Virtual Reality for Skill Enhancement and Affective Regulation in Post Secondary Education

by

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Abstract

Background: Virtual reality (VR) in post-secondary education features the use of digitally rendered learning environments, allowing students to practice actions that resemble professional real-world tasks. This report addresses the prevalence, technical and non-technical implementation of VR across a wide array of education disciplines, while also providing details of an investigation that used immersive VR for affective regulation in Occupational Therapy students, who were preparing for clinical practical exams. This report aimed to fill the gaps in the literature, regarding how immersive VR was implemented in post-secondary education curricula while also determining the effectiveness of immersive VR to reduce anxiety in students.

Methods: A systematic review was performed to determine how immersive VR was being incorporated into post-secondary settings, noting favourable outcomes from VR's use after comparing it to other learning methods. The affective regulation investigation used a prospective experimental nonrandomized control trial to compare two groups of first-year Occupational Therapy students' state anxiety, test anxiety and academic self-efficacy levels, measured at four different timepoints by self-reported psychometric scales, analyzed with a mixed factorial ANOVA. The affective regulation investigation utilized an immersive VR simulation, depicting a virtual clinic and standardized patient, who students could interview in natural language.

Findings: This report shows evidence of VR's capability to enhance post-secondary students' technical, non-technical and affective regulatory skill. Immersive VR's capability to reduce state anxiety in Occupational Therapy students was also observed. VR in Health Science education has repeatedly demonstrated its ability to show positive affective reaction in students while enhancing their skills across a wide variety of skill learning tasks. However, skill transferability from the virtual to real-world, showing favourable incentive for VR's adoption into Health Sciences education with cost-effective outcomes, remains to be established.

Preface

This thesis is an original work by Brendan Joseph Concannon. Chapter 2 of this thesis provides details of a systematic "state-of-the-art" review of immersive VR's implementation in post-secondary education. M. Roberts and S. Esmail co-conceptualized the methods of the review, in addition to making revisions towards its writing process. Chapter 2 has been published on an open-access, peer-reviewed journal.[1] Chapter 3 provides details of an investigation: The use of immersive VR to reduce state anxiety in Occupational Therapy students who were preparing for upcoming clinical practical exams. For Chapter 3's investigation, I was responsible for the psychometric tool selection, data collection, analysis and thesis manuscript composition. S. Esmail provided vision design to The Rehabilitation Robotics Laboratory in the Edmonton Clinic Health Academy, which developed the simulation as described in the Simulation Design section of Chapter 3. Chapter 3's investigation received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Using virtual reality simulation for the management of student test anxiety in an OSCE setting", No. 00075582, 10/17/2018.

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Chapter 1 - Overview

Virtual Reality Continuum

Virtual reality (VR) allows people to engage with artificial stimuli as though they were real. This engagement is summarily comprised of two features, digitally rendered objects and reality itself, both of which are visible in varying degrees, to form what are known as virtual environments. One stereotypical view of VR, is the kind featuring an environment that is entirely comprised of digitally rendered objects, resulting in an otherworldly experience. However, note that VR can be placed into different subclasses, depending on the combination of visibly perceived real-world objects and/or digitally rendered objects. These subclasses of VR, with their own virtual and real-world compositions, are each designated a position along the *virtuality continuum* (Milgram & Kishino, 1994).

Refer to Figure 1.1 for a summary of Milgram and Kishino's (1994) *virtuality continuum.* Whenever both digitally rendered and real-world objects can both be perceived together, this resultant mixture becomes a virtual environment, designated as a *mixed reality*, residing somewhere on the *virtuality continuum,* between a total real environment and a total virtual environment (Milgram & Kishino, 1994). Total real environments and total virtual environments are sometimes known as "reality" and "virtual reality"[2] respectively, yet note that the label "virtual reality" may differ in definition between experts, due to differing of individual experiences, involving theoretical concepts regarding the real and nonreal world. For example, some experts state that characteristics of virtual reality are inclusive to artistic objects, not digitally projected by technology, such as panoramic paintings of battlefields and cities (Grau, 2003). Milgram and Kishino's (1994) report stated that classification of the various *mixed reality* designations provides clarification to which the

[2] In this report, a human-machine interface featuring a total virtual environment will be referred to as immersive virtual reality (immersive VR). All other stated instances of virtual reality, without the "immersive" prefix, will act as a catch-all term, including all designations of the *virtuality continuum* up to and including immersive VR.

various ways virtual reality can be defined.

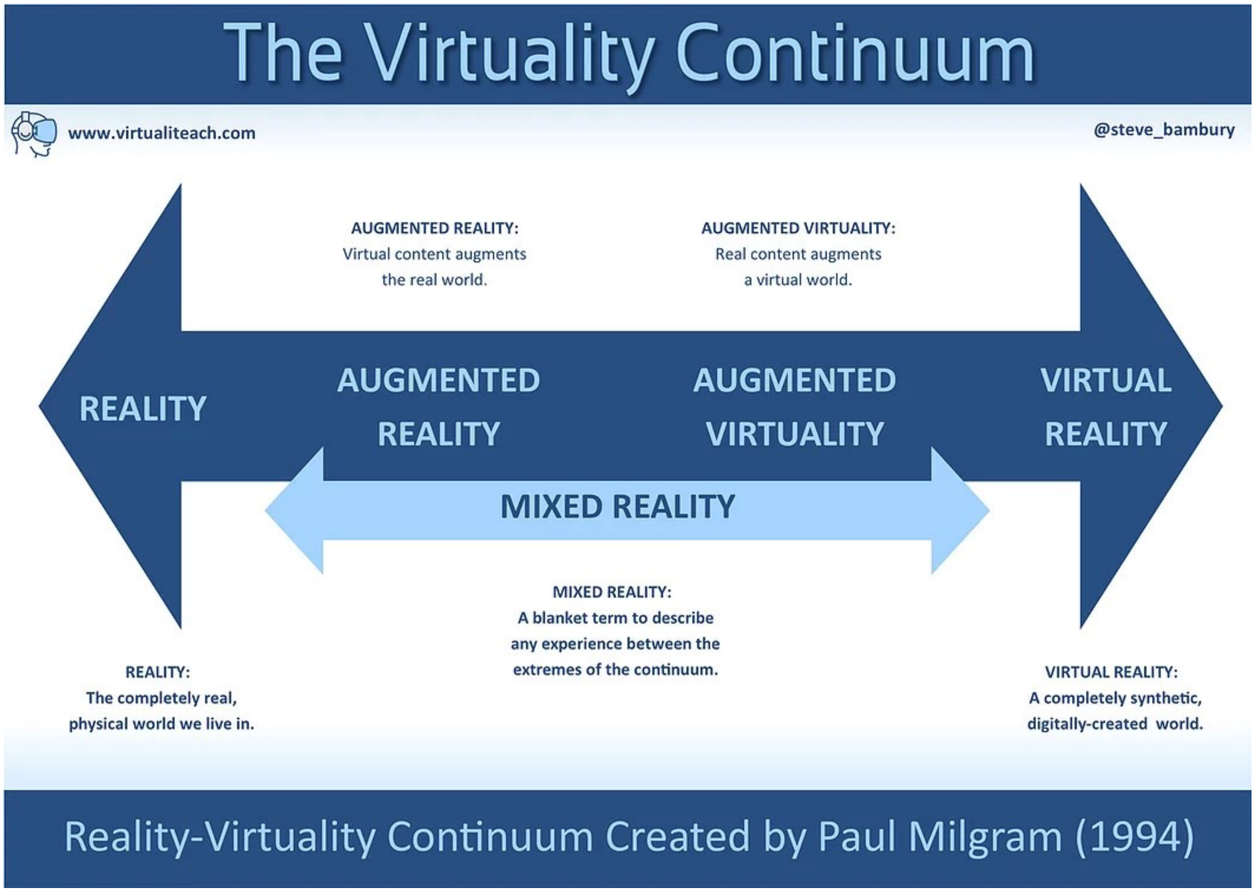

Figure 1.1. The Virtuality Continuum (Milgram & Kishino, 1994). Illustration reprinted with permission from "VirtualiTeach," by Bambury, S. (2019).

Examples of human-machine interfaces and their associated designations on the *virtuality continuum* include the following: Reality being the real-world environment (e.g., driving a motor vehicle in the real world), augmented reality showing mainly the real-world environment being supplemented with digital objects (e.g., heads-up display showing a digitally rendered speedometer on the vehicle's windshield), augmented virtuality showing mainly digital objects being supplemented with real-world objects (e.g., both the vehicle and environment are digital objects, yet photo-capturing equipment allows the driver to act as the only real-world object in this virtual environment) and immersive virtual reality (e.g., every object including the driver, vehicle and environment itself is digitally rendered).

