed the videos to generate a point cloud.

### 2.5.1 General Applications of Volumetric Videos

Zhang et al. recreated an office cubicle using VV [64]. The cubicle used multiple RGB-D cameras pointed towards the center to record an individual in the cubicle while presenting other meeting participants on screens around the user (Figure 2.13). The benefit of VirtualCube is that it is able to replicate eye contact that would be

[1]https://github.com/MarekKowalski/LiveScan3D

used during an in person meeting that is lost in a video meeting. The authors also developed a new form of rendering to improve texture fusion and showed that the algorithm improved fusion. The researchers also recognized that the lower body is not required for a meeting and can be ignored. For future work, the authors identified that the system encountered challenges with complex hand gestures [64]. Although VirtualCube does not pertain directly to education, their rendering algorithm's success could be used for VV in education and not rendering the lower half of a body is an easy way to reduce memory consumption and improve speed [64].

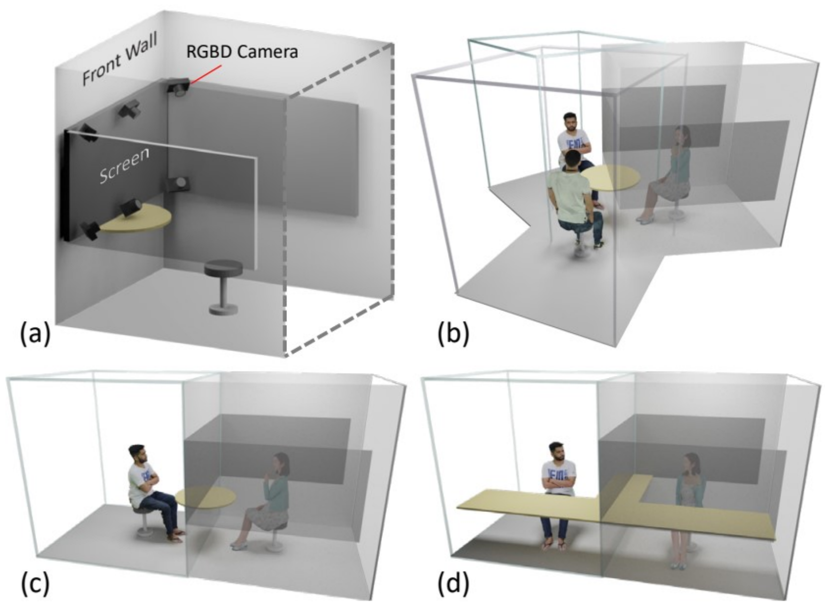


Figure 2.13: Zhang et al's VirtualCube allows for several ways to have a video conference [64]

Project Starline is a communication system that utilizes VV to improve on common 2D video conferencing systems [29]. It utilizes 3 stereo RGBD cameras to stream a video of the user to another user. The authors decided to use a computer screen instead of a head-mounted display (HMD) because of the bulkiness of HMDs. HMDs would also occlude the face, which would reduce eye-contact that would be used in an in-person meeting. The authors conducted two studies to compare their technology to traditional videos. The first had people only use the VV system and the second was a within-subject study to compare VV and the traditional form of video. In the former, over 100 participants used the system for nine months and it was found more favourable to the conventional form of communication. The study did not include a control population limiting the ability to compare the results to the conventional form of communication. The latter study had a smaller population and was controlled. The participants felt more connected to the other person in the VV system and also utilized nonverbal gestures like hand and head movements more in the VV system. A major limitation of the study is that the participants were self reporting the results. In addition, the first study should have had a control population to assess how the VV compared to the conventional forms of communication. [29].

Figure 2.14: Project Starline's system remote communication by making the video appear as if the remote participant is physical in the room.[29]

Kelly et al. utilized VVs to explore new forms of artistic expression by performing opera with a mobile AR device [23]. The volumetric capture was done with 36 cameras and therefore a 3-4 minute video was a terabyte of data. The size of the data had to be reduced for a consumer to view the video so Kelly et al. reduced the mesh to 12000 triangles but maintained important regions, such as the face and hands. The memory's size was further reduced by having sub-sequences of the meshes share a 2D texture. The data was finally compressed into a size that would be sufficient for a high end mobile phone. The people who watched the video had high praises for the opera, indicating that VVs and AR can be used for novel forms of artistic expression but the memory size of the videos must be considered during the creative process [23].

### 2.5.2 Applications of Volumetric Videos in Education

Regenbrecht et al. investigated three use cases for VVs (a musical performance, learning a language, and learning yoga) by having the participants watch the video in 2D and also through a VV (Figure 2.15). The VV was viewed in either AR or VR depending on the group that the participant was assigned to. When the participants were asked about the perceived effectiveness of VV and 2D videos, the VV was found to be more effective and participants had more perceived enjoyment out of a VV compared to the 2D video [51]. The authors observed that yoga's perceived usefulness was the highest out of the three [51]. The results raises an interesting question on what tasks would be greatly enhanced by using VV instead of a 2D video. Do physical tasks perform better in VV compared to non-physical tasks?

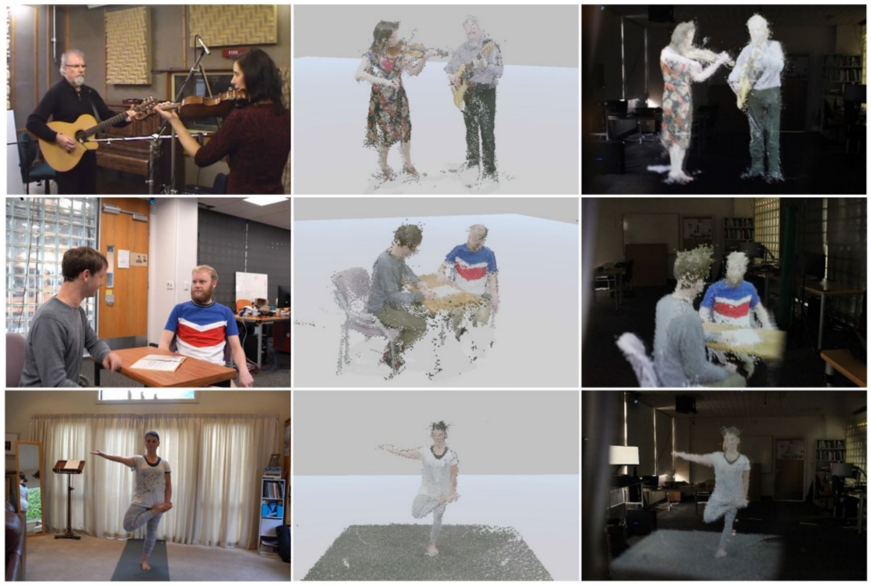

Figure 2.15: Regenbrecht et al. compared 2D videos with a VV watched in AR and VV watched VR [51].

Pope et al. performed a pilot study in a primary school to explore how "holoportation" can be used in XR remote teaching. The students observed their teacher in XR while the teacher could see the student through a 2D display. The students' perception of the experience was positive but measurable results is limited due to being a pilot study and the researchers intend to continue their research [49].

### 2.5.3 Applications of Volumetric Videos in Health Education

Surgery training has also used VV and VR [50]. The trainee was able to walk around a VV of a liver transplant operation. The experience was interactive and allowed for the student to perform actions such as accessing data about points of interest. Due to time constraints in an operating room, a trainee is not able to be fully engaged in an operation. The restrictions caused by Covid-19 also highlights the need for newer ways to teach future surgeons. A volumetric OR may relieve some of these issues [50]. Although the tool can be an alternative in response to restrictions in operating rooms, there was no analysis on how the student learned and compared the system to the conventional in-person formatting of teaching surgery. Strak et al. compared the results of using 2D videos and VVs in remote consultation for placing electrocardiogram (ECG) electrodes correctly to determine the potential benefits of using XR in an emergency situation when an expert is not physically available [52]. A local paramedic wore AR glasses while placing electrodes on a mannequin and a remote expert viewed a live VV of the paramedic's actions in VR (Figure 2.16). The two participants were able to communicate verbally through microphones but the remote expert was able annotate the mannequin, which the local paramedic could see in AR, and "point" using an AR avatar [52]. The XR experiment was compared to a top-down video of the paramedic that the remote expert watched to provide two-way verbal guidance. The electrode placement correctness was measured by another expert. Strak et al were unable to confirm the increased precision of ECG electrodes in the AR-condition and found insignificant differences in cognitive load between the two conditions [52].

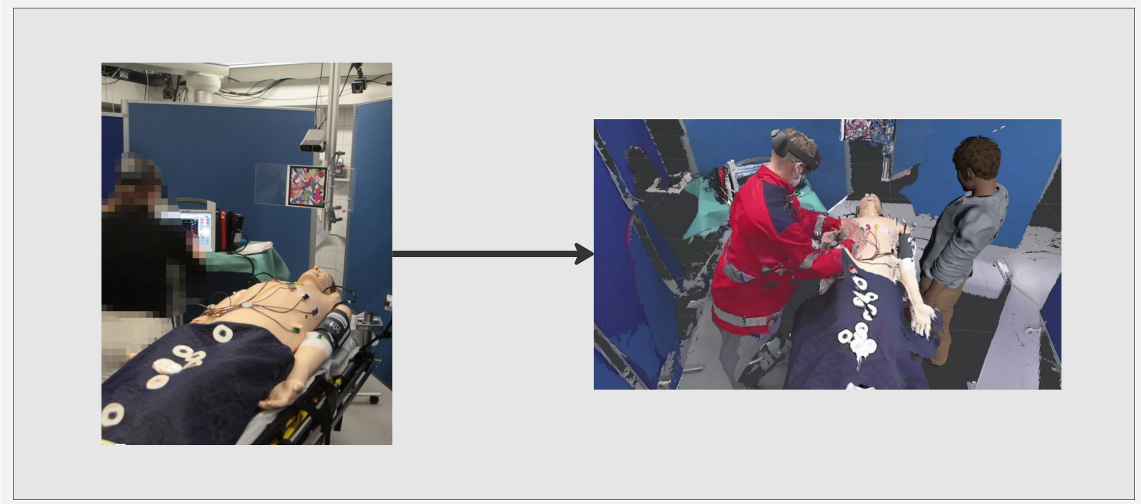

Figure 2.16: A participant was recorded playing electrodes was recorded as a VV and the VV was streamed to a remote instructor in VR [52].

## 2.6 Self-Efficacy & System Usability

Schwarzer and Jerusalem defined general self-efficacy as "...the belief that one can perform a novel or difficult tasks, or cope with adversity – in various domains of human functioning" [53]. According to Schwarzer and Jerusalem, general self efficacy is an indicator of how a person can adapt to difficult situations[53]. Kennedy defines self-efficacy similarly as "having a belief in one's capability to succeed" [24]. Many nurses are not confident in their own skills and there is a large attrition in nursing programs, but stronger self-efficacy may lead to stronger job satisfaction. The low self-efficacy in students may contribute to the large attrition numbers in nursing programs so Kennedy developed the Nursing Competence Self-Efficacy Scale (NCSES) to aid future researchers in addressing low self-efficacy [24]. Brooke found that evaluating system usability was often difficult due to the long time that a user may spend using a system that may have caused frustration and the was rarely cost-effective [6].

Therefore, Brooke developed the System Usability Scale to provide subjective but quick feedback on how usable a system.

## 2.7 Identified Research Gaps

A great deal of research has been conducted on how XR is able to aid in the healing of patients by improving medical education. It has been shown that XR is beneficial for medical education but longer studies should be conducted since learning is a long process. XR also has benefits over the traditional forms of teaching such as reduced cost and ethical considerations. XR has been used to teach doctors how to perform surgeries or even helping stroke patients. However, there is a major gap in using XR for medical education: Nurses are not benefiting from the potential benefits in using immersive technology in their training or in their work while co-workers that are surgeons or doctors are benefiting from immersive technology [56].

As discussed above, VV and digital 3D models has been applied to teaching. Many papers have shown that this technology is well received and could be potentially used for educational purposes by providing a virtual alternative of a physical object that would otherwise be inaccessible or provide a virtual alternative when time constraints prevent students from learning in a physical classroom. VVs and digital 3D models can also allow students to “take home”” a physical object that would normally not be allowed to be moved.

Overall, there is an overlap between XR and VV for education. This overlap has a great deal of potential benefits. The restrictions caused by Covid-19 highlighted the importance of portable or at-home education. XR and VV are potential solutions to portable or at-home education. However, these novel tools should be used in addition to more traditional approaches, not as a replacement. Further research needs to be conducted on how VV affects education to determine if VV will benefit students and the population of people who are benefiting from XR in the medical field should be expanded outside of doctors and surgeons to promote equality.

# Chapter 3

# Methodology

With a global health professional shortage, it is important to consider how XR can alleviate this ongoing crisis but the majority of uses cases with XR technology disproportionately benefit surgeons and doctors. If presence can contribute to spatial learning [45], we suspect that the 3-D nature of VVs may cause a higher presence and improve learning goals for nursing students compared to 2D videos. Therefore, we decided to investigate how VV can contribute to VR nurse education by investigating the difference between watching a VV in VR to watching a 2D video in VR. We did this by generating a VV and 2D video of an instructor teaching head bandaging by bandaging a mannequin. We then imported the VV and 2D video into a VR application so that a participant could watch one of the videos in VR. The type of video that the participant watched was chosen randomly so that we could compare the two types of videos. The participant then replicated what they saw in the video on a physical mannequin while they were being recorded. Finally, the participant would watch the same type of video as before of themselves and the instructor in VR to identify potential errors that the participant performed. Throughout the study the participant would answer questions about immersion and self-confidence. This chapter provides details as to our methodology used to compare the effects of VVs and 2D videos on self efficacy and immersion.

## 3.1 Experimental Apparatus

### 3.1.1 Mannequin & First Aid Supplies

We investigated how VV can be used in nurse education by utilizing a first aid training mannequin and first aid supplies with guidance from a expert in nurse education. The mannequin had a simulated head wound that participants were instructed to bandage using the provided first aid supplies. The first aid supplies included latex gloves, gauze, bandages, and bandage tape.

Figure 3.1: The mannequin used throughout the study.


Figure 3.2: The bandaging supplies for the mannequin. Top Left: Bandage wrappings. Top Right: Bandage Tape. Bottom: Gauze.

### 3.1.2 Capturing Volumetric Video

The volumetric capture system Soar was used in creating the volumetric videos since it was available in the lab and is currently the only real-time volumetric video capture system available. Soar requires Azure Kinect cameras to make a volumetric capture because Azure Kinects are able to record depth (RGBD)[1]. Having many cameras increases the quality of the video but will increase the bandwidth of data streaming to the computer and increase the file memory size of the capture so we used seven cameras which is the minimum amount required. Other systems could produce higher

[1] As of August 2023, the Azure Kinect was discontinued. Alternatives to Soar and the Azure Kinect can be found in Section 5.2.

quality VVs by using tens or ever hundreds of cameras but are prohibitively expensive due to hardware and software costs [19].

The depth cameras for the Azure Kinect have a small field of view vertically compared to the horizontal field of view so the cameras are mounted vertically instead of horizontally(Figure 3.1). The Azure Kinect's ideal depth capture range is 1 meter so we positioned the camera that the participant was facing about 1 meter away from the center so the hands and face would have a higher quality in the video. Placing the cameras close to the recording target would reduce the chance of a camera being occluded by the person being recorded.

Figure 3.3: The Azure Kinects were mounted around the centre of the cube.