Some experts may use the term, *interreality,* which refers to a virtual environment that contains "hybrid" characteristics, showing both physical-world artifacts and digitally rendered objects within the virtual world itself (Gaggioli et al., 2014). *Interreality* has characteristics inclusive to both virtual world design and functional intention to "bridge" virtual experiences (adjustable by operators) with those that are expected to occur in the real world (Gaggioli et al., 2014). For example, a virtual environment with digitally rendered walls, desks and books, developed to represent a classroom, containing students (both video and voice-recorded from the real world and placed into the virtual environment), allows a teacher (the visitor of this virtual classroom) to practice giving a lecture to either compliant or uncooperative students, adjusted in real-time by an operator.

These designations allow for clarification of essential real-world/virtual world mixtures to contrast differences in VR human-machine interfaces and definitions.

Prevalence of Virtual Reality in Education

VR has been adopted into educational systems and is expected to remain (Cochrane et al., 2017; Martin-Gutierrez, Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017; Saltan & Arslan, 2017). VR hardware, the computer technology that projects virtual environments, is in need of additional software content in order to better match the interests of specific educational disciplines (Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017). While the majority of VR hardware in education is expected to be in the form of mobile devices, such as smartphones, compatible eyewear is also expected to grow in both the consumer and educational market (Martín-Gutiérrez et al., 2017). However, VR software content, including applications that determine the characteristics of virtual environments themselves, are mainly developed for the purposes of entertainment instead of education (Jensen & Konradsen, 2018; Martín-Gutiérrez et al., 2017).

Despite this, it is expected that educational systems will show increased interest to adopt VR as a teaching tool, especially with the emergence of additional software content becoming increasingly available, resulting in improved accessibility for both students and teachers (i.e., user-friendliness, convenience, affordability and enhanced content relatability for specific educational disciplines) (Martín-Gutiérrez et al., 2017). While statistics on VR adoption continue to be determined, some experts base VR's prevalence in education off the financial growth rate of VR hardware companies themselves. The International Data Corporation (IDC) forecasts compound annual growth rates of VR to increase by 78.3% within the next five years, rising from $16.8 billion in 2019 to $160 billion by 2023 (Nagel, 2019). The fields for this growth are expected to include the education sector, with VR for lab and fieldwork in higher education settings having a 5-year compound annual growth rate of 183.4% (Nagel, 2019).

Virtual Reality for Technical and Non-technical Skill Development in Health Sciences

VR has been used to enhance the skills of students within the fields of emergency medicine, health education, urology, gastroenterology, cardiology and some procedural medical task training (Bracq, Michinov, & Jannin, 2019). Many reports also detail VR's usage in disciplines featuring surgical training. Surgical training encompasses the extremes of both technical and non-technical skill requirements, thus it is an optimal field to address when discussing how VR has impacted the field of Health Sciences. Due to VR, surgical training has experienced a "paradigm shift" in terms of teaching protocol (Alaker, Wynn, & Arulampalam, 2016). Previous teaching protocols allowed medical students to entirely practice their surgical skills in operating rooms, yet this practice is now considered obsolete (Alaker et al., 2016). The true definition of technical skills in surgical training has been debated by experts, yet typical scales of student performance may include surrogate measures such as time action analysis, error analysis (e.g., number and intensity of unnecessary tissue collisions by surgical tools), motion analysis and completion of global/specific procedural checklists (Rudarakanchana, Van Herzeele, Desender, & Cheshire, 2015). Experts have debated these requirement thresholds, attempting to determine the differences between novices and experts, yet research suggests that additional scales (e.g., Generic Rating Scales) should also be considered in addition to the surrogate measures (Rudarakanchana et al., 2015). It is the complexity of these measures that convinced surgical training to adopt VR into its teaching protocol, due to VR's capability to record objective measures of student performance while also providing safe, repeatable and predictive training outcomes (Alaker et al., 2016).

Non-technical assessment metrics may include, in order of most commonly measured to least: teamwork, communication, situation awareness, decision making, leadership and stress management (Bracq et al., 2019). Note that most of these metrics are interpersonal skills. Errors in real-world surgical teams often occur due to discrepancies in situational awareness, teamwork ability and communication skills (Rudarakanchana et al., 2015). Non-technical skill assessment of interdisciplinary teams typically include collaborative efforts from multiple disciplines, each working to achieve a primary goal. For example, a simulation of a surgical situation may require a surgical technologist, anaesthesiologist, surgical assistant, imaging expert and a nurse, in addition to the surgeon him/herself. VR has allowed each of the interdisciplinary team members to contribute their efforts towards a simulated surgical process in real-time, sometimes while located across different geographical locations. VR has been used extensively to measure performance levels of non-technical skills, within surgical teams, by using "multisuite setups," which incorporate screen-based operating stations that display digital renderings of virtual patient vitals instead of live patients (Aïm, Lonjon, Hannouche, & Nizard, 2016; Bracq et al., 2019). Non-technical scales include the Oxford Non-Technical Skills Scale (measures team modifiers, both before and after training, checking for parameters such as Leadership, Teamwork, Cooperation, Problem Solving and Situation Awareness (Mishra, Catchpole, & McCulloch, 2009)), Mayo High Performance Teamwork Scale (checks critical resource management skills (Malec et al., 2007)) and Observation Teamwork Assessment for

Surgery (measures both teamwork-related tasks and teamwork-related behaviors including communication, leadership, cooperation, coordination and monitoring (Sevdalis et al., 2009)) (Rudarakanchana et al., 2015). Although screen-based VR simulators are the most commonly used system for training non-technical skills, head-mounted display immersive VR has gained traction since 2016, which was when consumer models such as the Oculus Rift and HTC Vive were officially released (Bracq et al., 2019).

Refer to Chapter 2 for additional examples of VR being used for the training of technical and non-technical skills, across a variety of educational disciplines.

Virtual Reality for Affective Regulation

The discipline of Psychology has taken an interest in VR's ability to engage people in affective regulation. Affective regulation, also known as emotional regulation, pertains to inherent and extraneous processes required to monitor, evaluate and modify human emotional reactions, including their intensities and frequencies, in order to achieve objectives (Thompson, 1994). These objectives, utilizing human-machine interfaces to develop emotional regulation, include the enhancement of mental health, human relations, well-being and empathy (Schoeller et al., 2018). With VR's ability to transfer people to situations that induce feelings of fear, anger, addiction or anxiety, it is possible for investigators to observe people's reactions to these stimuli, which may be unavailable or unsafe outside of a VR controlled environment. Example reports have stated that VR, when combined with biofeedback mechanisms (e.g., interactive systems measuring physiological variables such as cardiovascular data, heartrate and heartrate variation) have concluded VR's capability to measure affective responses from stress-induced situations (Gaggioli et al., 2014; Kniffin et al., 2014; Schoeller et al., 2018). Prior to 2019, a meta-analysis stated that the majority of VR interventions in mental health were used for observing specific phobias (Turner & Casey, 2014), yet that trend has been moving towards the analysis of Virtual Reality Exposure Therapy (VRET) and Virtual Reality for psychological Treatment (VRT), for the treatment of mental disorders (Grochowska, Jarema, & Wichniak, 2019; Valmaggia, Latif, Kempton, & Rus-Calafell, 2016). Mental disorders being treated by VR include anxiety, PTSD, schizophrenia and addiction among others (Grochowska et al., 2019).

VRET and behavioral skill training are the two most common uses of VR in the field of mental health (Grochowska et al., 2019). Many of these previously mentioned mental disorders have been treated by using the following traditional method: cognitive-behavioural therapy, integrated with systematic desensitization, based on exposure to real or imagined stimuli (Grochowska et al., 2019). With VRET, the exposure of what would be a real or imagined stimulus is instead replaced with a virtual environment, depicting a situation that induces symptoms of the mental disorder. The exposure is controlled, safe, and adjustable, allowing for the normalization of affective regulation to take place in a client (Grochowska et al., 2019).

Refer to Chapter 3 for a report on the investigation of VR being used for the affective regulation of performance anxiety in Occupational Therapy students as they prepared for clinical practical exams.

Throughout the upcoming Chapters, there are common recurring themes regarding VR's involvement in education. These themes include the promotion of student engagement throughout the learning process. Other themes feature the student being granted the ability to make decisions within the virtual world, allowing them the ability to experiment and develop their own creativity skills. For the learning of concepts that are intangible or typically inaccessible, VR provides an accessible, safe, repeatable and adjustable option that can evaluate student performance objectively. In Chapter 4, an outline of VR's final task will be discussed: The transfer of its potential from the virtual world to the real world.

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Chapter 2 - Head-Mounted Display Virtual Reality in Post-Secondary Education and Skill Training: A Systematic Review

Abstract

Background: This review focused on how immersive head-mounted display virtual reality (VR) was used in post-secondary level education and skill training, with the aim to better understand its state of the art as found from the literature. While numerous studies describe the use of immersive VR within a specific educational setting, they are often standalone events not fully detailed regarding their curricular integration. This review aims to analyse these events, with a focus on immersive VR's incorporation into post-secondary education.

Objectives: O1) Review the existing literature on the use of immersive VR in post-secondary settings, determining where and how it has been used within each educational discipline. This criterion focused on literature featuring the use of immersive VR, due to its influence on a user's perceived levels of presence and imagination. O2) Identify favourable outcomes from the use of immersive VR when it is compared to other learning methods. O3) Determine the conceptual rationale (purpose) for each implementation of immersive VR as found throughout the literature. O4) Identify learning theories and recommendations for the utilization of immersive VR in post-secondary education.

Methods: A literature review was undertaken with searches of Education Research Complete, ERIC, MEDLINE, EMBASE, IEEE Xplore, Scopus and Web of Science: Core Collection to locate reports on the use of immersive VR in post-secondary curricula.

Results: 119 articles were identified, featuring disciplines across Arts and Humanities, Health Sciences, Military and Aerospace, Science and Technology. 35 out of 38 experiments reported to have found a positive outcome for immersive VR, after being compared with a non-immersive platform. Each simulation's purpose included one or more of the following designations: skill training, convenience, engagement, safety, highlighting, interactivity, team building and suggestion. Recommendations for immersive VR in post-secondary education emphasize experiential learning

and social constructivist approaches, including student-created virtual environments that are mainly led by the students themselves under team collaboration.

Conclusion: Immersive VR brings convenient, engaging and interactive alternatives to traditional classroom settings as well as offers additional capability over traditional methods. There is a diverse assortment of educational disciplines that have each attempted to harness the power of this technological medium.

Introduction

In the year 2012, Palmer Luckey initiated a Kickstarter campaign to fund the Oculus Rift: an affordable head-mounted display (HMD) virtual reality (VR) system that would allow tech-savvy enthusiasts to begin building and experiencing their own virtual environments. Prior to this time, HMD VR technology had often contained head-tracking issues, resulting in inaccurate and poor representations within the virtual world (Robinett, & Rolland, 1992). Despite using the most sophisticated HMD graphics processors that were available in the early and late 1990s, realistic image processing of virtual environments would often overburden the system's computation ability, causing the user to experience tracking and latency issues. In other words, the actions of the user from the real world would often fail to translate accurately into the virtual world. Latency issues were brought to acceptable standards in the early 2010s when computer engineers were able to identify and correct the delays associated between a user's actions and the hardware's capability. Since the mid-2010s, an "unprecedented" uptake of HMD VR has been seen in both academic and industry contexts (Elbamby, Perfecto, Bennis, & Doppler, 2018). VR has steadily been adopted into post-secondary educational systems with relative success, because of its ability to retain student learning and interest while saving resources and improving experimental efficiency (Liang & Xiaoming, 2013).

This review focused on immersive VR in post-secondary level education and skill training to gain a better understanding of its potential ability to train users under higher-order thinking conditions, which typically requires advanced judgment skills such as critical thinking and problem solving. Immersive VR is also capable of training users for advanced conditions that simulate hazardous environments or undesirable social situations that may be less appropriate for users below post-secondary educational levels. Although the literature regarding the use of immersive VR within post-secondary educational settings is quite diverse, these events are often standalone and seldom provide details on how immersive VR is adopted into associated curriculums. This review aims to analyse these events, focusing on how immersive VR can be incorporated into post-secondary education.

Rationale

The International Data Corporation (IDC) expects compound annual growth rates of VR to increase by 78.3% for the next five years, rising from $16.8 billion in 2019 to $160 billion by 2023 (Nagel, 2019). The fields for this growth are expected to include the education sector, with VR for lab and field work in higher education settings having a 5-year compound annual growth rate of 183.4% (Nagel, 2019). With the increased availability of consumer-level HMD VR hardware on the market, such as the Oculus Rift, HTC Vive, Playstation VR and mobile phone technology, this newfound accessibility has led to an upshift in immersive VR adoption into academic settings. There has also been an increase in available software that runs on HMD VR, yet research on what is utilized in academic settings is ever changing and upgrading. An update to understand the "how and for what" aspects of virtual technology, affecting performance in academia, has been recommended (Jensen & Konradsen, 2018). This state-of-the-art review observes the disciplines, methods and theories in post-secondary practice that features the use of immersive VR.

Virtual Reality (VR) – Definition and Features

VR is broadly defined as an environment where users can accept and respond to artificial stimuli in a natural way (Zhang, 2014). Other definitions of VR include the human-machine interface that allows users to "project" themselves into a computer generated world, where specific objectives can be achieved (Zhang, 2014). VR is sometimes known as "Ling-jing" technology (Hu & Wang, 2015; Hui-Zhen & Zong-Fa, 2013). Depending on the setup of the human-machine interface, the components of the hardware and the amount of real-world images that are placed into the virtual world; a user's experience will vary between the differing types of mixed reality including augmented reality (AR), augmented virtuality (AV), mirror reality (MR) and virtual reality (VR) (Cochrane, 2016; Tacgin & Arslan, 2017). See Table 2.1 for a glossary of terms. Note that the proper usage of these terms has not caught up with the rate in which virtual reality concepts have grown (Cochrane, 2016; Tacgin & Arslan, 2017). There are often misconceptions between VR concepts and types. For example, some scientific literature will refer to AR applications as VR and vice versa (Tacgin & Arslan, 2017).

Immersion

One feature of VR is its physical level of immersion, defined by the degree a user associates being within a virtual environment (Parsons, 2015; Rebelo, Noriega, Duarte, & Soares, 2012). Immersion is reduced when a user is able to perceive aspects of the real world while experiencing the virtual world. For example, users who can perceive the frame of a projection screen, depicting a virtual environment that simulates being in outer space, may compromise the users' level of immersion. When classifying the level of immersion, based on the human-machine interface, there are three types: full immersion is achievable when the user utilizes a HMD (goggles, VR helmet or headset); semi-immersion is achievable when the user utilizes large projection or liquid crystal display (LCD) screens; and non-immersion is achievable when utilizing typical desktop computer setups with keyboards and mice (Gutiérrez Alonso, Vexo, & Thalmann, 2008; Parsons, 2015; Rebelo et al., 2012). Note that the main difference between these levels of immersion is due to the user's field of vision (FOV), where an optimal FOV of 180 degrees horizontal and 60 or more degrees vertical is achievable with the HMD hardware (Rebelo et al., 2012). Reduced perception (seeing, hearing, touching) of the real world tends to result in greater levels of VR immersion (Gutiérrez Alonso et al., 2008; Rebelo et al., 2012).

Interactivity

The second feature of VR is its level of interactivity, defined as the degree of accuracy and responsiveness a user's actions represent when using the input hardware (Parsons, 2015; Rebelo et al., 2012). For example, with the use of physical hardware such as motion-sensing gloves, VR systems will allow users to interact with objects that are located within the virtual environment. Using input hardware to interact with a virtual environment is analogous to using a mouse and keyboard to give commands to a desktop computer. Common VR input devices include motion-sensing gloves, remotes, controllers, Lycra suits, Leap Motion (for barehanded gestures) or photo sensors to transfer the user's real-world actions into the virtual world. The position and motion of the user's hands can be updated in real-time with the use of sensors that allow for up to six degrees of freedom. Some input devices are equipped with features to provide kinaesthetic communication to the user, such as force or haptic feedback response. An example of this force feedback occurs in skill training when an operator's surgical tools become resistant to movement, after colliding with visceral tissues in a virtual patient, during simulated laparoscopic surgery.

Imagination

The third feature of VR is grounded with the user's imagination, defined as the extent of belief a user feels is within a virtual environment, despite knowing he or she is physically situated in another environment (Burdea & Coiffet, 2003; Rebelo et al., 2012). Note that interactivity and immersion have a direct effect on a user's level of imagination, which is dependent on the VR's input devices, graphics and objectives (Rebelo et al., 2012). These features of immersion, interaction and imagination form the "VR Triangle (Burdea & Coiffet, 2003)." Note that not all VR setups attempt to emphasize all three features (immersion, interaction and imagination) in a virtual environment. For example, a surgical simulator, designed for skill training, requiring force and haptic feedback controls would place interactivity above immersion and imagination.

Presence is a subjective concept that defines the psychological degree a user understands where it is possible to act within the virtual environment (Rebelo et al., 2012). A user feels present in a virtual environment when he or she feels the experience is derived from the virtual environment, rather than the real world (Rebelo et al., 2012). Deep presence occurs when a user feels both immersion and involvement in the virtual environment (Rebelo et al., 2012). Involvement has been formally defined as the user's attention and effort being placed on a "coherent set of stimuli or meaningful activities and events" (Witmer & Singer, 1994).

The state of presence can be explained with the term fidelity, derived from the Latin word "fidelis," meaning faithfulness or loyalty. A virtual environment is deemed to be of high fidelity when the user's actions, senses and thought-processes closely or exactly resemble those that would be experienced while in the same situation as in the real world. VR experts have classified fidelity into different parts including functional (Swezey & Llaneras, 1997), physical (Champney, Stanney, Milham, Carroll, & Cohn, 2017) and psychological fidelity (Rehmann, Mitman, & Reynolds, 1995). An example of a low fidelity virtual environment would be a driving simulator that uses a gamepad instead of a steering wheel, while the driver's FOV is limited to that of an LCD screen. Whereas an example of a high fidelity virtual environment would be an airplane simulator that has all the relevant controls and visual layout, exactly matching that of a cockpit from a real-world model, allowing pilots to conduct their skill training in the virtual world to prepare for flying in the real world.