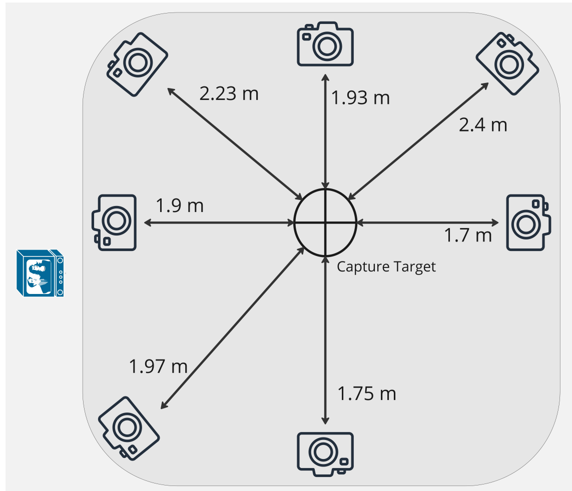


Figure 3.4: A top-down diagram of the camera places for Figure 3.1. The minimum number of cameras required was 7 so there is no camera in the bottom right corner. The TV location is included to understand the orientation of the diagram.

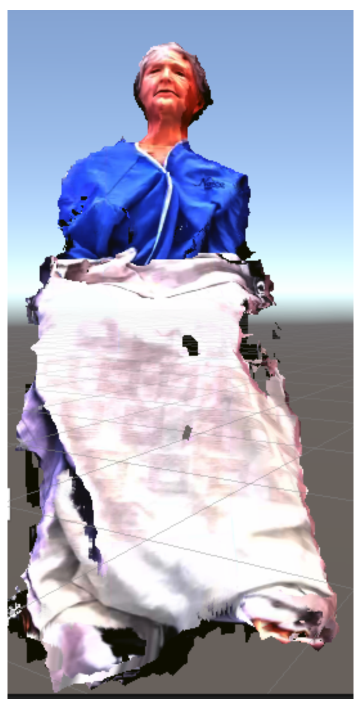

Figure 3.5: A VV of the mannequin exported to Unity.

Figure 3.6: Mounting the camera horizontally may not be able to capture the full height of a person, therefore the camera is mounted vertically so that the wider field of view can be utilized more effectively.

Prior to recording the VV, hardware syncing needs to be enabled in the Soar capture suite. Once the sync is enabled the cameras must be calibrated using the calibration cube provided by Soar. We controlled the lighting in the lab and closed blinds in front of windows because infrared light from the sun can prevent a camera from calibrating successfully due the interference of infrared light on the depth estimation in the cameras.

When capturing a volumetric video, we first start by recording the raw camera data and the capture suite will output a .SRD (soar raw capture) file (Figure 3.3). SRD files range from 23 gigabytes to over 100 gigabytes depending on the length of the video and resolution settings so available memory was checked before creating a capture. Once a raw capture was created, the SRD file is then compressed using the soar capture suite into a proprietary format that can be loaded into Unity using Soar's provided plugin.

## Volumetric Video Processing

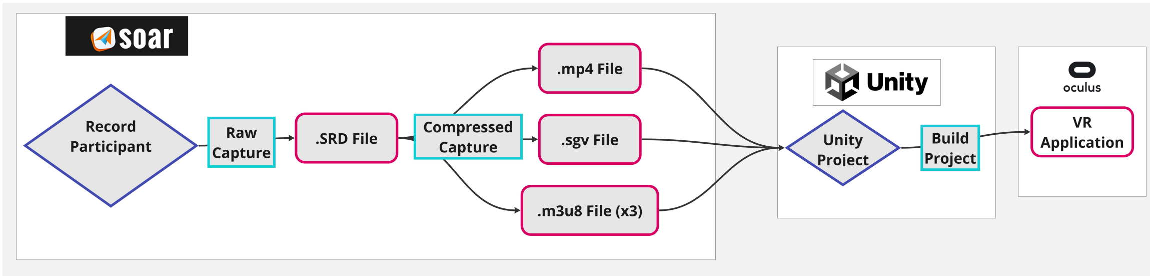


Figure 3.7: Each step for the VV processing

For this study we used the Meta Quest 2 since the Soar plugin supports the Meta Quest 2 and a Meta Quest 2 was borrowed to be used outside of the lab for a previous project. The Meta Quest 2 has an upper limit of 1 gigabyte per application with an additional 4 gigabytes of application extensions. The 1 gigabyte limit had to be considered when compressing the data and Soar's default settings had to be changed so the application's memory size would be below the 1 gigabyte limit (Figure 3.8). If a video was substantially long (> 2 minutes) we had to reduce the volumetric resolution setting to reduce the memory below the 1 gigabyte limit.


Figure 3.9: The volumization settings that we used for Soar.

Figure 3.8: An Oculus Quest 2 was used for this study and an USB-C / USB-3 data link cable was used to connect the headset to the computer.

In addition to the volumetric resolution, the length of the videos contributed significantly to the size of the application because it would quickly increase the amount of meshes for the video. Our control on the length of the video was greatly limited because it depending on each participant but most videos were approximately 1 minute and 30 seconds. If the video went significantly longer, approximately 3 minutes or more, we reduced the volumetric resolution to maintain a valid application size. The compression process produces five files:

- .mp4 file: A video file where each frame is the texture of the model for the respective frame.
- .sgv file: A binary file that contains the model for each frame.
- Three m3u8 files: Text files that contain metadata required to render the textured model.

The VV can be played back in the Soar Desktop Viewer, which is provided with the capture suite, or in Unity to verify that the VV was recorded successfully and the video should be able to played in full. The video may not play in full because the compressed file may be corrupted and the VV will need to be compressed again. If compression still fails, the VV would need to be recorded again. An additional recording would introduce a confounding variable because the participant would have practiced the skill more than once.

### 2D Video Processing

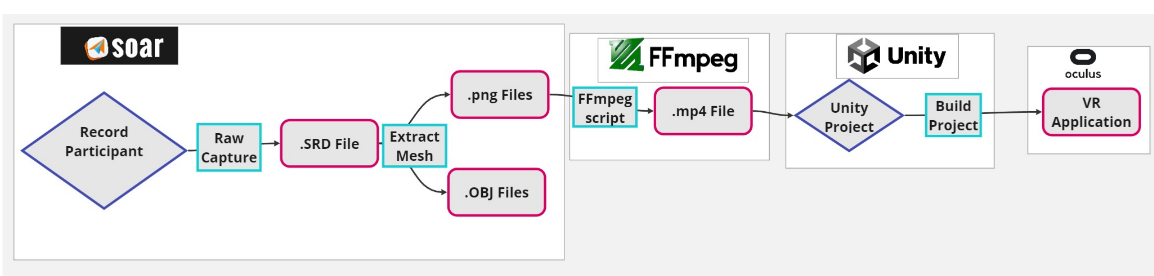


Figure 3.10: Each step for the 2D video processing

We decided to extract the 2D video from a raw capture because we did not want to introduce a confounding variable by not using a Azure Kinect and Soar was already set up to use the Azure Kinects. The raw capture is then loaded and the mesh output is extracted. This will output a mesh as an .OBJ file[2] for every frame. In addition, it will output an image for each camera and for every frame. Extracting .OBJ files can take several hours to complete depending on the duration of the video and the volumetric resolution. However, the .OBJ files are not required to create the 2D video so the quality of the .OBJ files is irrelevant in creating a 2D video. This means that the volumetric resolution setting can be reduced to near zero and reduces hours to complete the process to a few minutes. The free and open-source tool FFMPEG was then used for each camera to process the sequential images into a .mp4 video file [11][3]. The camera that the mannequin was facing was used for the study because the head wound was visible to that camera and it was the orientation that the instructor was recorded in the 2D video should play for the full duration in a media player application that supports .mp4 files to verify the video was recorded correctly. For the study, the default Windows Media Player was used but other media players should work.

Using these techniques, a VV and a 2D video of a person teaching head bandaging was created. Audio of the instructor explaining the steps for head bandage was also recorded through a lapel microphone so that the participant could listen to instructions in addition to visual cues, similar to an actual classroom.

### 3.1.3 Unity Project

The Unity game engine was used for developing the VR experience because of familiarity with the engine and the Soar Capture Suite comes with a Unity plugin that can

[2]OBJ files are a standard file type for mesh data.

[3]An Excel file that generates the required command for the command line can be found here

display the compressed VV data from the capture suite. The plugin contains multiple prefabs (a template of Unity game objects that can be imported into a scene) for rendering VVs. In practice, the VV files need to be in the **StreamingAssets/** folder that was automatically generated when the Soar package was imported. Since the 2D video was a .mp4 file, the video can be played using Unity's built in video player by attaching the **Video** component and setting the .mp4 file the video component. The plane should have the same width-to-height ratio as the video; otherwise, the video will appear squished or stretched. Similar to the VV file, the .mp4 file needs to be located in the upper most **Assets/** folder.

This project requires the Universal Rendering Pipeline (URP)[4] and the High Definition Rendering Pipeline (HDRP)[5] to be included in the unity project as per the Soar plugin documentation even though Unity gives a warning about two pipelines installed [54]. When both pipelines were not included and the project was deployed to the Oculus Quest 2, the project would crash soon after the project starts without providing an error notification.

A prefab from the Oculus Integration for Unity package was used to create a player rig that allowed the user to control an in-game avatar through the Oculus headset and Oculus controllers. This includes locomotion by walking in the physical lab. A mock medical room, which would simulate a medical environment for first aid training, was not established to not disrupt other concurrent activities in the lab. The prefab also has a camera that is configured for the Oculus VR headset and allows for the user to see in 3-D stereoscopic vision. We chose to use the Oculus Quest 2's physical controllers to control virtual hands because the physical controllers were the default option for the prefab and the controllers were easy to develop for.

[4]https://unity.com/srp/universal-render-pipeline

[5]https://unity.com/srp/High-Definition-Render-Pipeline

A component for the camera (Figure 3.11) that caused a fade to black between scene transitions was disabled because the effect was frequently triggered when there was no scene transition for unknown reasons. It was assumed that the frequent triggers would cause frustration for participants because it caused frustration while practicing the study.

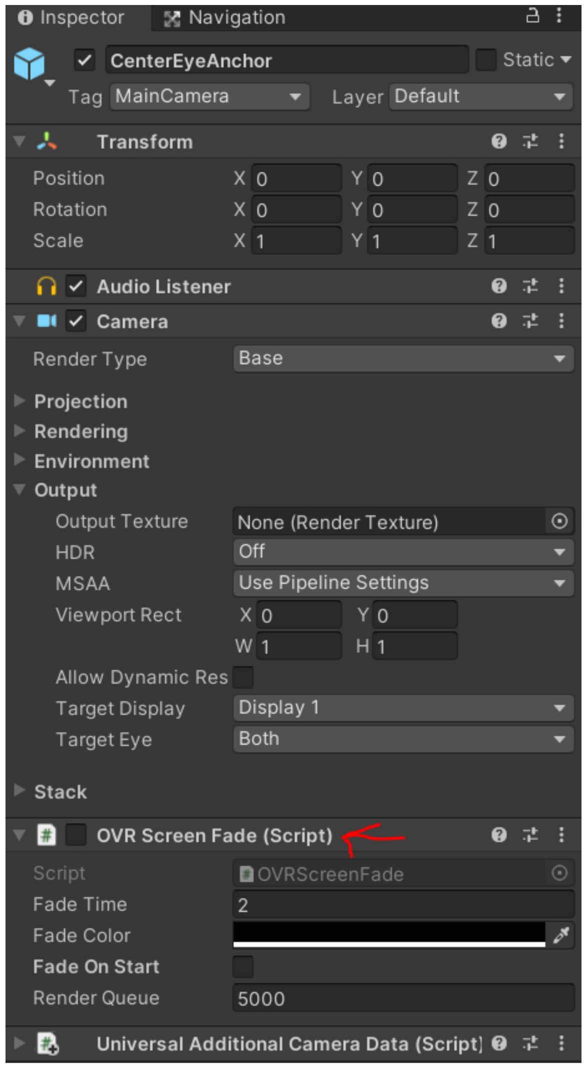


Figure 3.11: The OVR Screen Fade component on the CenterEyeAnchor game object was disabled to remove the undesired screen fade.

Components were added to hands to allow the user to pause or play the videos.

Pressing a button on the right hand controller would pause the video of the teacher and pressing a button on the left hand would pause the video of the user. A visual indicator on whether the video was paused or playing was included above each hand so that the user would know that the video was playing and not frozen. The user could press another button on the physical controllers to hide these indicators.

For most VR applications, it is possible to run the Unity project from the computer and the project will open on the VR headset if it is connected and configured to the computer. This provides several benefits such as being able to see what the user is doing through Unity and faster turnaround time since the program does not have to be built. This is not possible in the current project. Soar requires the graphics API to be OpenGLCore. However, to run the VR application through Unity, the graphics API cannot be in OpenGLCore.

This conflict means that it is required to build and deploy the project to the VR headset. Building and deploying the project takes approximately 5 minutes and two builds need to be done per participant. The first build was when the participant watched only the video of the instructor and the second build was when the participant watched the video of the instructor and themselves to self reflect. The build times should be taken into consideration when allocating time to conduct the study. The builds can be done while the participant is completing the surveys to reduce time consumption. From testing, building to the headset when it was asleep would sometimes cause the build to hang at "Deploying build to headset". To prevent this the headset was briefly woken up multiple times over the course of the build.

## 3.2 Study Design

Our hypotheses for this thesis are the following:

| **Null Hypothesis** | **Alternative Hypothesis** |
|---|---|
| H0: Training with a VV does not have an impact on self-efficacy | H1: Training with a VV does have an impact self-efficacy |
| H2: Participants will experience the same level of presence when watching a VV and 2D video | H3: Participants will experience a higher level of presence when watching a VV compared to a 2D video |

Table 3.1: Hypotheses for the thesis

Our hypothesis is that an increase in presence will improve a student's self-efficacy. In other words, training in a more realistic way will improve a student's confidence in the material. Our other hypothesis is that a VV will cause a participant to experience more presence compared to a 2D video when both are viewed in VR by measuring the participant presence through the Witmer-Singer Presence Questionnaire.

To test these hypotheses, a between-subjects study was conducted where one group of the population was exposed to the VV and another group of the population was exposed to the 2D video (Figure 3.13). We created a VR experience through the game engine Unity. The VR experience teaches the user how to perform head bandaging on a mannequin. The VR experience is composed of the following (Figure 3.12):

1. A volumetric video demonstration of a trainer performing head bandaging
2. A 2D video demonstration of a trainer performing head bandaging
3. A volumetric video recording of the user performing head bandaging
4. A 2D video recording of the user performing head bandaging

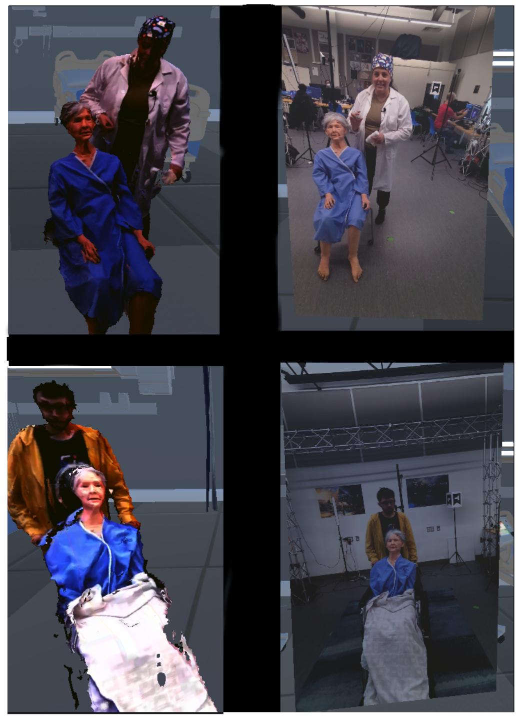

Figure 3.12: Top Left: VV of trainer. Top Right: 2D video of Trainer. Bottom Left: VV of user. Bottom Right: 2D video of user.

The study has two groups within in it to compare the differences between VV and 2D video. The first group is the intervention group and would watch the VV of the trainer and the VV of themselves. The second group is the control group and would watch the 2D video of the trainer and the 2D video of themselves. We minimized the differences between the two conditions by having both groups watch their respective videos in VR instead of a single group watching the video in VR. We further minimized the differences by generating the 2D video from the VV, therefore making the instructions of the 2D video the exact same instructions conveyed through the VV.