Incentives for Adopting Immersive VR into Post-Secondary Education

One principle underlying the development and evaluation of the VR experience is experiential learning, which is aligned with the constructivist theory of learning. Educational simulation is grounded in the pedagogy of mastery learning (Alaker, Wynn, & Arulampalam, 2016; Guskey, 2010). Users are generally more motivated to participate in a virtual environment, which can be instantly adjusted to differing levels of challenge, accommodating varying amounts of cognitive ability (Shin & Kim, 2015). VR can safely provide answers to inaccessible and intangible concepts that would otherwise be considered too dangerous or unethical to perform in real life (Grenier et al., 2015). It is a safe, ethical and repeatable system that produces objective measures of performance while providing real-time feedback to users (Alaker et al., 2016). Non-immersive VR has already been adopted in desktop and distributed platforms, allowing users to share a common virtual space, despite the users being physically located in geographically different locations (Hu & Wang, 2015). Immersive VR users have shown a piqued curiosity to learn with the HMD hardware, which often results in enhanced learning enjoyment (Moro, Å tromberga, Raikos, & Stirling, 2017).

Immersive VR users commonly feel that they have been projected into a different location (place illusion), while experiencing events that are perceived to be real (plausibility illusion) (Sanchez-Vives & Slater, 2005). Sometimes, users will feel their own body is different when represented as an avatar with varying characteristics (embodiment illusion) (Spanlang et al., 2014). Whenever a student is listening to an instructor or reading literature in order to better understand a concept, the student is mainly acting as an observer. The student may perhaps have the ability to interact with the learning experience by asking the occasional question or by completing exercises that are printed in the textbook, yet with immersive VR the student acts as both an observer and "the center of the system" (Gonzalez-Franco & Lanier, 2017). Place, plausibility and embodiment illusions are created by computer generated stimuli that may persuade a user's brain to respond as though the illusions were real. When multiple senses are incorporated into the user-to-object interaction within the virtual world such as vision, audition and tactile/proprioception, a coordination of brain mechanisms are required to process this afferent sensory input and interpret the data coherently (Kilteni, Maselli, Kording, & Slater, 2015). In other words, immersive VR allows a user to learn how they would feel and respond (physiologically, tactfully, and procedurally) when interacting with virtual situations that the brain treats as real.

Obstacles Inhibiting the Adoption of Immersive VR into Post-Secondary Education

One obstacle inhibiting the adoption of immersive VR may involve the ability of educators to schedule immersive VR into their traditional methods of teaching, potentially being unaware about VR technology and how it could be integrated into the curriculum (Cochrane, 2016). It is possible that some universities have concluded that the amount of knowledge or skill gained from using immersive VR is not worth the financial risk. Another possibility is the specific level of detailed knowledge the HMD VR hardware requires in order to use it properly, posing yet another barrier to entry (Gutierrez-Maldonado, Ferrer-Garcia, Pla-Sanjuanelo, Andres-Pueyo., & Talarn-Caparros, 2015). Perhaps VR's biggest obstacle to being accepted into post-secondary education systems is its psychometric validation, where stakeholders must carefully judge the degree to which virtual environments offer training in skills that can be obtained in other less expensive or complex modalities, which are free from simulator sickness (Parsons, 2015). There are two obstacles that inhibit the adoption of immersive VR into post-secondary education: a) Software – There is a lack of applicable content for each discipline and most of what is available is mainly marketed towards self-learners, b) Hardware – HMDs default to being entertainment systems that were not originally intended for classroom use (Jensen & Konradsen, 2018).

Criticisms of Immersive VR in Post-Secondary Education

Immersive VR offers a modern learning channel that caters to multi-sensory learning styles, which sometimes can be more effective than traditional learning methods (Bell & Fogler, 1995; Gutierrez-Maldonado et al., 2015). However, there is meta-analysis literature stating that there is no adequate evidence supporting the consideration of learning-style assessments into general educational practice (Pashler, McDaniel, Rohrer, & Bjork, 2008). Perhaps the most convincing argument for adopting immersive VR into post-secondary education systems would be the already existing disciplines that have integrated such simulations into their curriculums, such as full-room and team simulated robot-assisted (da Vinci Surgery) endovascular procedures in surgical education (Rudarakanchana, Van Herzeele, Desender, & Cheshire, 2015). Unfortunately, medical treatment injuries from these simulated endovascular procedures, due to faulty simulation trainings, have resulted in hundreds of lawsuits due to individual product liability cases (Moglia et al., 2016). The amount of evidence supporting the transfer of user surgical skill from simulation (da Vinci Surgery) applications to real-world settings has sometimes been found to be insufficient (Moglia et al., 2016). In matters of affordability, the incorporation of immersive VR into post-secondary educational systems was initially limited by the cost of the equipment used, yet commercialization of consumer headsets have brought down costs considerably (Gutierrez-Maldonado et al., 2017). Mobile phone technology has reached a level where immersive VR can be readily adapted into HMD format, simply by using low-cost Google Cardboard or Samsung Gear VR headsets (Hussein & Nätterdal, 2015). Although there is little data supporting the use of mobile phone HMD VR technology in post-secondary education, this accessible option is expected to be a "necessary tool in education in the near future" (Hussein & Nätterdal, 2015). Based on a survey that was presented in 2015 by the Educause Center for Analysis and Research (ECAR), 92% of university students within the United States have mobile phones that are capable of accessing enterprise level systems and VR software applications (Cochrane, 2016).

Aim of this Review

This review aims to uncover how post-secondary programs are incorporating immersive VR into post-secondary educational curricula. Its focus involves an interdisciplinary consideration, due to immersive VR's applicability across a wide variety of disciplines. The core assumption is that students optimize learning and practical skill acquisition through experiential learning and hands-on experience, thus a brief summary of each case when immersive VR's positive outcomes will be noted when applicable. The focus on post-secondary level education and its associated goal, skill training, is to gain further understanding of immersive VR's potential ability to train users under higher-order thinking conditions. Specific audiences for this review include: post-secondary education developers, program administrators, curriculum developers, technology research labs (video performance and enhancement labs on academic campuses) and potential instructors who are considering immersive VR as a technological option for experiential learning.

Research Questions

This state-of-the-art review was designed to answer the following research questions:

1. How is immersive virtual reality being used in post-secondary level education and skill training?
2. What conceptual and theoretical perspectives inform the use of immersive VR in post-secondary education and skill training?

Objectives

The following objectives were derived from the research questions:

1. Review the existing literature regarding the use of immersive VR in post-secondary settings, determining how it has been used within each educational discipline. This criterion focused on literature featuring the use of fully immersive VR, due to its influence on a user's perceived levels of presence and imagination.
2. Identify favourable outcomes from the use of immersive VR when it is compared to other methods. This was to determine incentive reasoning for immersive VR's adoption into post-secondary education.
3. Determine the conceptual rationale (purpose) for each implementation of immersive VR as found throughout the literature. This was to gain better understanding of immersive VR's role in post-secondary education.

4. Identify learning theories and recommendations for the incorporation of immersive VR into post-secondary education. This may provide perspectives for immersive VR's adoption into post-secondary education.

Method

Search Strategies

The initial literature search was performed during October 2017 and then updated in January 2019. Acceptable reports were required to have been published since March of 2013 as this was the date that Oculus Rift Developer Kits became first available. This date focused on the "unprecedented" adoption of HMD VR before the mid-2010s as stated by Elbamby and colleagues. After discussing the research question in consultation with a university librarian, the following bibliographic databases were searched (2013 to present): Education Research Complete (EBSCO*host*), ERIC (EBSCO*host*), MEDLINE (Ovid), EMBASE (Ovid), IEEE Xplore (IEEE/IEE), Scopus (Elsevier), Web of Science: Core Collection (Thomson Reuters and Clarivate Analytics). The search strategy included a combination of subject headings and keywords to combine the concepts of HMD Virtual Reality, post-secondary students, education and training. Refer to Table 2.2 for the inclusion and exclusion standards of each report.

Each report's screening process was performed by the lead author. All reports that indicated the use of virtual reality, in their title or abstract, were reserved to complete the first pass. For the second pass, all reserved reports from the first pass had their full texts screened again to confirm the context of immersive VR usage. Methodological quality of each report was not formally assessed beyond the study design used.

Determining the Purpose of Immersive VR

For each report, a designated purpose of immersive VR's implementation was applied to rationalize its function, throughout the literature screening process. Each purpose was based on the screening of keywords found from the literature in order of appearance: report title, keywords (index terms) and abstract. In the absence of an abstract, the main text was screened instead. Table 2.3 shows the keywords used to define immersive VR's purpose in post-secondary education.

Results

The search resulted in a total 1495 reports being found. After the first pass, 215 reports remained after titles and abstracts were screened, along with duplicates removed. During the second pass of screening, the full texts of 215 reports were screened to further confirm eligibility (see Figure 2.1). This resulted in a net total of 119 reports being included in this review. It is noteworthy that in the previous search of October 2017, there were 874 reports found with 58 studies deemed eligible after the screening process, resulting in a 105.17% increase in eligible immersive VR literature in post-secondary education in the span of 15-months.

The 119 reports included in this review discussed the use of immersive VR in experimental, proposal, review or curricular format. Note that some of the reports discussed usage of immersive VR across two or more disciplines, while others may not have included a specific discipline in their description. Table 2.4 provides a breakdown of the literature by discipline under each of the following headings: Arts and Humanities, Health Sciences, Military and Aerospace, and Science and Technology.

Where Immersive VR was Implemented

The majority of immersive VR usage was reported from the field of Science and Technology, specifically in the Education discipline (n = 17). Within the same field, the disciplines of Computer Science and Engineering – General constituted second and third-most of immersive VR usage at n = 6 and n = 4 respectively. The field of Health Sciences' most common disciplines were Psychology and Surgical Education – General at n = 16 and n = 9 respectively. Within the same field, Anatomy represented the third most common discipline at n = 4. The field of Arts and Humanities' most common disciplines to report on immersive VR were Music and Design Thinking at $n = 3$ and $n = 3$ respectively. Military and Aerospace was the field to include the minority of reported instances of immersive VR usage with Aerospace at $n = 1$ and Military at $n = 2$.

Objective 1 – How Immersive VR was used in Post-Secondary Education

Descriptions summarizing the use of immersive VR across each discipline are presented in Table 2.5. It was found that the field of Science and Technology had the majority of literature featuring the use of immersive VR, which is congruent with the findings Freina and Ott reported in 2015. The greatest distribution of reports in this review were found in Education disciplines, next to Psychology in the field of Health Sciences, unlike Freina and Ott's report from 2015 which had most of the representative disciplines being Computer Science, Engineering and Mathematics. While this review focused on the use of immersive VR at the post-secondary education level, Freina and Ott's review in 2015 was inclusive to all levels of education, including middle school. This paper's focus on higher level education could explain why disciplines such as of Education and Psychology had the greatest proliferation of immersive VR usage, possibly due to VR's ability to support environments that allow for more control than what would be available in real life, especially when dealing with intangible concepts. Having access to a platform that can subject users to intangible stimuli such as fear, addiction and violence was found to be a definite incentive for Psychology to adopt immersive VR.

The incentives for immersive VR being incorporated into post-secondary education and skill training may include one or more of the following: the maintenance of ethical principles, overcoming problems concerning time and space, increasing the physical accessibility of environments that are not normally accessible and/or overcoming what would normally be a dangerous situation (Freina & Ott, 2015). Surgical Education's demand for immersive VR can be explained by ethical principles, which allows users to train technical skills without subjecting patients or the users themselves to the possibility of harm (Freina & Ott, 2015; Ziv, Wolpe, Small, & Glick, 2003). This same ethical principle may also explain the demand of immersive VR in other disciplines such as Dentistry, Nursing, Optometry, Paramedicine, Public Health, Rehabilitation and Veterinary Education. The field of Health Science's main incentive to incorporate immersive VR is assumed to involve concepts of experiential learning, which allows users to learn by interacting with various environments affiliated with their disciplines. Experiential learning principles may explain the demand of immersive VR for the majority of disciplines in Science and Technology as well as Arts and Humanities. The increase of physical accessibility to environments that are not normally accessible would apply toward disciplines such as Astronomy, while VR's ability to overcome dangerous situations would apply to fields such as Military and Aerospace. Some universities (Maryland University College) are acting to ensure they remain on the technological "cutting edge," allowing students to learn by creating content (Becker et al., 2017).

Objective 2 – Favorable Outcomes from the use of Immersive VR

Thirty-eight experiments were found in the 119 reports, mostly comparing immersive VR (HMD) with one of the following non-immersive platforms: desktop display screen, 2D video, mobile phone, digital tablet or stereoscopic desktop display screen. Non-VR comparators included live actors, real-world analogs, "traditional methods," pencil-and-paper or nothing as a control. Of these 38 experiments, 35 reported to have found a positive outcome favouring the use of immersive VR with: 13 showing an increase in user skill or knowledge, 10 showing an increase in user engagement or enjoyment, 8 stating immersive VR had some form of extra capability over traditional methods and 4 stating both an increase in user skill and engagement.

When favourable outcomes were noted from the reports, only experimental processes were considered, since the absence of a comparator, be that either some form of established non-immersive VR or traditional method, may weaken quality inferences to be made. This review reported only the outcomes from reports that had such comparators in their study design and found that 35 out of the 38 experimental outcomes were positive, showing mainly an increase in user skill, knowledge, engagement and enjoyment. Some reports found immersive VR to have additional capability over those of traditional methods, such as the ability for users to train on an avatar that was diagnosed with a rare disease, which could not be replicated on a traditional model. Immersive VR should not render traditional methods obsolete, such as pencil-and-paper tests, since those methods are already well established and free from potential simulator sickness.

This review did not assess the quality of each study's experimental design as found throughout the literature, however a review conducted by Jensen and Konradsen in 2018 reported the quality assessment of 21 HMD VR experiments, showing a "below average quality" as outlined by the *Medical Education Research Study Quality Instrument.* Jensen and Konradsen identified in 2018 a number of setups where HMD VR is useful for skill training including the training of cognitive skills related to spatial and visual knowledge, psychomotor skills related to head-movement, visual scanning, observational skills and affective control of emotional response to stressful or difficult situations. Future quality assessments of HMD VR experimentation are warranted as optimal setups in learning and skill training contexts are found, along with continuous improvements to VR hardware and software.

Objective 3 – Conceptual Rationale of Immersive VR in Post-Secondary Education

This review aimed to understand the literature's reasoning for implementing immersive VR, with the use of a conceptual method to determine each system's rationale. This method, based on keywords found in each report's title, index terms and abstract, allowed for identification of immersive VR's purpose to further understand its role in each context. The majority of reports had the intention of using immersive VR for the purpose of skill training, followed by the optimization of interactivity between users and objects within the virtual world. Highlighting of objects in both the virtual or real world were other reasons for the implementation of immersive VR, especially when visual markers were provided to users in the form of AR. The use of immersive VR for the purposes of engagement, safety, convenience, team building and suggestion were also found. These purposes might be able to justify the reasoning of immersive VR in higher education, despite the literature rarely showing pedagogical rationales for its use (Savin-Baden et al., 2010).

Regardless of the sophistication of a virtual system's hardware, the rationale of each report affected how a virtual environment was designed, implemented and presented in the literature. A conceptual pattern of rationale was found, detailing the purpose of each instance of immersive VR's implementation. Each simulation's goal included one or more of the following purposes: skill training, convenience, engagement, safety, highlighting, interactivity, team building and suggestion.

Skill training

This purpose resulted in a virtual environment that focused on the development of knowledge and enhancement of a user's competency in a specific task. An example of this purpose includes the military training room-clearing tasks as reported by Champney and colleagues in 2017. Note that it is possible for the skill training to involve teacher-to-student interaction, such as the virtual environment as outlined in the gesture-operated astronomical virtual space as reported by Tajiri and Setozaki in 2016.

Convenience

These virtual environments focused on reducing the difficulties and/or resources required to train the same task in the real world. This purpose included factors such as time, location and cost. An example of immersive VR being used, with a purpose focused on cost convenience, would be the low cost surgical training system a reported by Mathur in 2015. For location convenience, this would feature a VR system designed to either allow multiple users to interact with one another, despite being in different geographic locations, or provide a portable system that allows training for a user at any convenient location. An example of immersive VR being used with a location convenience purpose would be the therapist-to-patient training VR system as reported by Wen and colleagues in 2014. Liang and Xiaoming's report in 2013 discussed the concept of a "self-simulation laboratory," used to reduce workspace requirements- a concept that expands on location convenience by featuring a multitude of different electronic engineering equipment that can be experienced within a single space. An immersive VR system that focused on time convenience would expand the windows of opportunities available to beyond what a user is normally allowed. Real-world time constraints that restricted a student's hours of lab availability, plus the preparation and clean-up time required, could be circumvented with VR simulation (Lau, Kan, & Lee, 2017).

Engagement

This purpose focused on the implementation of virtual environments that encouraged a user's desire to learn the presented material found in the simulation. This purpose included the use of virtual environments that gained a user's interest, yet expanded further by including VR features such as interaction, immersion and imagination. Purposes of engagement allowed a user to feel involved in the learning process, usually by being offered challenges or interactive elements within the educational virtual environment. An example of immersive VR being designed with a purpose focused on engagement would be the Jaunt VR video program study, which featured scenic views of Nepal, as reported by Lee and colleagues in 2017.