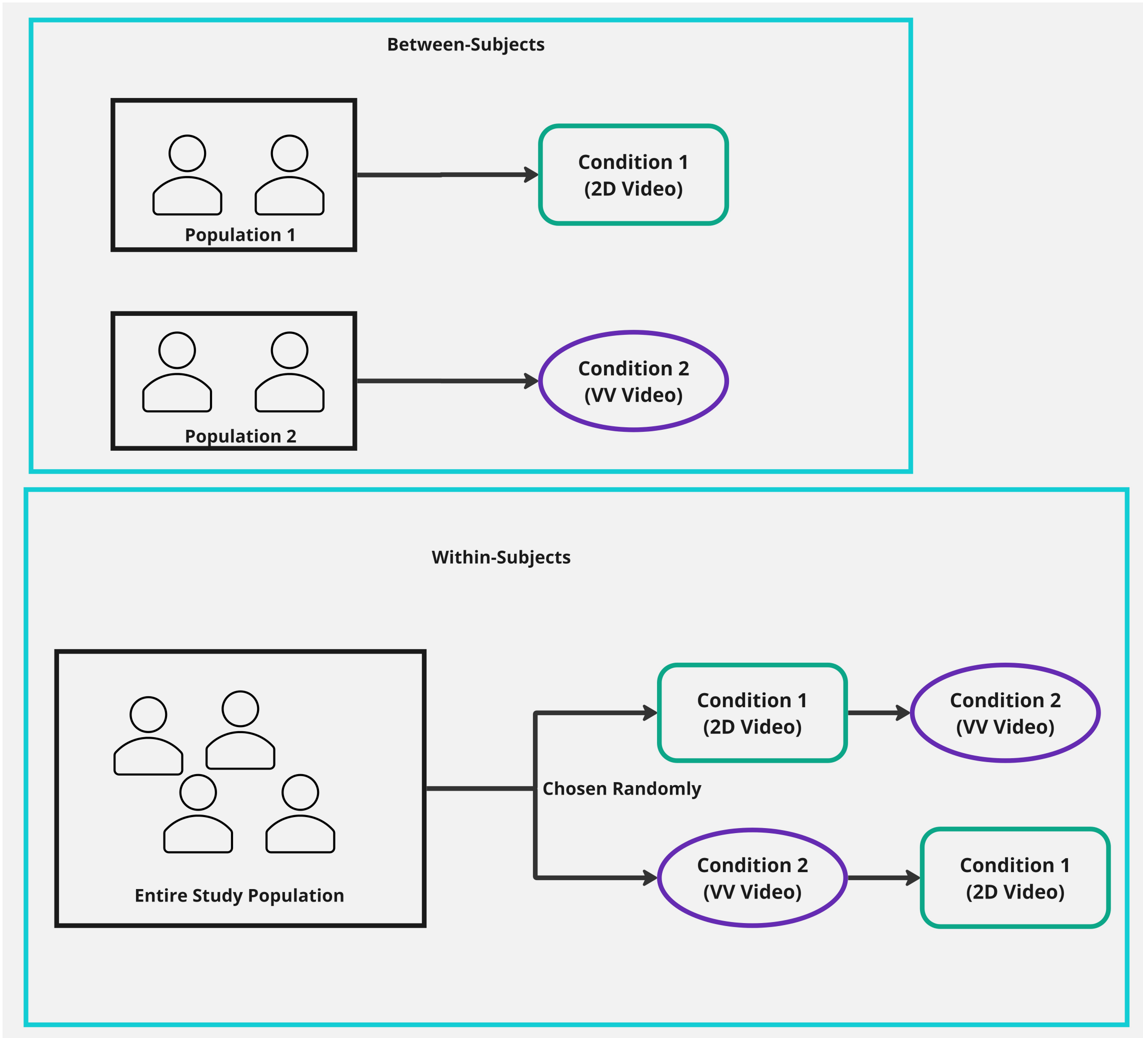


Figure 3.13: In a between-subjects study the population is split into two groups that are exposed to the conditions separately. In a within-subjects study the entire study population is exposed to both conditions.

## 3.3 Participants

We wanted to focus on the nursing student population but reaching the required number of participants to reach our desired statistical power would be difficult with such a focused population. Therefore, we expanded the participants to all students at Ontario Tech University to have a larger population but still focusing on a student population. Participants were recruited by sending an announcement email to all students within Ontario Tech University through the university's Student Life Communications. Students were also recruited from nursing courses by professors posting an announcement on the courses' online learning management system, Canvas. Conflicts of interest were mitigated by posting in courses that the study researchers were not teaching, and the study was stated to be optional. Finally, a recruitment poster was posted in the undergraduate game development lab at the university because several people in the lab expressed interest in the study. The participants were within the range of 18 to 25 years old and participants were excluded from the study if they were out of the age range. To minimize the influence of confounding variables arising from prior experience, participants with previous head bandaging experience were excluded from the study (they could, however, have experience with other forms of First Aid).

The population of our study was university students from a technology focused university in Canada. It was found that immersive technology is particularly effective in teaching K-12 compared to post-secondary students through a meta analysis by Wu et al. [63]. Thus, conducting a similar study for VV in a younger age range may yield different results. Likewise, conducting the study in an older age range may have different results. Cultural differences between countries may also influence a person's receptiveness to technology so we asked the participants which nationality(s) they identified as.

## 3.4 Procedure

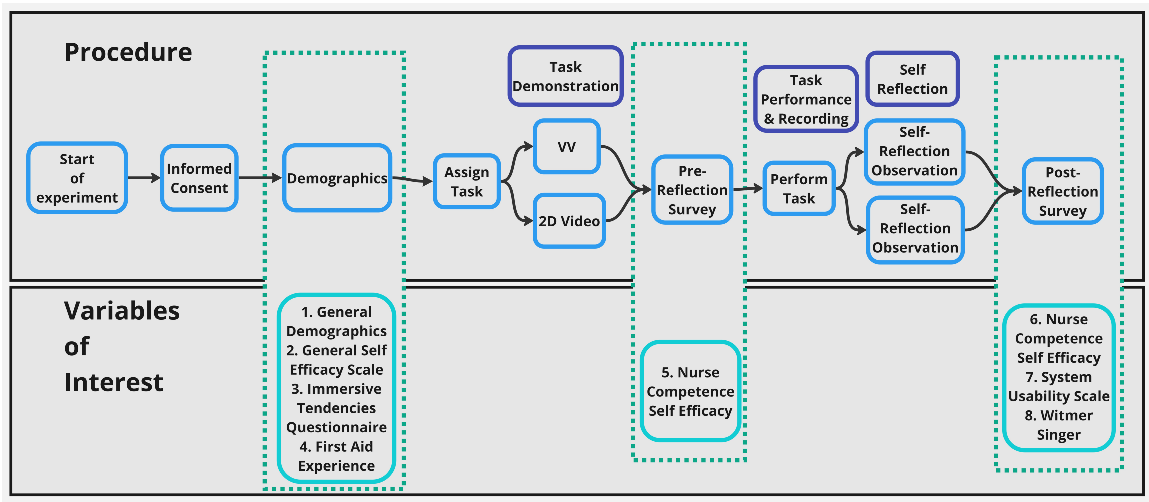


Figure 3.14: Each step of the procedure and the variables of interest that were investigated at each step. The variables of interest are covered in more detail in Section 3.5.

### 3.4.1 Trial

The trials were conducted from mid January 2023 to late March 2023 and were conducted in the undergraduate game development lab. The lab was open to the general university population and therefore could not be controlled during the study. Several distractions, such as loud talking, occurred during different studies and may have impacted a participant's ability to understand the concepts being conveyed in the videos. We collaborated with the lab monitors to find times, such as the evening and weekends, that would have a low amount of people in the lab. The setting should be controlled in future studies. Some participants were in the lab when a different participant was doing the study and therefore the former participants were pre-exposed to the study.

### Informed Consent

This study received ethics approval under Research Ethics Board # 17145 on December 19, 2022. When the participants came to the lab, the study was explained to them and they were told what their role was in the study. The participants were then given a consent form and the potential risks of the study, such as tripping over wires and cyber sickness from the VR headset, were summarize to the participants verbally. The participants read and signed the informed consent form with the investigator available to clarify any questions regarding the consent form.

### Demographics

Once the participant signed the consent form, they performed a demographic survey. This survey included sections such as national identity, general self efficacy, and immersive tendencies. A full list of the demographics survey can be found in Appendix A.1.

### Task Demonstration

The participant then watched a video in VR of an instructor, who was a nurse technologist and an expert in first aid, performing head bandaging on a mannequin. The video that the participant watched could either be a volumetric video or a 2D video. The type of video that the participant watched was chosen by a simple sequence of randomize zeros or ones so that the groups were counter-balanced. The video could be paused / played and would restart from the beginning once the video was finished. The participants were instructed to watch the video until they felt ready to perform the head bandaging.

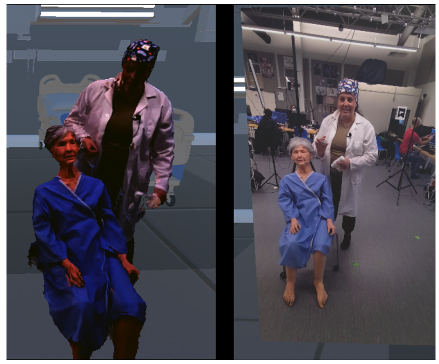

Figure 3.15: Left - VV of the instructor. Right - 2D video of the instructor. The VV would be seen in stereoscopic vision because of the VR headset.

### Pre-Reflection Survey

The participant then filled out a questionnaire about their confidence in what they had just learned. This survey can be found in Appendix A.2.

### Task Performance & Recording

The available memory on the computer was checked so that there was sufficient memory to save a recording of the participant performing head bandaging because of the size of the VV. If there was insufficient memory, the recording would be cutoff without a warning from the Soar capture suite. The participant then performed head bandaging on a mannequin identical to the one in the video and the participants were not given any further instructions on how to perform the bandaging. The type of video that was recorded is the same type chosen in the *task demonstration* phase. The video was then processed by the investigator while the participant waited 5 to 15 minutes depending on the size of the video and if the video had to be processed again to reach a memory size that would not cause the VR application's memory to be greater than 1 gigabyte.

### Self-Reflection

The participants would watch the video of themselves and that of the instructor in VR. The participants were instructed to self reflect on their actions by comparing what they did to the instructor to identify potential mistakes that the participant performed. The participant could pause / play the videos independently of each other and the videos would restart independent of each other. We initially considered having a subject matter expert to evaluate the success of the participants but decided against it due to time scheduling conflicts.

Figure 3.16: Left - Two VVs side by side. Right - The two 2D videos.

### Post-Reflection Survey

Once the participant finished their self-reflection, the participant performed a post-reflection survey. The survey asked about their confidence in the task, their immersion in the experience, and the uncanny valley. A feedback section was also included so that the participant could give non-measurable feedback on the system. The survey can be found in Appendix A.3.

### Completion

Finally, the participants were thanked for their time and reminded that they can still withdraw their consent after the study is completed.

## 3.5 Variables of Interest

### 3.5.1 Demographics Survey

As can be seen in Figure 3.14, the demographics surveys were conducted between the informed consent step and task assignment step of the procedure. [6]

#### General Demographics

The general demographics was to investigate details about the participants that are not focused self efficacy or immersion and instead asks questions about the participants age, nationality, and the type of degree they were pursuing so that confounding variables about the population might be found.

**Analysis Strategy:** The age was analyzed through basic descriptive statistics. The participants self-identified nationality was used to calculate the percentage of the population that identify with their respective nationality(s). Participants that self-identified as more than one nationality had both nationalities counted separately in the percentage.

The participants' degree type was aggregated into four separate categories, Information Communication and Technology (ICT), Engineering, Health Science, and Other, because of similarities between the types of degrees (Table 3.2) and then the percentage of population in the categories was calculated. We did not include a Sci-

[6] The demographics survey can be found in Appendix A.1

ences category because of the very few science degrees, excluding computer science, being pursued in the study population.

| **ICT** | **Engineering** | **Health Science** | **Other** |
|---|---|---|---|
| Game Development, Computer Sciences | Mechanical Engineering, Mechatronics Engineering, Nuclear Engineering | Life Science, Biological Science, Health Science, Nursing | Criminology & Justice, Physics, Commerce |

Table 3.2: Categorization of degrees.

#### General Self Efficacy

The General Self Efficacy Scale was used to measure general self efficacy, a person's self efficacy in all the tasks that they do, because a person's general self efficacy may influence their self efficacy in head bandaging [53].

#### Immersive Tendencies

The Immersive Tendencies Questionnaire was used to measure how much a participant usually gets immersed in a task [62]. The immersive tendencies was measured because immersive tendencies would influence the participant's presence while watching the videos.

### 3.5.2 Pre-Reflection Survey

As can be seen in Figure 3.14, the pre-reflection survey was conducted after the task demonstration step but before the task performance step of the procedure. [7]

[7] The pre-reflection survey can be found in Appendix A.2

#### Nurse Competence

The Nurse Competence Self Efficacy Survey [24] was used to measure the participant's self efficacy in head bandaging because this study is in the context of nursing education.

**Analysis Strategy:** Alongside basic descriptive statistics of each experimental group, the Shapiro-Wilks test was used to verify the data's normality. T-tests were then used to indicate significant differences in the averages. It should be noted that self efficacy is self-reported and our study is limited by the subjectivity of the participants.

### 3.5.3 Post-Reflection Survey

As can be seen in Figure 3.14, the post-reflection survey is the last step of the procedure and was conducted because participants may have different self-efficacy after practicing head bandaging. In the post reflection survey, the participant completed a survey about their self-efficacy, the presence they felt while using VR, and the usability of the system. Additionally, the participant could provide comments on the system.

#### Nurse Competence Self Efficacy

The Nurse Competence Self Efficacy Survey was used again to measure the participant's self efficacy in head bandaging because self-reflecting may have influenced the participant's self-efficacy.

**Analysis Strategy:** We utilized the same analysis strategy that was in the Pre-Reflection Survey section.

### Presence

The Witmer-Singer Presence Questionnaire was used to measure the participant's presence while they were watching both the 2D video and VV because the difference between a VV and a two video may have influenced the participant's presence [62].

**Analysis Strategy:** Alongside basic descriptive statistics of each experimental group, the Shapiro-Wilks test was used to verify normality and T-Tests were used to indicate significant differences in the averages to test Hypothesis H2.

To test Hypothesis H0, an ANOVA test was performed with the nurse competence self-efficacy as the dependent variable and the Witmer-Singer presence questionnaire result as an independent variable. If a relationship was found, an ANOVA test was performed again with the nurses competence self efficacy as the dependent variable and the sub-variables of the Witmer-Singer questionnaire as the independent variable. This process was done for both the pre-reflection self-efficacy and post-reflection self-efficacy.

### Uncanny Valley

The Godspeed survey was used to measure the uncanny valley because the VV and 2D video are significantly different and may have influenced the uncanny valley.

**Analysis Strategy:** Alongside basic descriptive statistics of each experimental group, the Shapiro-Wilks test was used to verify normality. It was expected that the uncanny valley would be significantly different for the VV because of the quality of the VV's mesh and texture due to the memory limitation on the Oculus Quest 2. Therefore, T-Tests were used to indicate significant differences.

To determine if presence influences self-efficacy, an ANOVA test was performed with the nurse competence self efficacy as the dependent variable and the the Godspeed questionnaire result as an independent variable. If a relationship was found, an ANOVA test was performed again with the nurses competence self efficacy as the dependent variable and the sub-variables of the Godspeed questionnaire as the independent variable. This process was done for both the pre-reflection self-efficacy and post-reflection self-efficacy.