Safety

A virtual environment that focused on safety may have included some or all of the following: a) The practice of awareness skills necessary to reduce the probability of accidents occurring, b) The practice of technical or non-technical skills necessary to handle an abnormal operating condition, c) The ability to interact with virtual objects that would be deemed too dangerous in the real world. Some virtual environments were mentioned to have been programmed to allow for damage to occur within the virtual world, allowing users to safely learn from mistakes that would normally cause real-world machinery to collapse or cause personal injury (Potkonjak et al., 2016). Dangerous motors and gearboxes in mechanical devices were reported to be exposed in the virtual world, allowing users to see working parts in action (Potkonjak et al., 2016). Taljaard stated in 2016 that virtual field trips allow users to visit simulated places, which could be inaccessible or dangerous. For example, geologists could experience a VR field trip that takes place on the top of a volcano (Taljaard, 2016). An example of immersive VR being implemented with a purpose focused on safety would be the Distributed Situation Awareness study, featuring safety awareness training in industrial plant operators, reported by Nazir and colleagues in 2015. Another example would be the virtual environment Jouriles and colleagues presented in 2016, which was used to measure bystander behaviour in response to sexual violence.

Highlighting

This purpose focused on virtual environments that emphasized key elements and variables of objects, supplementing users with additional information. Highlighting was inclusive but not limited to AR. It was also capable of providing quantitative feedback to users, based on their performance on specific tasks within the virtual world. An example of immersive VR being implemented, with a purpose focused on highlighting, would be the software editing training markers as reported by Stigall and Sharma in 2017. Another example of highlighting, featuring the use of AR, would be the use of Google Glass in art galleries to provide the user with supplementary information, reported by Leue, Jung and tom Dieck in 2015.

Interactivity

Although interaction is the core emphasis for many immersive VR systems, a simulation with interactivity as the main purpose would attempt to make the virtual environment feel as natural as possible. Interactivity also focused on optimizing the user control, arranging the system to respond to user input information both quickly and accurately, granting users a sense of real human-computer interaction (Liang & Xiaoming, 2013). When computer engineers reported an attempt to optimize user control by reducing latency, increasing computer processing speed or improving motion tracking; the main purpose focused on interactivity from a hardware perspective. An increase in interactivity from a software perspective would be accomplished by programming the virtual object to respond appropriately to multiple forms of user input or by increasing user-friendliness. Purposes of interactivity may have included virtual environments that were designed to feature optimal accessibility, such as the virtual multiplayer child-operated puppet story as presented by Liang and colleagues in 2017.

Team Building

A virtual environment that focused on team building may have included some or all of the following: a) The practice of technical and/or non-technical skills in groups of trainees so that they achieve proficiency in a skill before the real procedure is performed (Rudarakanchana et al., 2015), b) The promotion of team collaboration during production and planning. An example of immersive VR being implemented with purpose focused on team building would be the team collaboration in game design curriculum as reported by Timcenko and colleagues in 2017.

Suggestion

This purpose was focused on the use of immersive VR to improve a user’s attitude toward a community, cultural movement or service. Immersive VR was reported to be capable of stimulating enthusiasm within the learning of students, changing the way they think about certain perspectives (Hui-Zhen & Zong-Fa, 2013). An example of immersive VR being implemented, with a purpose focused on suggestion, would be Real and colleagues 2017 study on best-practice communication skills, encouraging patients to receive vaccinations. Another example featuring the use of immersive

VR to discourage specific behaviour, would be the cue reactivity study as reported by Gupta and Chadha in 2015, aimed at discouraging cigarette smoking for users with an addiction problem.

Additional Rationale

Suh and Prophet (2018) reported a classification of research themes and contexts for immersive VR by using the stimulus-organism-response (S-O-R) framework, where the variables of their found 54 studies were classified to determine relationships. Several factors were found to be related between immersive VR's system features and sensory, perceptual and content stimuli (Suh & Prophet, 2018). Content stimuli included immersive VR topics such as learning and training, psycho- and physiotherapy, virtual tours, interactive simulation and gaming stimuli (Suh & Prophet, 2018). The 119 reports as identified from the literature in this review is relatable to Suh and Prophet's 2018 reported classification system, especially for the topics identified as content stimuli.

Objective 4 – Theories and Recommendations for Incorporating Immersive VR into Post-Secondary Education

This review found two papers recommending a social constructivist approach for how immersive VR could be incorporated into post-secondary education curricula (Cochrane, 2016; Haefner, Haefner, & Ovtcharova, 2013). Social constructivist approaches include proposals on how student-created virtual environments are mainly led by the students themselves, using a team collaborative style. Experiential learning allows the students to use their newly created virtual environments to role-play their actions in simulated scenarios, aiming to achieve mastery over their discipline. This is reminiscent of Gonzalez-Franco & Lanier's (2017) idea on the student acting as "the center of the system," providing the computer-generated virtual environment triggers the user's learning response as though the virtual stimuli matches that of the real world. The training of student awareness for paramedic clinical practice by using VR 360-degree interactive images, projected by HMD (smartphone), allows for the facilitation of student-created content in authentic simulation

(Cochrane et al., 2017). Although Cochrane's recommendations were exemplified in design thinking, journalism and paramedicine; the method's potential transferability seemed convincingly capable of being used in other disciplines within the fields of Arts and Humanities or Health Sciences. The theory of implementing a virtual event that makes the user feel central to the environment, resulting in an authentic illusion, is a key feature that must be retained when adapting VR learning frameworks from one discipline to another. Haefner and colleagues' recommendations (2013), which mentioned interdisciplinary teamwork, also possessed convincing transferability beyond just the discipline of Engineering. A future study that focuses on a curriculum that is feasible and vastly adaptable to most disciplines would be a definite recommendation for future research. Table 2.6 summarizes the educational theories associated with the use of immersive VR.

Discussion

This review focused on how immersive VR was used in post-secondary level education and skill training, determining if any new educational perspectives have emerged, with the goal of obtaining an improved understanding of the state of the art as found from the literature. The most important considerations when conducting this method of literature search included: a) attaining an unbiased selection of papers for review, b) accepting only the literature that stated the use of fully immersive VR (HMD hardware or similar), c) limiting the literature by date of publication to no earlier than March of 2013.

Curricular Recommendations

Immersive VR programs could be incorporated into an academic curriculum as either a full-course program or as supplementary material to an already-existing course. Immersive VR for supplementing a large classroom size would possibly be best performed by finding relevant software, in the form of 360-panormic images or videos for mobile phones, depicting environments that resemble lecture materials for users to experience. For example, students of surgical or nursing education could experience 360-operative video, similar to the one used in Harrington and colleagues' surgical study in 2018. Supplementing a small classroom size would possibly allow for relevant software to be experienced on an immersive HMD VR consumer model, similar to the cardiac anatomy setup (Sharecare VR) in Maresky and colleagues study in 2018.

For full-course programs that may attempt to integrate immersive VR, Alfalah (2018) reported the following:

- Faculty members should be prepared to allocate time for training in the development of software and utilization of immersive VR hardware.
- Detail a realistic and practical plan for the transformation or creation of the course.
- Increase the awareness to faculty members about the technology integration via staff emails, learning management systems, seminars and posters.
- Consider administrative support to reduce faculty member load.
- Enable collaboration between faculty members to share ideas for enhancing the system.

Full-course programs that prefer to feature student-developed immersive VR programs could either be: *Simple* – Videos adapted into 360-degree format for mobile phone VR by using GoPro cameras with their videos merged into a single equirectangular video by Kolor Video Pro and Giga software (Harrington et al., 2018), or *Advanced* - Software creation as an immersive VR program for consumer based HMDs, developed by a graphics rendering engine (Timcenko, Kofoed, Schoenau-Fog, & Reng, 2017). It is possible for an immersive VR program to be programmed so that it can switch between HMD VR and desktop PC controls, which would allow for users who are sensitive to simulator sickness to have access to a non-immersive alternative. The option to add platform crossover versatility to software would be expected to require more development time.

Cochrane in 2016 summarized a post-secondary educational framework that allowed students to devise and submit their own VR content in order to learn and classify AR projects, featuring disciplines including journalism, paramedicine and graphic design. For example, paramedicine would feature students using immersive VR (mobile) to conduct pre-practice of a critical care scenario before they entered a simulation room where they performed resuscitation procedures (Cochrane, 2016). Cochrane in 2016 and 2017 summarized six informing pedagogies and their definitions for the application of mobile VR in education: Rhizomatic Learning – "Negotiated ecology of resources," Social Constructivism – "Collaboration tools for project planning (e.g., Google Docs)," Heutagogy – "Student-generated content: 360 degree camera rig and stitching software," Authentic learning: situated content – "Shared 360 video (e.g., YouTube 360 via HMD and Google Cardboard), Authentic learning: situated context – "360 degree immersive environment simulation," Connectivism – "Community Hub (e.g., Google Plus, Facebook and Twitter)."