### System Usability

The System Usability Scale was used to measure how usable the VR system was for both types of videos. The process to record videos and importing the videos into Unity was done by the investigator, not the participant, and therefore were not measured through the System Usability Scale. Since the user interacts with the system the same way for both types of videos, it is expected the system usability should similar for both types of videos.

**Analysis Strategy:** Alongside basic descriptive statistics of each experimental group, the Shapiro-Wilks test was conducted to verify normality and the Kruskal Wallis test was used to measure significant differences between the average of the two types of videos.

### Feedback

Finally, participants were able to provide feedback on the system in a text box so that the system could be analyzed in ways that the previous surveys could not. The feedback was analyzed by finding similarities among the feedback because numerical analysis is not possible on the feedback.

## 3.6 Summary

We performed a between-subject study to compare the differences between a 2D video (control group) and a VV (intervention group) to investigate how VVs may influence self-efficacy while learning in VR. We also investigated the uncanny valley and presence by comparing the two types of videos. To investigate these variables we created a VR experience where a participant watched a 2D video or VV of a person teaching head bandaging. The participant then practiced head bandaging and watched a video of themselves in VR performing the head bandaging next to the instructor to learn from their mistakes. Throughout the procedure participants answered questions regarding the variables we were investigating. The following chapter are the results of this procedure.

# Chapter 4

# Results & Discussion

This thesis proposed to analyze how VV may influence a trainee's self efficacy in head bandaging to determine if VV is a valid tool for education. The participant data was divided into two groups for analysis: 12 participants watched the VV (intervention group), 11 participants watched the 2D video (control group). The video modality that they watched was randomly chosen by using a randomly generated list of numbers to remove potential biases in the data. Potential biases could have been caused by potential stressors from the time of the year (ex. participants may have been less focused during exam time). The participants were then asked to replicate what they watched and the replication was recorded. After the participant replicated the bandaging technique the participant watched the teaching video in addition to the video of themselves concurrently in VR so that the participant could compare their actions to the teachers and learn from potential mistakes that the participant made. The participant then filled out questionnaires regarding self-efficacy, their presence in the scene, and the uncanny valley of the videos. The goal of this process was to answer the following two hypotheses:

1. VV will be seen has more realistic that a traditional video in VR

2. An improved presence will improve self-efficacy.

Section 4.1 contains the results of processing the data while Section 4.2 contains our interpretation of the results what we suspect are the causes for the results.

## 4.1 Descriptive Analysis

23 participants were recruited from Ontario Tech University's general student population with an age range of 18-25. The average age was 20 years (SD = 2.01). The When asked which nationality the participants identified with most students identified as Canadian (31.8%). 3 participants did not provide their nationality. See Figure 4.1 for all identifications.

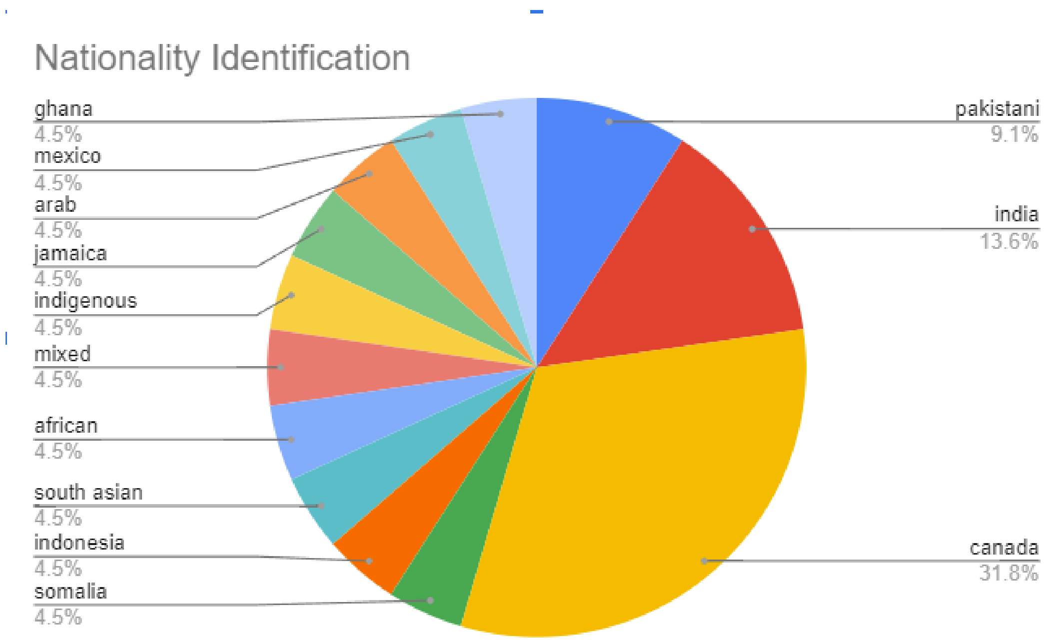


Figure 4.1: Nationality Identification of the population

The type of degree that population were pursuing can be found in Figure 4.2.

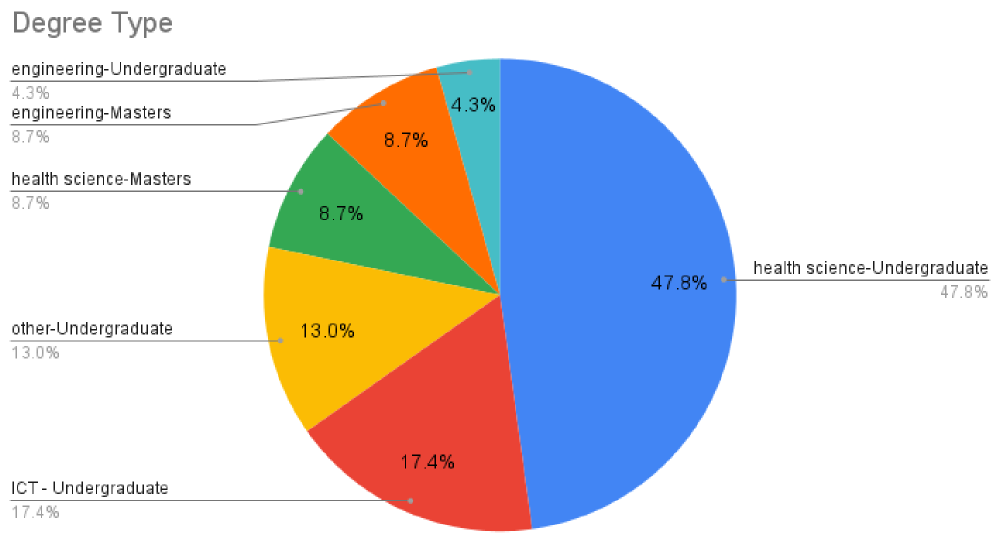


Figure 4.2: Degree being pursued

The percentage of the population that use corrective lenses can be found in Figure 4.3. 47.8% of the population does wear corrective lenses and the other 52.2% of the population does wear corrective lenses. The difference between glasses and contact lenses was not considered until after the study was completed. The Oculus Quest 2 glasses spacer was used to accommodate for glasses and attached to the Quest 2 for all participants.

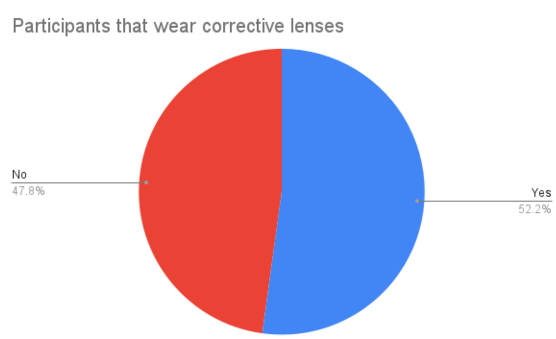


Figure 4.3: Percentage of population that wear corrective lenses

| Type of Video | Average Watch Time (Seconds) | Standard Deviation (Seconds) |
|---|---|---|
| VV Instructor | 179.8 | 77 |
| VV Participant | 185 | 85.7 |
| 2D Instructor | 147.1 | 66.3 |
| 2D Participant | 186.7 | 71.4 |

Table 4.1: Average watch time and standard deviation for the participants.

The average watch time in seconds for the videos can bee found in Table 4.1.

### 4.1.1 Presence

#### Hypothesis

The first hypothesis of this thesis was to determine if participants will experience more presence when viewing VVs compared to 2D videos when watching either of them in VR. The Witmer-Singer Presence (WSP) scale was used to measure the presence experienced during the intervention. and the 23 participants completed the Witmer-Singer Presence Survey after they self-reflected on their actions to collected data for this hypothesis [62].

#### Data Processing

The survey answers were processed as per the instructions for the Witmer-Singer survey [62] to find the results for the factors for each participant. These factors have been shown [62] to correlate with Realism, Possibility to Act, Quality of the Interface, Possibility to Examine, and Sound. One participant in the intervention group missed a question for the Possibility to Act factor and another participant in the intervention group missed a question for the Quality of the Interface factor. Both participants' scores were excluded from their respective factors and were excluded from the final WSP score so that the factors were not influenced by missing data.

| Factor | Total Sample Size | Effective Size |
|---|---|---|
| WSP | 21 | 0.9976133 |
| Realism | 23 | 0.9998864 |
| Possibility to Act | 22 | 0.509589 |
| Quality of Interface | 22 | 0.09146511 |
| Possibility to Examine | 23 | 0.8680851 |
| Sound | 23 | 0.8179193 |

Table 4.2: Effective Sizes for the Witmer-Singer Presence scale using Glass's Delta

**Data Analysis**

T-tests find evidence for significant difference between the mean of two groups but t-tests assume that the groups are normally distributed because they are parametric tests. Therefore, the Shapiro-Wilks test was performed to determine if the data is normally distributed. A T-Test was then performed on the factors and overall WSP score to find potential difference between the two populations.

**Results**

The results of Glass's Delta can be found in Table 4.2. The results of the Shapiro-Wilks tests can be found in Table 4.3 for the intervention population and the Table 4.4 for the control population.

| Factor | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| WSP | 0.89843 | 0.3317 | 101.80 | 13.36496 |
| Realism | 0.92517 | 0.3317 | 38.17 | 4.50925 |
| Possibility to Act | 0.92077 | 0.3251 | 22.18 | 3.429816 |
| Quality of the Interface | 0.92563 | 0.3684 | 8.364 | 2.766685 |
| Possibility to Examine | 0.92223 | 0.3049 | 14.67 | 2.498484 |
| Sound | 0.96107 | 0.799 | 16.67 | 2.839121 |

Table 4.3: Shapiro-Wilk Results for Intervention Population

As can be seen in Table 4.3 and Table 4.4 the Shapiro-Wilks tested failed to find evidence of non-normality (P-Value $> 0.05$) and therefore T-tests can be used to find

| Factor | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| WSP | 0.96707 | 0.2449 | 84.82 | 17.02245 |
| Realism | 0.92517 | 0.3317 | 31.64 | 6.531045 |
| Possibility to Act | 0.92077 | 0.3251 | 19.91 | 4.459923 |
| Quality of the Interface | 0.92563 | 0.3684 | 8.091 | 2.981763 |
| Possibility to Examine | 0.92223 | 0.3049 | 11.91 | 3.176619 |
| Sound | 0.96107 | 0.799 | 13.27 | 4.14948 |

Table 4.4: Shapiro-Wilk Results for Control Population

significant differences in mean. The results for the T-Tests can be found in Table 4.5.

| Factor | Degrees of Freedom | T-Value | P-Value |
|---|---|---|---|
| WSP | 19 | 2.524 | 0.02067 |
| Realism | 21 | 2.8115 | 0.01046 |
| Possibility to Act | 20 | 1.3398 | 0.1954 |
| Quality of the Interface | 20 | 0.22237 | 0.8263. |
| Possibility to Examine | 21 | 2.3248 | 0.03019 |
| Sound | 21 | 2.307 | 0.03134 |

Table 4.5: T-Tests for WSP

As can be seen in Table 4.5, the T-tests found evidence for a significant difference in mean for WSP, Realism, Possibility to Examine, and Sound (P-Value $< 0.05$).

### 4.1.2 Uncanny Valley

#### Hypothesis

Due to the quality of the VV of the participant (low polygon count, texturing artifacts, etc.), it was expected that the VV would appear more uncanny than the 2D video. Therefore, the Godspeed index was used to measure the uncanny valley of both the 2D video and the VV. The 23 participants completed the Godspeed Survey after they self-reflected on their actions to collected data for this hypothesis.

| Factor | Total Sample Size | Effective Size |
|---|---|---|
| Godspeed | 23 | 0.2154612 |
| Likeability | 23 | 0.2591642 |
| Perceived Intelligence | 23 | 0.4084611 |
| Perceived Safety | 23 | -0.1994508 |

Table 4.6: Effective Sizes for the Godspeed scale using Glass's Delta

### Data Processing

The survey answers were inputted into a Google Sheet so that the data can be easily interpreted in R and the survey answers were then processed together as per the instructions in Godspeed to find the results for the factors for each participant. These factors measure Likeability, Perceived Intelligence, Perceived Safety. The factors were then summed together to get the total Godspeed score.

### Data Analysis

T-tests find evidence for significant difference between the mean of two groups but t-tests assume that the groups are normally distributed because they are parametric tests. Therefore, the Shapiro-Wilks test was performed to determine if the data is normally distributed. A T-Test was then performed on the factors and overall Godspeed score to find potential difference between the two populations.

### Results

The results of Glass's Delta test can be found in Table 4.6. The results of the Shapiro-Wilks tests can be found in Table 4.7 for the intervention population and the Table 4.8 for the control population.

As can be seen in Table 4.7 and Table 4.8 the Shapiro-Wilks tested failed to find evidence of non-normality (P-Value $> 0.05$) and therefore T-tests can be used to find significant differences in mean. The results for the T-Tests can be found in Table 4.9.

| Factor | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| Godspeed | 0.8811 | 0.09054 | 54.58 | 7.354137 |
| Likeability | 0.88596 | 0.1045 | 21.5 | 3.316625 |
| Perceived Intelligence | 0.86852 | 0.06259 | 22.17 | 3.010084 |
| Perceived Safety | 0.94534 | 0.5702 | 10.92 | 2.020726 |

Table 4.7: Shapiro-Wilks Results for Intervention Population

| Factor | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| Godspeed | 0.92864 | 0.3973 | 52.64 | 9.03629 |
| Likeability | 0.90365 | 0.2047 | 20.45 | 4.033947 |
| Perceived Intelligence | 0.9 | 0.1849 | 20.73 | 3.523944 |
| Perceived Safety | 0.89461 | 0.1587 | 11.45 | 2.696799 |

Table 4.8: Shapiro-Wilks Results for Control Population

As can be seen in Table 4.9, the T-tests did not find evidence for a significant difference in the mean for the Godspeed survey and the factors (P-Value > 0.05).

### 4.1.3 System Usability

#### Hypothesis

The way that the participant used the system was identical between the two types of videos. Therefore, there should not be a significant difference on the usability of the system. To test this hypothesis, the System Usability Scale (SUS) was used to measure the system usability of both the 2D video and the VV. The 23 participants completed the the SUS after they self-reflected on their actions to collected data for this hypothesis.

| Factor | Degrees of Freedom | T-Value | P-Value |
|---|---|---|---|
| Godspeed | 21 | 0.56893 | 0.5754 |
| Likeability | 21 | 0.68138 | 0.5031 |
| Perceived Intelligence | 21 | 1.0562 | 0.3029 |
| Perceived Safety | 21 | -0.54442 | 0.5919 |

Table 4.9: T-Tests for Godspeed

| Survey | Total Sample Size | Effective Size |
|---|---|---|
| SUS | 23 | 0.4249156 |

Table 4.10: Effective Sizes for the System Usability Scale using Glass's Delta

### Data Processing

The answers were processed together according to the instructions provided by Brooke [6] to find the SUS score for each participant.

### Data Analysis

T-tests find evidence for significant difference between the mean of two groups but t-tests assume that the groups are normally distributed because there are parametric tests. Therefore, the Shapiro-Wilks test was performed to determine if the data is normally distributed. Insufficient evidence was found to determine if the intervention group's SUS score was normally distributed so the Kurskal-Wallis test was used to find significant difference.

### Results

The results of the Shapiro-Wilks tests can be found in Table 4.11 for the intervention population and Table 4.12 for the control population.

| Survey | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| SUS | 0.82883 | 0.02031 | 77.71 | 16.18284 |

Table 4.11: Shapiro-Wilks Results for Intervention Population

| Survey | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| SUS | 0.88069 | 0.1062 | 71.36 | 14.93166 |

Table 4.12: Shapiro-Wilks Results for Control Population

As can be seen in Table 4.11, the intervention population has evidence of non-normality and Table 4.12 shows that the control group does not have have evidence of non-normality. Therefore, t-tests cannot be performed and the Kurskal-Wallis test was performed instead to test for significant difference. The results of the Kurskal-Wallis test can be found in Table 4.13.

| Survey | Degrees of Freedom | H-Value | P-Value |
|---|---|---|---|
| SUS | 1 | 1.5341 | 0.2155 |

Table 4.13: Kurskal-Wallis Results

As can be seen in Table 4.13, there is a lack of evidence to show that there is a difference in SUS between the two populations (P-Value $>$ 0.05).

### 4.1.4 Self Efficacy

#### Hypothesis

The second hypothesis of this thesis was to determine if realism influences a person's self-efficacy. To do this, the Nurse Self Efficacy scale was adapted for first aid. The 23 participants answered this survey twice. The first time was after they watched the teaching video but perform they performed first aid on the mannequin. The second time was after they self-reflected.

#### Data Processing

The survey scores were summed together as per the instructions of Kennedy [24].

#### Data Analysis

T-tests find evidence for significant difference between the mean of two groups but t-tests assume that the groups are normally distributed because they are parametric tests. Therefore, the Shapiro-Wilks tests was performed to determine if the data is normally distributed. A T-test was then performed on the survey. To find potential

| Survey | Total Sample Size | Effective Size |
|---|---|---|
| Pre NSE | 23 | 1.328086 |
| Post NSE | 23 | 0.5481227 |

Table 4.14: Effective Sizes for the NSE scale using Glass's Delta

relationships between realism and self-efficacy, ANOVA was performed on both the pre and post self efficacy results with WSP and Godspeed as the independent variables. To gain further insights of the ANOVA results, ANOVA was repeated with the WSP factors as the independent variables.

**Results**

The results of the Shapiro-Wilks tests can be found in Table 4.15 for the intervention population and Table 4.16 for the control population.

| Survey | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| Pre Self reflection | 0.98312 | 0.9932 | 21.17 | 3.242707 |
| Post Self reflection | 0.96781 | 0.8866 | 21.75 | 2.490893 |

Table 4.15: Shapiro-Wilks Results for Intervention Population

| Survey | W Value | P-Value | Mean | Standard Deviation |
|---|---|---|---|---|
| Pre Self reflection | 0.90636 | 0.2207 | 18.36 | 2.110579 |
| Post Self reflection | 0.967 | 0.8547 | 19.73 | 3.690282 |

Table 4.16: Shapiro-Wilks Results for Control Population

As can be seen in Table 4.15 and Table 4.16, both the intervention and control population do not have evidence of non-normality (P-Value $> 0.05$) and therefore T-tests can be used to find significant differences in mean. The results for the t-tests can be found in Table 4.17.

As per Table 4.17, there is evidence of a significant difference in means for the pre-self reflection survey ($P < 0.05$) but not for the post self reflection survey.

| Survey | Degrees of Freedom | T-Value | P-Value |
|---|---|---|---|
| Pre Self reflection | 21 | 2.4312 | 0.02409 |
| Post Self reflection | 21 | 1.5531 | 0.1353 |

Table 4.17: T-Tests for Self Efficacy

ANOVA was then performed with the self efficacy as the depend variable and the independent variables WSP and godspeed. Table 4.18 shows the results for the pre-self reflection and Table 4.19 shows the results for the post-self reflection.

| Independent Variable | Degrees of Freedom | F-Value | P-Value |
|---|---|---|---|
| WSP | 1 | 2.399 | 0.139 |
| Godspeed | 1 | 1.319 | 0.266 |

Table 4.18: ANOVA for pre-self reflection

| Independent Variable | Degrees of Freedom | F-Value | P-Value |
|---|---|---|---|
| WSP | 1 | 7.136 | 0.0156 |
| Godspeed | 1 | 0.001 | 0.9739 |

Table 4.19: ANOVA for post-self reflection

As can be seen from Table 4.18 and Table 4.19, there is evidence that WSP has a relationship with the post self reflection ($P < 0.05$), WSP does not have sufficient evidence for a relationship with the pre-self reflection, and Godspeed does not have sufficient evidence for both self-reflections. ANOVA was performed again with the dependent variable as post self reflection and the independent variables as the factors of the WSP survey so that the results from Table 4.19 can be explored in greater detail. The results of the sub-survey ANOVA can be found in Table 4.20.

As can be seen in Table 4.20, there is significant evidence that there is a relationship between Realism and Post-Self reflection efficacy ($P < 0.05$) and there is insufficient evidence that the other sub surveys have a relationship with post-self reflection efficacy.

| Independent Variable | Degrees of Freedom | F-Value | P-Value |
|---|---|---|---|
| Realism | 1 | 9.646 | 0.00723 |
| Possibility to Act | 1 | 0.300 | 0.59202 |
| Quality of Interface | 1 | 2.687 | 0.12198 |
| Possibility to Examine | 1 | 3.871 | 0.06791 |
| Sound | 1 | 2.133 | 0.16475 |

Table 4.20: ANOVA for Sub Surveys

## 4.2 Discussion

**Nurse Competence**

We found a significant difference in the pre-self reflection competency scores which indicates that VVs may significantly influence nurse self-efficacy. The VV would have been viewed in stereoscopic vision and the stereoscopic vision may have caused the difference in competency scores. Stereoscopic vision for the Oculus Quest 2 is easily toggle-able through Unity and therefore stereoscopic vision's impact on self-competency can be easily tested in future works. Interestingly, VV's stereoscopic viewing has conflict results with Bennett et al.'s research on how stereo vision and monovision do not have significant differences in memory recall [5]. Unlike the pre-self reflection competency scores, there was an insignificant difference in the post-self reflection competency scores.

The difference between pre and post reflection could have been caused by participants having the ability to practice head bandaging, the participants having the ability to reflect on their actions, or a mixture of both practicing and self-reflection. Repeating the experiment again but having the participants fill out the nurse competence survey between practice and self-reflection may find the cause for the differences between pre and post self reflection. A systematic review on the benefits of augmented reality and competency for surgery came to a similar conclusion and found that AR is at least on par in improving competency compared to traditional forms of learning

[61].

### Presence

The WSP scale did have evidence of a significant difference between the two versions of videos. The sub-scales of the WSP scale showed that Realism, the Possibility to Examine, and Sound had a significant difference between the two versions. The difference in sound can be attributed to a bug discovered during the study where the 2D video's audio was heard in one ear but the VV's audio was heard in both ears. The background of the 2D video was not a hospital room but the virtual environment was and the participants' presence may have been negatively influenced by the contrast between the 2D video and virtual environment. Future studies could record the 2D video in front of a green screen and then use chroma-key techniques[1] to remove the background and remove the contrast between the 2D video and virtual environment. The insignificant difference in the Quality of the Interface and Possibility to Act may be because the way the participant interacted with the scene was nearly identical for both the videos so it should be expected for an insignificant difference in the Quality of the Interface and Possibility to Act.

### System Usability

The Kurskal-Wallis test found no significant difference between the two types of videos' system usability and supports our hypothesis that the system usability would be the same for both types of videos. Similar to the Quality of Interface and Possibility to Act, there was no difference in how the users interact with the system. Therefore, it should be expected that system usability would not be different between the two types of videos. Both the VV and 2D video mean SUS (77.1 and 71.36

[1]A chroma-key shader for Unity that works with the Video Player component can be found here: https://github.com/otdavies/UnityChromakey

respectively) are similar to the mean SUS (78.5) for the VR condition for Strak et al's 3D teleconsulation for electrode placement [52]. This similarity is likely because of the novelty of VR and the SUS may improve as VR becomes more common place.

### Uncanny Valley

There was no evidence of a significant difference for the Godspeed scale and its subscales between the VV version and the 2D version which indicates that VVs and 2D videos cause a similar intensity of the uncanny valley. There was no significant difference in the godspeed scores between the two video types. The VV of the participant performing the bandaging had a significantly lower quality compared to the 2D video because of the gigabyte limitation for the Oculus Quest 2 and was expected to impact the uncanny valley. Furthermore, the lighting of the scene and the saturation of the videos would have also potentially influenced the perceived realism of both videos. More realistic lighting and video saturation could potentially improve the uncanny valley and should be considered in future works. Similarly, the hospital assets had a low polygon count and did not reflect the physical world. We decided to use this virtual hospital over a more detailed hospital because the the chosen assets were within our price range but future researchers should consider a more detailed hospital or a 3D scan of a hospital room using similar methods discussed in Section 2.3. A potential cause of the actual results not being similar to the expected results could be because of ambiguity in the godspeed questionnaire since the questionnaire did not specify if the participant was reviewing the higher quality teaching VV or the lower quality student video. The 2D video, however, did not have a difference in quality between the student and teaching video because quality did not need to be reduced to fit within the gigabyte limit. Gasques et al. found that the quality of their point clouds for surgical telementoring was unable to replicate fine details, such as veins, because current depth cameras have a gap in resolution [14]. Although the quality of our VV could be improved in the future, head bandaging was specifically chosen because finer details were not required to teach the skill and future studies should consider exploring large scale skills until hardware has sufficiently improved.

### Feedback

Participant feedback for the VV was overall positive, however several participants stated that the quality and resolution of the VV could be improved. Since the mannequin was being used for head bandaging, the torso and lower of the mannequin does not need to be recorded and the memory requirements can be reduced by focusing on the head of the mannequin in future studies. However, one participant stated *"... I found the volumetric version's quality distracting (and the mannequin's lack of feet)"* in response to the feet of the mannequin not being captured in the VV. A single participant's feedback is insufficient evidence of a overall quality but future studies should consider exploring if having extraneous parts of a mannequin cut off in a VV would contribute to a lower perceived quality and potentially influencing the uncanny valley.

### Summary

Traditional 2D videos should still be used in the classroom until VVs' affects on education is explored in greater detail or the cost to create VVs are reduced because of the high memory and monetary cost to create a VV compared to a traditional 2D video. A specific area to explore is if VVs have an equal or greater impact on education compared to in-person learning. If VVs are equivalent to in-person learning, then a student can benefit from features of a VV such as watching it multiple times, increased mobility compared to a classroom, and able to manipulate the video (rewind, pause, slow down, etc.).

## 4.3 Limitations

This study was initially a within-subjects study (each participant was exposed to both types of videos) and the first video the participants watched was randomly assigned. We did this to lower the number of participants required and reduce potential noise because each participant would be interacting with both conditions. We were concerned about how exposure to the first video might influence the second video's results so we converted the study into a between-subject study (a participant was exposed to only one video) by disregarding the second video's data. We then split the participants into two groups based on the video that they watched first. We computed the number of participants required to reach our desired statistical power (0.95) for a within-subject study a priori. Some of our post hoc effective sizes for the within-subject design were below our desired effective size of 0.70 and therefore weakens the strength of our data. The low quality of the participants' VVs would have most likely impacted presence and the uncanny valley because the quality may have been off-putting for some participants. The low quality was caused by needing to develop within the memory limitations of the Oculus Quest 2. This limitation can be improved by reducing the quality of the instructor video so that more memory can be allocated to the participants' video which would also result in both the participants' and instructor videos having a similar quality and reduce inconsistencies in the scene. A bug was found during the study that caused the VV to start playing before the participant entered the scene to view the VV. The participant may have been confused which lowered their self-efficacy or lowered presence since the video was not seen in sequence. Part way through the study the tape used to secure the bandage had gone missing and therefore may have influenced the participants' self efficacy when performing the head bandaging. Two participants completed the Pre-Self Reflection survey after performing head bandaging due to a mistake during the study. The participants were still included in the data because of the already low number of participants but exposure to head bandaging may have influenced the their responses in the Pre-Self Reflection survey.

# Chapter 5

# Conclusions

The relatively short training time for first aid means that a large number of people in a community are able to learn first aid and provide life saving intervention in an emergency when a highly skilled person, such as a doctor, may not be available. Researchers have found that immersive technology has similar or greater learning performance compared to the conventional forms of learning when using immersive technology in medical training. Despite the importance of early intervention, there is limited research on utilizing immersive technology to teach a lay person medical intervention and instead most research focuses on highly skilled workers such as medical doctors and surgeons. In addition to immersive technology, volumetric videos allow a user to view a highly realistic video and is being explored with immersive technology for new media formats. In addition, volumetric videos and VR has the potential to bring realistic free-view training to remote communities that do not have experts locally. Although VV is being explored, most results are focused on user feedback and do not analyze how the technology affects measurable data such as self-efficacy or test scores.

Haji et al. adapted the Medical Research Council (MRC) framework because sim-

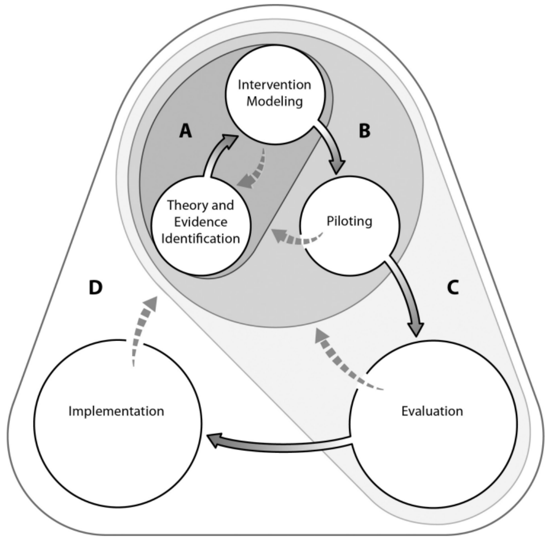


Figure 5.1: The MRC framework is an iterative framework consisting of four major stages to develop new health care simulators. It is important to iterate on section A (development phase) and section B (development and piloting) before moving onto evaluating the overall system [16].

ulations are often complex interventions that are also hindered due other challenges such as limited participant pools and difficulty controlling confounding variables [16]. The MRC framework is an iterative framework for developing the new health care simulators (Figure 5.1). Our system is firmly in the "Piloting" stage of the MRC framework. Within the "Piloting" stage investigators test their system to answer four major questions [16]:

1. How feasible and acceptable is the system for the users?
2. What uncertainties are there in the system and how is the outcome evaluated?
3. What system is the control group using?
4. What are potential methodological challenges that can be resolved before a more complex evaluation of the system?

As a summary of our contributions, the answer to the above questions are:

1. The way our system uses VR for self-reflection is not feasible in a classroom setting. Future researchers should consider using VR only for teaching and not self-reflection or to utilize a web-based system.

2. Future researchers should consider performing the study in a classroom so that there are additional ways to measure success, such as test scores.

3. Our control group was people watching 2D videos. Future researchers should consider having in-person teaching as a control group.

4. We had a low number of participants and some of the population were not nursing students. Future researchers should work within a nursing classroom to have a higher number of participants and have a more specific population.