The key requirements of a successful practical VR course in interdisciplinary engineering education were found to be as follows: a) primary emphasis on VR task design while maintaining student creative freedom, b) clearly defined tasks for each individual group member's role, c) the use of software platforms that were open source with strong community followings (Haefner et al., 2013). Based on the student group configuration and information from instructor-to-student collaboration, the students were recommended to define each individual group member's role in accordance to their knowledge and interests. In smaller groups, status meetings of the project's development were expected to be easier to organize and yield qualitative, well-structured project results (Haefner et al., 2013). Larger groups that consisted of more than 10 students would require a project manager (student designated) who is proficient in handling conflict management, with less emphasis on sub-task support (Haefner et al., 2013). It was important for the students to provide continuous progress updates, within the status meetings, so that any issues regarding design of the VR project are detected early (Haefner et al., 2013).

Considerations of Virtual System Design

The purpose of a virtual environment will determine how it is designed and implemented. A post-secondary educational virtual environment can be divided into two types: an environment that represents the real world (e.g., historical location) and/or a computer generated 3D object (e.g., interactive control panel) (Lee & Wong, 2008). Depending on whether or not the system is designed to be portable and the amount of interaction a user needs to have with the virtual environment will determine its varying HMD hardware and input devices. If the user is expected to interact with the virtual environment and perform actions that are meant to accurately represent those that would be performed in real life; the input hardware is expected to maximize fidelity (e.g., a haptic arm that provides force feedback during surgical simulation). Likewise, if the user is not expected to interact with the virtual environment or the user's actions do not have to accurately represent those that would be performed in real life; the input hardware can be of low fidelity (e.g., using a gamepad to move within the virtual environment instead of walking).

Although low fidelity simulation may initially seem less useful than high fidelity, low fidelity virtual environments are associated with lower hardware costs and allow for acquiring "procedural knowledge" at the expense of "higher-order skills and strategic knowledge (Champney et al., 2017)." It is important to note that high fidelity virtual environments are associated with greater hardware costs and may "overwhelm and distract early procedural learning" (Champney et al., 2017). An example of public-speaking skill development, featuring low amounts of user interaction, would be a virtual environment depicting a large crowd, where the user is tasked with standing on stage to be exposed to this social anxiety stimulus. The use of exposure therapy in VR simulation in this manner would be designed to habituate a user's fear thought-process into a more adapted one, removing the pathological kind that distorts reality and increases escapist tendencies (Bissonnette, Dubé, Provencher, & Sala, 2016).

It should be noted that a user's level of technical proficiency should be factored into how virtual objects are intended to be interacted with. A user with a university background in mechanical engineering would most likely have no trouble utilizing complex button-operated input controllers to interact with a virtual object (e.g., Virtual Workshop as reported by Muller and colleagues in 2017). Likewise, a user who is inexperienced with technical hardware would likely benefit with a simpler input device to interact with virtual objects (e.g., Liang and colleagues' (2017) child-operated virtual puppet story with gesture control, detected by Leap Motion).

Limitations of this Review

Limiting the literature search to March of 2013 and onward allowed this review to focus on a specific point when educational perspectives were formed at a time when immersive VR's rate of availability was greater than before. This date limit, however, may have come at a cost as some papers not included may have discussed educational perspectives, formed prior to this date, which may still be in use. By accepting only the literature featuring the use of immersive VR, this review was able to determine educational perspectives that were potentially and optimally invoked by concepts such as experiential learning, immersion, interactivity and imagination. This consideration also allowed this review to find positive outcomes determined by the literature when immersive VR was compared with non-immersive VR. This review focused on immersive VR's performance in post-secondary educational settings, containing interpretations that may not be adequate for less advanced levels of education. Further defined subtypes of post-secondary education terms, such as Masters or Bachelor, were not used in this review's search method, which may have impacted the ability to find all applicable literature.

Conclusion

This review on the use of immersive VR in post-secondary education and skill training has revealed recommendations and purposes for how it could be implemented into curricula. Common positive outcomes, featuring the use of immersive VR, have shown to promote student engagement and skill acquisition. Immersive VR brings convenient, engaging and interactive alternatives to traditional classroom settings as well as offers additional capability over traditional methods. This review has highlighted detailed reports that have successfully implemented immersive VR into their curricula. There is a diverse assortment of educational disciplines that have each attempted to harness the power of this technological medium. It is expected for immersive VR to become further adopted into academic settings in the future. Will your facility be the next to implement immersive VR?

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

BC, SE, and MR co-conceptualized the review study. BC completed the literature search and analysis in consultation with and guidance from MR. BC led the manuscript writing process. SE and MR contributed to the writing process and revisions. All authors approved the final version.

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Table 2.1

Glossary of common terms describing Virtual Reality

Term	Definition	Examples
Immersive VR	The user is entirely surrounded by the virtual environment, encompassing optimal field-of-view (Rebelo et al., 2012).	HMD VR. CAVE.
Non-immersive VR	The user is not entirely surrounded by the virtual environment, allowing images of the virtual world and real world to both be seen simultaneously (Rebelo et al., 2012).	AR. AV. Desktop computer experience.
Augmented Reality (AR)	Also known as stacked VR, computer images are superimposed onto a glass or lens display, simultaneously showing both real world and computer generated images. The view is mainly the real world, supplemented with computer generated graphics.	A marker overlay is projected onto a pair of glasses (Smart Glasses) so the user can see both the real world and virtual overlay at the same time.
Augmented Virtuality (AV)	A real-world image is projected into a virtual world, allowing the integrated real-world image to interact with the virtual world in real-time. A view that is mainly the virtual world, supplemented with captured real-world images.	A camera places a real-world image of the user into a computer generated soccer field, allowing the user to see him or herself move and kick a virtual ball. (Immersive Rehabilitation Exercise (IREX) systems).
Avatar	Derived from the Sanskrit word that refers to the God Vishnu's manifestation on earth (Milgram, Takemura, Utsumi, & Kishino, 1995; Trepte, Reinecke, & Behr, 2010), this is a projected image and representation of a user or artificially intelligent character within a virtual world.	User acts as a firefighter in a fire-safety virtual environment. World of Warcraft character.
Cave Automatic Virtual Environment (CAVE)	Images are projected onto the walls, ceilings and floors of a room-sized cube, which change based on a user's actions while he or she is inside the room. The movements of the user are often detected by tracking technology.	A user sits in a fixed wheelchair, placed in the middle of a room. The projected images on the floors, ceilings and walls create the effect that the user is moving along a path, within a garden, as the chair's wheels are spun. Second life.

Distributed Reality	A web-based virtual environment, where multiple users control their avatars to interact with each other in the virtual world, despite the users being physically located in different geographical locations.	World of Warcraft.
Engine	A framework of coding used to script and animate computer programs such that they become virtual worlds.	Unity. Unreal Engine 4.
Latency	The delay between a user's action (head rotation) and corresponding change in the virtual environment to represent the user's new field of view.	Lag. Sensor sampling delay. Image Processing delay. Network delay.
Mirror Reality	A virtual environment that aims to recreate a copy of the real world.	The digital viewfinder of a camera shows a pixel image of the real world.
Mixed Reality	Also known as hybrid reality, real-world images are combined with a virtual world. The amount of real-world images that are used in the virtual world determines the mixed reality's abilities as defined by the reality-virtuality continuum (Milgram et al., 1995).	AR. AV.
Smart Glasses	Mobile computers that combine HMD with sensors to display computer graphics in the real world.	Google Glass. Microsoft HoloLens.
Stereoscopy	Also known as stereoscopics or stereo imaging. The perception of three-dimensional (3D) images that are often created by presenting two offset images, separately shown to the left and right eye.	Anaglyph 3D films, viewed with red and blue filter glasses. Most modern HMD units feature stereoscopic 3D.
Tracking Technology	Sensors that detect movement, position and angle of an object or user while in a virtual space. The sensors relay numeric coordinates to the computer or base station for processing.	A user's hands are represented in the virtual space with the use of controllers. Infrared sensors or gyroscopes on the controllers provide positional data to a base station for processing.
Virtual Reality (VR)	A computer system that creates an artificial environment where users can project themselves and respond to artificial stimuli in a natural way or complete specific objectives (Zhang, 2014).	A user enters a virtual world, seeing and interacting with the virtual environment, with the use of a HMD and gloves respectively.

Table 2.2

Search criteria and terms

Inclusion Criteria	Exclusion Criteria
• Report stated immersive VR usage for post-secondary curricula (graduate, undergraduate or college) or skill training • Mentioned the potential use of immersive VR in the future, despite conducting an intervention with an alternative method. • All methods of immersive VR including qualitative, quantitative, descriptive and review reports were accepted. • Reports were accepted in all languages in article, conference, book or magazine format.	• VR platform was not immersive or report does not introduce or discuss possible usage of immersive VR technology. • Participants were not specified as post-secondary students (the exception is the investigators were performing the study as part of post-secondary curricula). • The report stated that "VR was used" but the exact platform, nature of simulation modality or hardware configuration failed to confirm immersive VR hardware.