## 5.1 Contributions

A VR experience was created to teach people how to perform head bandaging on a mannequin to investigate how a VV compares to a 2D video in influencing self-efficacy. The participant watched either a 2D video or a VV in VR of a teacher bandaging a mannequin. Once the participant felt like they had watched enough of the video, the participant moved onto replicating the video on a mannequin. The participant's actions were recorded so that the participant could watch their actions in VR alongside with the teacher so the participant can self-review. The version of the participant's video would be that of the teacher. The participant would answer questions regarding how immersive the experience was, the uncanny valley, and their self efficacy. This thesis contributed the following:

### Theoretical

Our results from the Witmer-Singer Presence scale (P-Value = 0.02067, $\text{Mean}_{\text{VV}}$ = 101.80, $\text{Mean}_{\text{2D}}$ = 84.82) shows that presence caused by VVs are significantly higher than 2D videos. VVs being stereoscopic may have influenced the presence. Evidence did not support a difference in the uncanny valley between VVs and 2D videos even though the quality of the VVs were reduced because of the application size limit. Evidence on realism's influence on self efficacy was found.

### Methodological

The study was to investigate how VV can influence the nursing student population but people from the general student population were recruited as participants so that a significant number of participants could be reached. Similar to Miljanovic and Bradbury's methodology for GidgetML, the VV application could be integrated into a lab exercise for nursing students [34]. Integrating the system into an actual course would focus the population for the study and provide additional ways to measure student success (i.e test or lab scores). However, integrating the VV system into a classroom would be more challenging than the current implementation because of the technical skills required to create a VV, the time to build the application, and the physical space required to capture a VV.

### Technological

Unity, the Soar Capture Studio, Azure Kinects, and the Oculus Quest 2 were used to create the VR experience in this study. No significant issues that impacted the development of the system caused by Unity were found and it is recommended for future studies in VV. Although Soar was adequate for this study, Soar does have several limitations that caused challenges during the study. A developer must deploy the full Unity build to an Oculus Quest 2 in order to use Soar in VR which requires approximately 5 minutes and makes the debugging process quite long compared to VR applications that can be deployed to the headset by starting the game in Unity. No major challenges were encountered when using the Azure Kinects. The 1 gigabyte application limit for the Oculus Quest 2 significantly impacted the development of the VR application because it limited the quality of the self-reflection video. Future developers should rigorously keep track of the raw capture data of both the self-reflection and instructor videos so that a lower quality compressed video can be generated to reach the 1 gigabyte application limit.

### Practical

Generating a VV and inputting the video into Unity requires skills in Soar and Unity. In practice, a nursing instructor may not have the skills in Soar and Unity to generate a student's VV for self-reflection. Building the Unity project to the Oculus Quest 2 also causes barriers in using this system in a class room because of the gigabyte size limit, time to build, and the building sometimes hanging. It is recommended to use this system only to show the instructor explaining the first aid skill and not for student self-reflection because the VVs can be created by a person skilled in Soar and built to the Oculus Quest 2 before the students utilize the system. Furthermore, the price of a VR headset may be a limiting factor. VR may also cause cyber sickness for some users and therefore make the classroom less accessible [28]. An alternative for VR, such as a web application, should be consider for practical use. For this thesis, we only made a VV of head bandaging but practical applications could make a VV of multiple types of first aid that nursing students can easily switch between.

The instructor component of the system could be easily expanded to include other forms of first aid and used to teach first aid in remote locations around the globe without needing an expert to be physically present. An expert not needing to be physically present would allow the expert to allocate time to teaching more nurses and the monetary cost to send an expert to a remote location could be allocated to other teaching projects.[1]

## 5.2 Future Work

With Azure Kinects deprecated and no longer being produce, reproducing this thesis may be difficult because Soar relies on Azure Kinects. Guo et al.'s Vid2Avatar allows for 3D reconstruction of humans without the need of an Azure Kinect, however Vid2Avatar will not necessarily reconstruct the static mannequin because Vid2Avatar relies on pose estimation [15]. Similarly, Volograms relies on artificial intelligence to reconstruct humans and may not reconstruct the mannequin [42, 58]. A potential alternative that shows promise is to replace the Azure Kinect cameras with Intel RealSense cameras [20] and to use Open3D [65] as an alternative to Soar because Open3D is compatible with RealSense cameras and constructing a VV with RealSense cameras is well documented[2].

This study only measured self efficacy, presence, system usability, and the uncanny valley but future studies should consider exploring other aspects of successful learning and immersion by using additional surveys to observe if VVs influence aspects of learning not covered in this study. Both 2D video and VV can be used as alternatives to a physical teaching environment and therefore future researchers should investigate how successful VVs are at teaching students compared to the conventional experience of being in a physical classroom. This study was not conducted in an actual classroom

[1]Reducing the environmental cost from flying experts to remote locations is an additional benefit but does not reduce the nurse shortage.

[2]http://www.open3d.org/docs/release/tutorial/sensor/realsense.html

setting so participants may not have acted as they would have because there was little incentive to succeed (i.e good grades). Therefore, future researchers should explore VVs in an actual classroom setting but should consider using laptops or mobile devices instead of a VR headset because of the ubiquitous of computers and mobile devices.

The lockdowns during Covid-19 have highlighted how much the modern world relies on digital media and VVs have the potential to be a form of digital media used by consumers in their homes. The pros and cons for VVs must be explored using measurable data to pass another form of digital media into the hands of the general population.

# Appendix A

# Surveys

## A.1 Demographics Survey

1. What is your age in years?
    - Short answer response
2. Which nation do you identify with?
    - Short answer response
3. What year are you currently in?
    - 1st (Undergraduate)
    - 2st (Undergraduate)
    - 3st (Undergraduate)
    - 4st (Undergraduate)
    - 5+ (Undergraduate)
    - Masters

- PhD

4. What is your program?

   - Short answer response

5. Have you been diagnosed with any disability or impairment that may affect your learning?

   - Yes
   - No
   - I prefer not to answer

6. If yes, which of the following have been diagnosed? (Mark all that apply)

   - A sensory Impairment (vision or hearing)
   - A mobility impairment
   - A learning disability (Eg. Dyslexia, Dysgraphia)
   - A mental health disorder
   - A disability or impairment not listed above
   - I prefer not to say

7. Do you wear corrective lenses? (glasses, contact lenses)

   - No
   - Yes

8. I can always manage to solve difficult problems if I try hard enough.

   - Scale from 1-5 (1 = Not at all true, 5 = exactly true)

9. If someone opposes me, I can find means and ways to get what I want.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
10. It is easy for me to stick to my aims and accomplish my goals.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
11. I am confident that I could deal efficiently with unexpected events.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
12. Thanks to my resourcefulness, I know how to handle unforeseen situations.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
13. I can solve most problems if I invest the necessary effort.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
14. I can remain calm when facing difficulties because I can rely on my coping abilities.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
15. When I am confronted with a problem, I can usually find several solutions.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
16. If I am in a bind, I can usually think of something to do.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)
17. No matter what comes my way, I'm usually able to handle it.
    - Scale from 1-5 (1 = Not at all true, 5 = exactly true)

18. How comfortable are you with technology?
    - Scale from 1-5 (1 = Very uncomfortable, 5 = Very comfortable)
19. How often have you used a Virtual Reality (VR) headset (Oculus Quest, etc.)
    - Scale from 1-5 (1 = Never, 5 = Very frequently)
20. Do you easily become deeply involved in movies or tv dramas?
    - Scale from 1-7 (1 = Never, 7 = Often)
21. Do you ever become so involved in a television program or book that people have problems getting your attention?
    - Scale from 1-7 (1 = Never, 7 = Often)
22. How mentally alert do you feel at the present time?
    - Scale from 1-7 (1 = Not Alert, 7 = Fully Alert)
23. Do you ever become so involved in a movie that you are not aware of things happening around you?
    - Scale from 1-7 (1 = Never, 7 = Often)
24. How frequently do you find yourself closely identifying with the characters in a story line?
    - Scale from 1-7 (1 = Never, 7 = Often)
25. Do you ever become so involved in a video game that it is as if you are inside the game rather than using a controller and watching the screen?
    - Scale from 1-7 (1 = Never, 7 = Often)

26. How physically fit do you feel today?

    - Scale from 1-7 (1 = Not fit, 7 = Extremely Fit)

27. How good are you at blocking out external distractions when you are involved in something?

    - Scale from 1-7 (1 = Not very good, 7 = Very good)

28. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

    - Scale from 1-7 (1 = Never, 7 = Often)

29. Do you ever become so involved in a daydream that you are not aware of things happening around you?

    - Scale from 1-7 (1 = Never, 7 = Often)

30. Do you ever have dreams that are so real that you feel disoriented when you awake?

    - Scale from 1-7 (1 = Never, 7 = Often)

31. When playing sports, do you become so involved in the game that you lose track of time?

    - Scale from 1-7 (1 = Never, 7 = Often)

32. How well do you concentrate on enjoyable activities?

    - Scale from 1-7 (1 = Not at all, 7 = Very well)

33. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

- Scale from 1-7 (1 = Never, 7 = Often)

34. Have you ever gotten scared by something happening on a TV show or in a movie?

    - Scale from 1-7 (1 = Never, 7 = Often)

35. Have you ever remained apprehensive or fearful long after watching a scary movie or video?

    - Scale from 1-7 (1 = Never, 7 = Often)

36. Do you ever become so involved in doing something that you lose all track of time?

    - Scale from 1-7 (1 = Never, 7 = Often)

37. What is your level of First Aid?

    - I don't know First Aid
    - I was taught First Aid but don't have a certificate
    - I was taught First Aid and have a certificate

38. If you have a certificate, which versions of First Aid have you been taught? (Check all that apply)

    - Emergency First Aid
    - Standard First Aid
    - CPR / AED Level A (unresponsive adults)
    - CPR / AED Level B (unresponsive child or infant)
    - CPR / AED Level C (unresponsive adult, child or infant)

- Mental Health First Aid

39. When was the last time you took a First Aid course?

    - Within the Last Year
    - 1 year ago
    - 2 years Ago
    - 3 or more years ago
    - Never

40. If you had to perform First Aid in an emergency, how confident would you be in trying to save the person's life?

    - Scale from 1-5 (1 = Not very confident, 7 = Very confident)

41. Have you had to utilize your First Aid knowledge in an actual emergency?

    - No
    - Yes

## A.2 Self-Reflection Survey (Pre Self Review)

1. How confident are you that you can find near misses or errors regarding head bandaging, including your own?

    - Scale from 1-9 (1 = Certain cannot do, 9 = Certain can do)

2. How confident are you that you can demonstrate knowledge of head bandaging?

    - Scale from 1-9 (1 = Certain cannot do, 9 = Certain can do)

3. How confident are you that you can teach another person head bandaging?
    - Scale from 1–9 (1 = Certain cannot do, 9 = Certain can do)

## A.3 Self-Reflection Survey (Post Self Review)

1. How confident are you that you can find near misses or errors regarding head bandaging, including your own?
    - Scale from 1-9 (1 = Certain cannot do, 9 = Certain can do)
2. How confident are you that you can demonstrate knowledge of head bandaging?
    - Scale from 1-9 (1 = Certain cannot do, 9 = Certain can do)
3. How confident are you that you can teach another person head bandaging?
    - Scale from 1-9 (1 = Certain cannot do, 9 = Certain can do)
4. How natural did your interactions with the environment seem?
    - Scale from 1–7 (1 = extremely Artificial, 7 = Completely Natural)
5. How much did the visual aspects of the environment involve you?
    - Scale from 1–7 (1 = Not at all, 7 = Completely)
6. How natural was the mechanism which controlled movement through the environment?
    - Scale from 1–7 (1 = extremely Artificial, 7 = Completely Natural)
7. How compelling was your sense of objects moving through space?
    - Scale from 1–7 (1 = Not at all, 7 = Very compelling)

8. How much did your experiences in the virtual environment seem consistent with your real world experiences?
   - Scale from 1–7 (1 = Not consistent, 7 = Very consistent)
9. How compelling was your sense of moving around inside the virtual environment?
   - Scale from 1–7 (1 = Not at All, 7 = Very Compelling)
10. How involved were you in the virtual environment experience?
    - Scale from 1–7 (1 = Not involved, 7 = Completely Engrossed)
11. How much were you able to control events?
    - Scale from 1–7 (1 = Not at All, 7 = Completely)
12. How responsive was the environment to actions that you initiated (or performed)?
    - Scale from 1–7 (1 = Not responsive, 7 = Completely responsive)
13. Were you able to anticipate what would happen next in response to the actions that you performed?
    - Scale from 1–7 (1 = Not at All, 7 = Completely)
14. How completely were you able to actively survey or search the environment using vision?
    - Scale from 1–7 (1 = Not at All, 7 = Completely)
15. How much delay did you experience between your actions and expected outcomes?

- Scale from 1–7 (1 = No delays, 7 = Long delays)

16. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

    - Scale from 1–7 (1 = Not at all, 7 = Prevented task performance)

17. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

    - Scale from 1–7 (1 = Not at all, 7 = Completely)

18. How closely were you able to examine objects?

    - Scale from 1–5 (1 = Not at all, 5 = Very closely)

19. How well could you examine objects from multiple viewpoints?

    - Scale from 1–7 (1 = Not at all, 7 = Extensively)

20. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

    - Scale from 1–7 (1 = Not at all, 7 = Completely)

21. How much did the auditory aspects of the environment involve you?

    - Scale from 1–7 (1 = Not at all, 7 = Completely)

22. How well could you localize sounds?

    - Scale from 1–7 (1 = Not at all, 7 = Completely)

23. Please rate your impression of the video on this scale.

    - Scale from 1–5 (1 = Dislike, 5 = Like)

24. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Unfriendly, 5 = Friendly)
25. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Unkind, 5 = Kind)
26. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Unpleasant, 5 = Pleasant)
27. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Awful, 5 = Nice)
28. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Incompetent, 5 = Competent)
29. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Ignorant, 5 = Knowledgeable)
30. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Irresponsible, 5 = Responsible)
31. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Unintelligent, 5 = Intelligent)
32. Please rate your impression of the video on this scale.
    - Scale from 1–5 (1 = Foolish, 5 = Sensible)
33. Please rate your emotional state while watching the video on this scale.

- Scale from 1–5 (1 = Anxious, 5 = Relaxed)

34. Please rate your emotional state while watching the video on this scale.

    - Scale from 1–5 (1 = Agitated, 5 = Calm)

35. Please rate your emotional state while watching the video on this scale.

    - Scale from 1–5 (1 = Quiescent, 5 = Surprised)

36. I think I would like to use this system frequently.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

37. I found the system unnecessarily complex.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

38. I thought the system was easy to use.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

39. I think that I would need the support of a technical person to be able to use this system.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

40. I found the various functions in this system were well integrated.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

41. I thought there was too much inconsistency in this system.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

42. I would imagine that most people would learn to use this system very quickly.

- Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

43. I found the system very cumbersome to use.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

44. I felt very confident using the system.

    - Scale from 1-5 (1 = Strongly disagree, 5 = Strongly agree)

45. I needed to learn a lot of things before I could get going with this system.

    - Scale from 1–5 (1 = Strongly disagree, 5 = Strongly agree)

46. Feel free to provide any comments.

    - Long answer response.

# Appendix B

# Consent Form

The following pages are the consent form that participants signed before participating in the study.

## Consent Form to Participate in a Research Study

**Title of Research Study:** Volumetric Video & Virtual Reality in First Aid Training

**Name of Principal Investigator (PI):** Andrew Hogue

**PI's contact:** andrew.hogue@ontariotechu.ca

**Names of Co-Investigator and Student Lead:** Co-PI: Adam Dubrowski (adam.dubrowski@ontariotechu.net) Student Lead: Colin Orian (colin.orian@ontariotechu.net)

**Departmental and institutional affiliation:** Faculty of Business & IT

**External Funder/Sponsor:** Natural Sciences and Engineering Research Council of Canada (NSERC)

### Introduction

You are invited to participate in a research study entitled *Volumetric Video & Virtual Reality in First Aid Training*. You are being asked to take part in a research study. Please read the information about the study presented in this form. The form includes details on study procedures, risks and benefits that you should know before you decide to participate. You should take as much time as you need to make your decision. You should ask the Principal Investigator (PI) or study team to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish including your friends and family. Participation in this study is voluntary.

This study has been reviewed by the University of Ontario Institute of Technology (Ontario Tech University) Research Ethics Board REB # 17145 on December 19, 2022.

### Purpose and Procedure:

*Background:*

Volumetric video is similar to a normal video that you would watch on TV or on the Internet. The difference is that a volumetric video is a 3D object. Since a volumetric video is a 3D object, viewers can move around the video and see the object at any angle. The viewer can also move closer or farther away from the object.

*Purpose:*

The purpose of this study is to evaluate how volumetric video affects self-confidence, also called self-efficacy, in learning first aid skills.

You have been invited to participate in this study because participants without experience in head bandaging are needed to explore how volumetric video aids in their self-confidence in head bandaging. If you haven't been taught head bandaging and are 18 years or older you meet the criteria for participation.

*Procedures:*

This study will have one visit and the duration of the visit will be about 1 hour. The procedure is the following:

1) You will come in and do a demographic survey. This survey asks for information such as gender and education level. It will also ask about your general self-confidence (Approximately 10 minutes).
2) You will be randomly assigned to either watch a volumetric video or conventional video using a virtual reality head mounted display.
3) While watching the video you have the choice to walk around and pause / play the video. The headset will collect information about your experience in virtual reality such as your position, number of pauses / plays, and duration of watching the video (Approximately 5 minutes).
4) You will then do a survey on how confident you are in head bandaging skills (Approximately 1 minute).
5) You will then practice head bandaging on a mannequin. You will be recorded while practicing (Approximately 5 minutes).
6) You will rewatch the training video with the video of yourself beside it to self-reflect your learning (Approximately 5 minutes).
7) You will do another survey asking about your experience in virtual reality and self-confidence (Approximately 20 minutes).
8) Repeat steps 3) - 7) using the alternative video format.

Total Study Time: Approximately 92 minutes.

It is typical for demographic questionnaires to be done in research like this. This research is wanting to compare the difference between volumetric video (experiment) and conventional video (control). By doing the experiment twice, once for each type of video, you will be a part of the experimental group and control group. 30 participants will take part in this study. If you choose to participate your responsibility will be to arrive at SIRC 4310 at the designated time and perform the procedure above.

**Potential Benefits:**

You will not directly benefit from participating in this study. However, this still will explore how to improve educating people in First Aid which would lead to a better and safer society.

**Potential Risk or Discomforts:**

***Oculus Quest 2*****:** This study utilizes an Oculus Quest 2 virtual reality (VR) head mounted display (HMD). There is risk involved with using a HMD. While walking with the HMD display your view of your physical surroundings is greatly limited. In addition, there are several other risks while utilizing the Oculus Quest 2:

- Epileptic seizures or other photosensitive conditions (about 1 in 4000)
- Motion sickness / simulator sickness which may cause conditions such as:
  - Nausea / vomiting
  - Impaired balance
  - Dizziness
  - Disorientation
- Motion sickness is not an uncommon side effect of using VR HMD and may last a few hours after the experience. However, the effects are temporary discomforts. To avoid physical injury you should refrain from activities such as cutting items, cycling, driving or operating heavy machinery after using the Oculus Quest 2. Driving while feeling these conditions may lead to legal or monetary repercussions if driving results in a collision.

- Using a headset without cleaning it may spread infectious diseases.

You can find the full list of risks for the Oculus Quest here: https://securecdn.oculus.com/sr/oculusquest-warning-english#:~:text=Some%20people%20(about%201%20in,before%20or%20have%20no%20history

To prevent injury (such as falling) while wearing the HMD the researchers may hold onto you. Please state if you consent to this or not at the end of this form. You will be reminded of this when you are wearing the HMD and can withdraw this consent during the experiment.

***Minimizing Risks:*** To minimize risks we will:

- remove any potential tripping or collision risks, such as chairs, from the designated area to prevent you from walking into them

- If you walk outside of a designated area the Oculus Quest 2 will show what your physical surroundings are.

- A chair will be provided if you want to rest while recovering from any motion / simulator sickness.

- To reduce the risk of disease spread, the headset will be cleaned with antibacterial wipes and clothes between uses.

***COVID-19:*** Please note, there is a risk of contracting the COVID-19 virus when participating in face to face research. There may be additional risks to participating in this research during the COVID-19 pandemic that are currently unforeseen and, therefore, not listed in this consent form.

We ask that you reschedule your study visit to participate in the research study if you a) have any new or worsening symptoms associated with COVID-19 (See list of COVID-19 symptoms), b) have COVID-19 as confirmed by a test, and/or c) have been in close-contact with someone with confirmed or suspected COVID-19.

At this time, the university has a mask mandate in effect. This means that you will be required to wear a mask inside any building on our university campus. The researchers you will be working with will also be wearing a mask.

**Use and Storage of Data:**

*Data Storage:* The data will be stored on a Google Drive. This drive will only be accessible to the research team. This data will not be shared outside of the institution. The physical consent forms will be stored in the PI's locked office on campus and will be destroyed once the study is completed.

*Identifiable Information:* Some identifiable information will be collected. This data will include your name and email address. This data will be stored in a separate file to the study data but will be associated with a number. In addition, you will be video recorded. Video data cannot be anonymized. However, the videos will be deleted once the study is completed.

There are several types of research data that will be collected:

1) Demographic information: This data will be collected through a questionnaire using Google Forms. This data is anticipated to be used to see potential trends in the study population and will benefit the research by finding potential influences on the dependent variables (self-confidence in First Aid, realism, and presence). This data is not identifying. This data will be kept 2 years after the study.
2) Virtual Reality Data: This data will be collected automatically through the virtual reality program. This data is anticipated to learn how you use the virtual reality system. It will benefit the research by finding potential influences on the dependent variables. This data will be kept 2 years after the study.
3) System Useability & Self-Reflection Data: This data will be collected through a questionnaire through Google Forms. This data are our dependent variables and important to our research because it is the data that will be influenced by our interventions (the different types of videos). This data will be kept 2 years after the study.

*Storage Time:* Identifying data will be stored until the study is published (Approximately April 2023) and non-identifying data will be kept for 2 years.

*Aggregation:* The data of all participants will be aggregated into a single set of data. This will be aggregated into the means of the two populations (potentially removing outliers).

*Destroying Data:* After the data is finished being used on a computer, the data will be deleted and the recycling bin will be emptied. Once 2 years have passed, the data on the Google Drive will be deleted and the recycling bin will be cleaned.

All information collected during this study, including your personal information and videos of you will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.

\

Ontario Tech UNIVERSITY

**Miscellaneous:**

*Lack of First Aid Certification:* Although you will be learning some First Aid skills in this study, this study does not constitute a First Aid certification course and performing First Aid without a certificate may lead to legal repercussions. Do not perform First Aid on people unless you have a certificate to do so.

**Confidentiality:**

*Safeguarding Confidentiality:* Your data will only be viewable by the researchers by a password protected Google Drive. To safeguard your anonymity identifying information will be deleted as soon as the data is no longer needed.

Your privacy shall be respected. No information about your identity will be shared or published without your permission, unless required by law. Confidentiality will be provided to the fullest extent possible by law, professional practice, and ethical codes of conduct. Please note that confidentiality cannot be guaranteed while data is in transit over the Internet.

This research study includes the collection of demographic data which will be aggregated (not individually presented) in an effort to protect your anonymity. Despite best efforts, it is possible that your identity can be determined even when data is aggregated.

There will be 2 files. One file will contain the participants identifying information to an anonymized ID. The other will contain aggregated data with the anonymized ID. There is no possibility for participant identification with aggregated data.

**Voluntary Participation:**

Your participation in this study is voluntary and you may partake in only those aspects of the study in which you feel comfortable. You may also decide not to be in this study, or to be in the study now, and then change your mind later. You may leave the study at any time without affecting your academic standing, grades in a course, or relationship with Ontario Tech University. You will be given information that is relevant to your decision to continue or withdraw from participation. You may refuse to answer any question(s) you do not want to answer, or not answer an interview question by saying, 'pass'

**Right to Withdraw:**

If you withdraw from the research project at any time, any data ~~or human biological materials~~ that you have contributed will be removed from the study and you do not need to offer any reason for making this request.

Identifying information will be kept until the research is published (Approximately April 2023). Non-identifying information will be kept 2 years after the study is completed. If you withdraw before April 2023, all your data will be deleted. After that time efforts will be made to delete the data but there is no guarantee.

*Published Data:* Data will be published in an aggregated form. When it is published it will be impracticable to withdraw your data.

**Conflict of Interest:**

There are no known conflicts of interest concerning this study.

**Debriefing and Dissemination of Results:**

After the research is published you will receive a follow-up email on how to access the published research.

**Participant Rights and Concerns:**

Please read this consent form carefully and feel free to ask the researcher any questions that you might have about the study. If you have any questions about your rights as a participant in this study, complaints, or adverse events, please contact the Research Ethics Office at (905) 721-8668 ext. 3693 or at researchethics@ontariotechu.ca.

If you have any questions concerning the research study or experience any discomfort related to the study, please contact the researcher Colin Orian at colin.orian@ontariotechu.net.

By signing this form you do not give up any of your legal rights against the investigators, sponsor or involved institutions for compensation, nor does this form relieve the investigators, sponsor or involved institutions of their legal and professional responsibilities.

**Consent to Participate:**

1. I have read the consent form and understand the study being described;
2. I have had an opportunity to ask questions and those questions have been answered. I am free to ask questions about the study in the future;
3. I freely consent to participate in the research study, understanding that I may discontinue participation at any time without penalty. A copy of this consent form has been made available to me.

______________________ ______________________ ______________________

Print Study Participant's Name Signature Date

My signature means that I have explained the study to the participant named above. I have answered all the questions.

_____________ ___________________ ________________

Print Name of Person Obtaining Signature Date

I consent to being physically moved or grabbed in case I am at risk of hurting myself while using the virtual reality headset.

____________________ ___________________ ________________

Print Study Participant's Name Signature Date

# Bibliography

[1] Mike Allen, Edward A. Mabry, Michelle Mattrey, John Bourhis, Scott Titsworth, and Nancy Burrell. 2004. Evaluating the Effectiveness of Distance Learning: A Comparison Using Meta-Analysis. *Journal of Communication* 54, 3 (Sept. 2004), 402–420. `https://doi.org/10.1111/j.1460-2466.2004.tb02636.x` MAG ID: 2121903702 S2ID: ee310f54a0b2376fdba87e996e9eec3bc5395ca2.

[2] Stephanie M. Attardi, Stefanie M. Attardi, Noah M. Mintz, and Kem A. Rogers. 2022. Perspectives of online anatomy teachers: A neglected study population struggles with the invisible student. *Anatomical Sciences Education* (Jan. 2022). `https://doi.org/10.1002/ase.2169` MAG ID: 4205169402.

[3] Stefanie M. Attardi and Kem A. Rogers. 2015. Design and implementation of an online systemic human anatomy course with laboratory. *Anatomical Sciences Education* 8, 1 (Jan. 2015), 53–62. `https://doi.org/10.1002/ase.1465` MAG ID: 1580884296.

[4] Christoph Bartneck, Dana Kulić, Elizabeth Croft, and Susana Zoghbi. 2009. Measurement Instruments for the Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety of Robots. *International Journal of Social Robotics* 1, 1 (Jan. 2009), 71–81. `https://doi.org/10.1007/s12369-008-0001-3`

[5] Adam Bennett, Matthew Coxon, and Katerina Mania. 2010. *The effect of stereo and context on memory and awareness states in immersive virtual environments.* https://doi.org/10.1145/1836248.1836275 Journal Abbreviation: Proceedings - APGV 2010: Symposium on Applied Perception in Graphics and Visualization Pages: 140 Publication Title: Proceedings - APGV 2010: Symposium on Applied Perception in Graphics and Visualization.

[6] John Brooke. 1995. SUS: A quick and dirty usability scale. *Usability Eval. Ind.* 189 (Nov. 1995).

[7] Josip Car, Jan Carlstedt-Duke, Jan Carlstedt-Duke, Jan Carlstedt-Duke, Lorainne Tudor Car, Pawel Posadzki, Penny Whiting, Nabil Zary, Rifat Atun, Azeem Majeed, James Campbell, James Campbell, James Campbell, and James R. Campbell. 2019. Digital Education in Health Professions: The Need for Overarching Evidence Synthesis. *Journal of Medical Internet Research* 21, 2 (Feb. 2019). https://doi.org/10.2196/12913 MAG ID: 2910506194.

[8] The Pokemon Company and Niantic. 2023. Pokémon GO. Retrieved 2023-10-20 from https://pokemongolive.com/

[9] Anuja Darekar, Bradford J. McFadyen, Anouk Lamontagne, Joyce Fung, and Joyce Fung. 2015. Efficacy of virtual reality-based intervention on balance and mobility disorders post-stroke: a scoping review. *Journal of Neuroengineering and Rehabilitation* 12, 1 (May 2015), 46–46. https://doi.org/10.1186/s12984-015-0035-3 MAG ID: 1515664738.

[10] Sabine Fabriz, Julia Mendzheritskaya, and Sebastian Stehle. 2021. Impact of Synchronous and Asynchronous Settings of Online Teaching and Learning in Higher Education on Students' Learning Experience During COVID-19. *Frontiers in*

*Psychology* 12 (Oct. 2021). https://doi.org/10.3389/fpsyg.2021.733554 MAG ID: 3206167459 S2ID: b5d715a65b215a255f8d026b18889b0f1f0325d4.

[11] FFmpeg. 2023. FFmpeg. Retrieved 2023-11-30 from https://ffmpeg.org/

[12] Hello Games. 2023. No Man's Sky. Retrieved 2023-10-20 from https://www.nomanssky.com/

[13] Mark Garcia. 2022. Innovative 3D Telemedicine to Help Keep Astronauts Healthy. Retrieved 2022-04-18 from http://www.nasa.gov/feature/innovative-3d-telemedicine-to-help-keep-astronauts-healthy

[14] Danilo Gasques, Janet G. Johnson, Tommy Sharkey, Yuanyuan Feng, Ru Wang, Zhuoqun Robin Xu, Enrique Zavala, Yifei Zhang, Wanze Xie, Xinming Zhang, Konrad Davis, Michael Yip, and Nadir Weibel. 2021. ARTEMIS: A Collaborative Mixed-Reality System for Immersive Surgical Telementoring. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (CHI '21)*. Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3411764.3445576

[15] Chen Guo, Tianjian Jiang, Xu Chen, Jie Song, and Otmar Hilliges. 2023. Vid2Avatar: 3D Avatar Reconstruction from Videos in the Wild via Self-supervised Scene Decomposition. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*.

[16] Faizal A. Haji, Celina Da Silva, Delton T. Daigle, and Adam Dubrowski. 2014. From Bricks to Buildings: Adapting the Medical Research Council Framework to Develop Programs of Research in Simulation Education and Training for the Health Professions. *Simulation in Healthcare* 9, 4 (Aug. 2014), 249. https://doi.org/10.1097/SIH.0000000000000039

[17] Ayah Hamad and Bochen Jia. 2022. How Virtual Reality Technology Has Changed Our Lives: An Overview of the Current and Potential Applications and Limitations. *International Journal of Environmental Research and Public Health* 19, 18 (Sept. 2022), 11278. https://doi.org/10.3390/ijerph191811278

[18] Darragh Higgins, Donal Egan, Rebecca Fribourg, Benjamin Cowan, and Rachel McDonnell. 2021. Ascending from the valley: Can state-of-the-art photorealism avoid the uncanny?. In *ACM Symposium on Applied Perception 2021*. ACM, Virtual Event France, 1–5. https://doi.org/10.1145/3474451.3476242

[19] Andrew Hogue, Cindy Poremba, Veronika Szkudlarek, Nick Fox-Gieg, Alvaro Quevedo, Colin Orian, and Jakob Anderson. 2022. A Visual Programming Interface for Experimenting with Volumetric Video. In *2022 IEEE Games, Entertainment, Media Conference (GEM)*. 1–6. https://doi.org/10.1109/GEM56474.2022.10017777 ISSN: 2766-6530.

[20] Intel. [n. d.]. Intel® RealSense™ Technology. Retrieved 2023-10-23 from https://www.intel.com/content/www/us/en/architecture-and-technology/realsense-overview.html

[21] Johanna Elizabeth Nieuwoudt and Johanna Elizabeth Nieuwoudt. 2020. Investigating synchronous and asynchronous class attendance as predictors of academic success in online education. *Australasian Journal of Educational Technology* 36, 3 (Jan. 2020), 15–25. https://doi.org/10.14742/ajet.5137 MAG ID: 3003733110.

[22] Brennan Jones, Yaying Zhang, Priscilla N. Y. Wong, and Sean Rintel. 2021. Belonging There: VROOM-ing into the Uncanny Valley of XR Telepresence. *Pro-*

*ceedings of the ACM on Human-Computer Interaction* 5, CSCW1 (April 2021), 59:1–59:31. https://doi.org/10.1145/3449133

[23] Sean Kelly, Samantha Cordingley, Patrick Nolan, Christoph Rhemann, Sean Fanello, Danhang Tang, Jude Osborn, Jay Busch, Philip Davidson, Paul Debevec, Peter Denny, Graham Fyffe, Kaiwen Guo, Geoff Harvey, Shahram Izadi, Peter Lincoln, Wan-Chun Alex Ma, Jonathan Taylor, Xueming Yu, Matt Whalen, Jason Dourgarian, Genevieve Blanchett, Narelle French, Kirstin Sillitoe, Tea Uglow, Brenton Spiteri, Emma Pearson, Wade Kernot, and Jonathan Richards. 2019. AR-ia: Volumetric Opera for Mobile Augmented Reality. In *SIGGRAPH Asia 2019 XR (SA '19)*. Association for Computing Machinery, New York, NY, USA, 1–3. https://doi.org/10.1145/3355355.3361890

[24] Evelyn Kennedy. [n. d.]. The Nursing Competence Self-Efficacy Scale (NCSES): An Instrument Development and Psychometric Assessment Study. ([n. d.]).

[25] Leyan Khayruddeen, Daniel Livingstone, Daniel Livingstone, Daniel Livingstone, and Eilidh Ferguson. 2019. Creating a 3D Learning Tool for the Growth and Development of the Craniofacial Skeleton. *Advances in Experimental Medicine and Biology* 1138 (Jan. 2019), 57–70. https://doi.org/10.1007/978-3-030-14227-8_5 MAG ID: 2943443254.

[26] Marek Kowalski, Jacek Naruniec, and Michal Daniluk. 2015. *Livescan3D: A Fast and Inexpensive 3D Data Acquisition System for Multiple Kinect v2 Sensors.* https://doi.org/10.1109/3DV.2015.43 Pages: 325.

[27] Bhone Myint Kyaw, Nakul Saxena, Pawel Posadzki, Jitka Vseteckova, Charoula Konstantia Nikolaou, Pradeep Paul George, Ushashree Divakar, Ushrashree Divakar, Italo Masiello, Andrzej A. Kononowicz, Nabil Zary, and

Lorainne Tudor Car. 2019. Virtual Reality for Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. *Journal of Medical Internet Research* 21, 1 (Jan. 2019). https://doi.org/10.2196/12959 MAG ID: 2905602303.

[28] Joseph J. LaViola. 2000. A discussion of cybersickness in virtual environments. *ACM SIGCHI Bulletin* 32, 1 (Jan. 2000), 47–56. https://doi.org/10.1145/333329.333344

[29] Jason Lawrence, Danb Goldman, Supreeth Achar, Gregory Major Blascovich, Joseph G. Desloge, Tommy Fortes, Eric M. Gomez, Sascha Häberling, Hugues Hoppe, Andy Huibers, Claude Knaus, Brian Kuschak, Ricardo Martin-Brualla, Harris Nover, Andrew Ian Russell, Steven M. Seitz, and Kevin Tong. 2021. Project starline: a high-fidelity telepresence system. *ACM Transactions on Graphics* 40, 6 (Dec. 2021), 242:1–242:16. https://doi.org/10.1145/3478513.3480490

[30] Violeta Lopez, Judith Anderson, Judith Anderson, Sancia West, Sancia West, Michelle Cleary, and Michelle Cleary. 2021. Does the COVID-19 Pandemic Further Impact Nursing Shortages? *Issues in Mental Health Nursing* (Sept. 2021), 1–3. https://doi.org/10.1080/01612840.2021.1977875 MAG ID: 3204048571.

[31] Meta. 2023. Meta Quest 2: Immersive All-In-One VR Headset | Meta Store. Retrieved 2023-10-22 from https://www.meta.com/ca/quest/products/quest-2/

[32] Metastage. 2023. Metastage – Volumetric Capture Studio. Retrieved 2023-10-19 from https://metastage.com/

[33] Microsoft. 2023. Buy the Azure Kinect developer kit. Retrieved 2023-10-15 from https://www.microsoft.com/en-us/d/azure-kinect-dk/8pp5vxmd9nhq

[34] Michael A. Miljanovic and Jeremy S. Bradbury. 2020. GidgetML: an adaptive serious game for enhancing first year programming labs. In *Proceedings of the ACM/IEEE 42nd International Conference on Software Engineering: Software Engineering Education and Training*. ACM, Seoul South Korea, 184–192. https://doi.org/10.1145/3377814.3381716

[35] Mohammad Dehabadi, Mohammad H Dehabadi, Bimbi Fernando, and Pasquale Berlingieri. 2014. The use of simulation in the acquisition of laparoscopic suturing skills. *International Journal of Surgery* 12, 4 (April 2014), 258–268. https://doi.org/10.1016/j.ijsu.2014.01.022 MAG ID: 2080911493.

[36] Masahiro Mori, Karl MacDorman, and Norri Kageki. 2012. The Uncanny Valley [From the Field]. *IEEE Robotics & Automation Magazine* 19 (June 2012), 98–100. https://doi.org/10.1109/MRA.2012.2192811

[37] Mozilla. [n. d.]. Mozilla Hubs - Private, virtual 3D worlds in your browser. Retrieved 2023-10-20 from https://hubs.mozilla.com/

[38] Thomas R. Nelson and Dolores H. Pretorius. 1998. Three-dimensional ultrasound imaging. *Ultrasound in Medicine and Biology* 24, 9 (Dec. 1998), 1243–1270. https://doi.org/10.1016/s0301-5629(98)00043-x MAG ID: 2052282007.

[39] Sergio Orts-Escolano, Christoph Rhemann, Sean Fanello, Wayne Chang, Adarsh Kowdle, Yury Degtyarev, David Kim, Philip L. Davidson, Sameh Khamis, Mingsong Dou, Vladimir Tankovich, Charles Loop, Qin Cai, Philip A. Chou, Sarah Mennicken, Julien Valentin, Vivek Pradeep, Shenlong Wang, Sing Bing Kang, Pushmeet Kohli, Yuliya Lutchyn, Cem Keskin, and Shahram Izadi. 2016.

Holoportation: Virtual 3D Teleportation in Real-time. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16)*. Association for Computing Machinery, New York, NY, USA, 741–754. https://doi.org/10.1145/2984511.2984517

[40] Judith A. Oulton. 2006. The Global Nursing Shortage: An Overview of Issues and Actions. *Policy, Politics, & Nursing Practice* 7, 3_suppl (Aug. 2006), 34S–39S. https://doi.org/10.1177/1527154406293968 Publisher: SAGE Publications.

[41] Néill O'dwyer, Emin Zerman, Gareth W. Young, Aljosa Smolic, Siobhán Dunne, and Helen Shenton. 2021. Volumetric Video in Augmented Reality Applications for Museological Narratives: A User Study for the Long Room in the Library of Trinity College Dublin. *Journal on Computing and Cultural Heritage* 14, 2 (May 2021), 22:1–22:20. https://doi.org/10.1145/3425400

[42] Rafael Pagés, Jan Ondřej, and Konstantinos Amplianitis. 2020. Forge: A volumetric video processing platform for everyone. In *NEM SUMMIT*. Dublin, Ireland, 2.

[43] Fabrizio Palmas and Gudrun Klinker. 2020. Defining Extended Reality Training: A Long-Term Definition for All Industries. In *2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT)*. 322–324. https://doi.org/10.1109/ICALT49669.2020.00103 ISSN: 2161-377X.

[44] George Papagiannakis, George Papagiannakis, Panos Trahanias, Eustathios Kenanidis, Eleftherios Tsiridis, Eleftherios Tsiridis, and Eleftherios Tsiridis. 2018. Psychomotor Surgical Training in Virtual Reality. (Jan. 2018), 827–830. https://doi.org/10.1007/978-3-319-64177-5_41 MAG ID: 2849833800.

[45] Jocelyn Parong, Kimberly A. Pollard, Benjamin T. Files, Ashley H. Oiknine, Anne M. Sinatra, Jason D. Moss, Antony Passaro, and Peter Khooshabeh. 2020. The mediating role of presence differs across types of spatial learning in immersive technologies. *Computers in Human Behavior* 107 (June 2020), 106290. https://doi.org/10.1016/j.chb.2020.106290

[46] Paul Buyego, Elizabeth Katwesigye, Grace Kebirungi, Mike Nsubuga, Shirley Nakyejwe, Phillip Cruz, Meghan C McCarthy, Darrell Hurt, Andrew Kambugu, Joseph Walter Arinaitwe, Umaru Ssekabira, and Daudi Jjingo. 2022. Feasibility of virtual reality based training for optimising COVID-19 case handling in Uganda. *BMC Medical Education* 22, 1 (April 2022). https://doi.org/10.1186/s12909-022-03294-x MAG ID: 4226271819.

[47] Aldis H. Petriceks, Ashley S Peterson, Miguel Angeles, W. Paul Brown, and Sakti Srivastava. 2018. Photogrammetry of Human Specimens: An Innovation in Anatomy Education. *Journal of Medical Education and Curricular Development* 5 (Sept. 2018), 2382120518799356–2382120518799356. https://doi.org/10.1177/2382120518799356 MAG ID: 2892364378.

[48] Emma Elizabeth Phelps, Richard M. Wellings, Richard Wellings, Frances Griffiths, Charles E. Hutchinson, Charles E. Hutchinson, and Melina A. Kunar. 2017. Do medical images aid understanding and recall of medical information? An experimental study comparing the experience of viewing no image, a 2D medical image and a 3D medical image alongside a diagnosis. *Patient Education and Counseling* 100, 6 (June 2017), 1120–1127. https://doi.org/10.1016/j.pec.2016.12.034 MAG ID: 2566135639.

[49] Nicolas Pope, Sebastian Hahta, Erkki Rötkönen, Naska Goagoses, Jason Mendes, Erkki Sutinen, and Heike Winschiers-Theophilus. 2022. Remote Presence: Live

Holograms for a Social Classroom. In *Proceedings of the 2022 ACM International Conference on Interactive Media Experiences (IMX '22)*. Association for Computing Machinery, New York, NY, USA, 249–252. https://doi.org/10.1145/3505284.3532821

[50] Moritz Queisner, Michael Pogorzhelskiy, Christopher Remde, Johann Pratschke, and Igor M. Sauer. 2022. VolumetricOR: A New Approach to Simulate Surgical Interventions in Virtual Reality for Training and Education. *Surgical Innovation* 29, 3 (June 2022), 406–415. https://doi.org/10.1177/15533506211054240

[51] Holger Regenbrecht, Claudia Ott, Noel Park, Stuart Duncan, and Jonny Collins. 2021. Voxelvideos for Entertainment, Education, and Training. *IEEE Access* 9 (2021), 68185–68196. https://doi.org/10.1109/ACCESS.2021.3076488 Conference Name: IEEE Access.

[52] Robin Strak, Kevin Yu, Frieder Pankratz, Marc Lazarovici, Benedikt Sandmeyer, Julia Reichling, Simon Weidert, Clemens Kraetsch, Barbara Roegele, Nassir Navab, Ulrich Eck, and Daniel Roth. 2021. Comparison Between Video-mediated and Asymmetric 3D Teleconsultation During a Preclinical Scenario. (Sept. 2021), 227–235. https://doi.org/10.1145/3473856.3473883 MAG ID: 3201231398.

[53] Ralf Schwarzer and Matthias Jerusalem. [n. d.]. The General Self-Efficacy Scale (GSE). ([n. d.]), 2.

[54] Soar. 2022. Soar | Home. https://streamsoar.com/

[55] Vladimiros Sterzentsenko, Antonis Karakottas, Alexandros Papachristou, Nikolaos Zioulis, Alexandros Doumanoglou, Dimitrios Zarpalas, and Petros Daras. 2018. A Low-Cost, Flexible and Portable Volumetric Capturing System. In *2018*

*14th International Conference on Signal-Image Technology Internet-Based Systems (SITIS)*. 200–207. https://doi.org/10.1109/SITIS.2018.00038

[56] Yuk Ming Tang, Ka Yin Chau, Pak Ki Kwok, Tongcun Zhu, and Xiangdong Ma. 2021. A systematic review of immersive technology applications for medical practice and education - Trends, application areas, recipients, teaching contents, evaluation methods, and performance. *Educational Research Review* (Dec. 2021), 100429–100429. https://doi.org/10.1016/j.edurev.2021.100429 MAG ID: 4200344160.

[57] Dénes Tóth, Karola Petrus, Veronika Heckmann, Gábor Simon, and Viktor Soma Poór. 2021. Application of photogrammetry in forensic pathology education of medical students in response to COVID-19. *Journal of Forensic Sciences* 66, 4 (2021), 1533–1537. https://doi.org/10.1111/1556-4029.14709 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/1556-4029.14709.

[58] Volograms. 2022. Volograms — AI-powered 3D volumetric holograms. Retrieved 2023-10-15 from https://www.volograms.com/

[59] volucap. 2021. The Matrix Resurrections. Retrieved 2022-03-16 from https://volucap.com/portfolio-items/the-matrix-resurrections/

[60] Stefan Weber, David Weibel, and Fred W. Mast. 2021. How to Get There When You Are There Already? Defining Presence in Virtual Reality and the Importance of Perceived Realism. *Frontiers in Psychology* 12 (2021). https://www.frontiersin.org/articles/10.3389/fpsyg.2021.628298

[61] Matthew Williams, Matthew Williams, James McVeigh, James McVeigh, Ashok Inderraj Handa, Ashok Handa, Ashok Handa, and Regent Lee. 2020.

Augmented reality in surgical training: a systematic review. *Postgraduate Medical Journal* 96, 1139 (March 2020), 537–542. https://doi.org/10.1136/postgradmedj-2020-137600 MAG ID: 3013125479.

[62] Bob G. Witmer and Michael J. Singer. 1998. Measuring Presence in Virtual Environments: A Presence Questionnaire. *PRESENCE: Teleoperators & Virtual Environments* 7, 3 (June 1998), 225–240. https://doi.org/10.1162/105474698565686 Publisher: MIT Press.

[63] Bian Wu, Xiaoxue Yu, and Xiaoqing Gu. 2020. Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology* 51, 6 (Nov. 2020), 1991–2005. https://doi.org/10.1111/bjet.13023 Publisher: John Wiley & Sons, Ltd.

[64] Yizhong Zhang, Jiaolong Yang, Zhen Liu, Ruicheng Wang, Guojun Chen, Xin Tong, and Baining Guo. 2022. VirtualCube: An Immersive 3D Video Communication System. *IEEE Transactions on Visualization and Computer Graphics* (Jan. 2022), 1–1. https://doi.org/10.1109/tvcg.2022.3150512 MAG ID: 4213011881.

[65] Qian-Yi Zhou, Jaesik Park, and Vladlen Koltun. 2018. Open3D: A Modern Library for 3D Data Processing. *arXiv:1801.09847* (2018).