Search terms used: "virtual reality" OR "Head-mounted display" OR HMD
AND undergraduate OR college OR post-secondary OR postgraduate
AND curricul* OR educat* OR teach OR learning OR training

These terms were entered into the databases mapped to the following fields: title, abstract, subject heading word and keyword heading word. Each search was limited to reports published on March of 2013 (emergence of Oculus Rift Developer Kits) to January 2019.

Table 2.3

Determining the purpose of immersive Virtual Reality in Post-Secondary Education

Keywords in Title, Index Terms, Abstract or Main Text	Assigned Purpose
Augmented Reality or Guiding	Highlighting
Attitude, Enjoyment or Interest	Engagement
Education, Training, Teaching or Learning	Skill Training
Interaction, Response, Real, Gesture, Role Play	Interactivity
Low Cost, Cost or Portability	Convenience
Empathy, Influence or Motivate	Suggestion
Leadership, Team Collaboration or Virtual Teams	Team Building
Risk-assessment, Accident avoidance Safety	Safety
A report with four or more above qualifying labels	Various

Table 2.4

Frequency of immersive Virtual Reality literature across educational disciplines

Heading	Frequency of Use in Literature	Total
Arts and Humanities	2x Art, 2x Business, 3x Design Thinking, 2x History, 2x Journalism, 3x Music, 1x Political Science, 1x Religious Studies	16
Health Sciences	4x Anatomy, 1x Dentistry, 3x Nursing, 1x Optometry, 3x Paramedicine, 3x Physical Education, 16x Psychology, 2x Public Health, 2x Rehabilitation, 9x Surgical Education – General, 3x Surgical Education – Neurosurgery, 2x Veterinary Education	49
Military and Aerospace	1x Aerospace, 2x Military	3
Science and Tech	3x Architecture, 2x Astronomy, 1x Chemistry, 6x Computer Science, 2x Driving, 17x Education, x3 Engineering – Civil, 2x Engineering – Computer, 1x Engineering – Electrical, 4x Engineering – General, 2x Engineering – Mechanical, 1x Engineering – Numerical Control, 1x Engineering – Pneumatic, 1x Forensics, 1x Geology, 1x Industrial Plant Operation, 1x Information Interfaces, 3x Physics	52
Various	4x Various	4

Table 2.5

Literature summary of immersive VR usage across educational disciplines

Heading	Discipline	Authors	Purpose	Description
Arts and Humanities	Art	(Kuhn, Lukowicz, Hirth, & Weppner, 2015; Leue, Jung, & tom Dieck, 2015)	Skill Training / Highlighting	Google Glass implemented in art galleries.
Arts and Humanities	Business	(Lee, Sergueeva, Catangui, & Kandaurova, 2017)	Engagement	Experiment: Compared Google Cardboard HMD units to non-immersive VR. Google Cardboard users reported greater levels of enjoyment and interest than the non-immersive users
Arts and Humanities	Business	(Schott & Marshall, 2018)	Convenience / Interactivity	A virtual environment of a Pacific Island allowed users to find avatars of community members and government officials, who explained how the island's relationship with tourism acted as the main source of income. The project was based on a "situated experiential education environment."
Arts and Humanities	Design Thinking	(Cochrane, 2016)	Interactivity	Proposal: A curriculum for the field of new media production and design, where artwork and graphical design showpieces can be displayed in virtual showrooms and allow user interactivity.
Arts and Humanities	Design Thinking	(Cochrane et al., 2017)	Team Building	Proposal: A curriculum for the field of visual design, where students can collaboratively share their artwork through Google Maps, providing 360-panoramic views of their project ideas.
Arts and Humanities	Design Thinking	(Rive & Karmokar, 2016)	Team Building	Proposal: VR design communities to team-collaborate online.
Arts and Humanities	History	(Checa, Alaguero, Arnaiz, & Bustillo, 2016)	Skill Training / Engagement	Experiment: Compared HMD VR to regular video for historical virtual environments tour. Students' overall satisfaction was found to be rated higher for the immersive VR method.
Arts and Humanities	History	(Yildirim, Elban, & Yildirim, 2018)	Skill Training / Interactivity / Engagement	VR glass experience featured historical 360-degree views of Kaaba to learn about Islamic History. Users could interact with learning points to receive audio information. Users stated during interviews that VR in history course activities would be beneficial.
Arts and Humanities	Journalism	(Cochrane, 2016)	Engagement	Panoramic VR video to enhance readers' experience.
Arts and Humanities	Journalism	(Markowitz, Laha, Perone, Pea, & Bailenson, 2018)	Engagement / Skill Training / Suggestion	HMD VR (Oculus) users experience climate change (ocean acidification) from the perspective of either a human scuba diver or piece of coral reef. Users reported positive knowledge gained and improved interest about climate change.

Arts and Humanities	Music	(Orman, Price, & Russell, 2017)	Highlighting / Skill Training	Experiment: Compared HMD VR to no VR to enhance a user's wind band conducting ability. HMD VR learning environment demonstrated greater conducting ability than those not using VR
Arts and Humanities	Music	(Hong-xuan Bian, 2016)	Skill Training / Engagement	VR musical teaching system was found to enhance student enthusiasm and learning.
Arts and Humanities	Music	(Kilteni, Bergstom, & Slater, 2013)	Engagement	Experiment: Behavioural changes in a user's hand drumming ability, while performing as an appropriately perceived avatar while using HMD VR.
Arts and Humanities	Political Sciences	(Hui-Zhen & Zong-Fa, 2013)	Skill Training / Suggestion / Team Building	Proposal: HMD VR classrooms to encourage communication between students and teachers.
Arts and Humanities	Religious Studies	(Johnson, 2018)	Convenience / Skill Training	360-videos of each religion were shown with HMD VR, requiring users to identify each based on narrative and environmental cues. Students learned empathetic understanding, ritual and behaviour involving religious theory.
Health Sciences	Anatomy	(Moro et al., 2017)	Highlighting / Skill Training / Engagement	Experiment: Immersive VR compared with non-immersive for cranial anatomy learning. No differences found between immersive and non-immersive VR, AR or tablet devices on student learning, except immersive VR promoted user immersion and engagement and promise to enhance student learning in anatomical education.
Health Sciences	Anatomy	(Maresky et al., 2018)	Skill Training / Interactivity	Experiment: Immersive VR compared with independent study for cardiac anatomy learning (Sharecare VR). VR condition demonstrated enhanced learning performance and student engagement.
Health Sciences	Anatomy	(Albabish & Jadeski, 2018)	Skill Training	Proof of concept: Dissection-based human anatomy course (for thorax and abdominal regions) both for on-site and distance learning.
Health Sciences	Anatomy	(Stepan et al., 2017)	Skill Training / Engagement	Experiment: Randomized controlled study compared online textbooks with VR HMD (Oculus) to enhance student neuroanatomical knowledge (ventricular and cerebral). HMD VR was shown to be more engaging and similar to online for knowledge acquisition.
Health Sciences	Dentistry	(Hoffman et al., 2001; Sabalic & Schoener, 2017)	Engagement/ Convenience	3D goggles to patients, depicting relaxing virtual environments, in an effort to reduce anxiety during dental procedures.
Health Sciences	Nursing	(Kleven et al., 2014)	Various	Proof of concept: Both medical and non-medical users learn applicable material in a Virtual University Hospital.
Health Sciences	Nursing	(Smith et al., 2018)	Skill Training / Interactivity	Experiment: Immersive VR compared with desktop to enhance student learning on decontamination skills. No significant difference found between groups, but immersive VR system showed greater interactivity capability.

Health Sciences	Nursing	(Aebersold, 2018)	Skill Training /	Report summarizes VR concepts in nursing, providing simulation design ideas that are supported by theoretical concepts.
Health Sciences	Optometry	(Leitritz et al., 2014)	Highlighting / Skill Training	Experiment: Measured user's ability to draw an optic disc, comparing conventional binocular indirect ophthalmoscopy vs HMD AR ophthalmoscopy (ARO). ARO found to allow for learning various retinal diseases.
Health Sciences	Paramed.	(Cochrane et al., 2017; Cochrane, 2016)	Safety	Proposal: A curriculum for students to use VR (Google Cardboard) to analyze potential safety risks, prior to entering paramedical situations.
Health Sciences	Paramed.	(Ferrandini et al., 2018)	Skill Training	Experiment: HMD VR (Samsung Gear) compared with clinical simulation (live actors) to enhance student rapid treatment ability in Mass Causality Incidents. HMD VR found to be as efficient as clinical simulation. HMD VR users showed lesser stress levels than clinical simulation.
Health Sciences	Physical Education	(Li, 2014)	Skill Training / Highlighting	HMD VR used for sports training and telemetry data.
Health Sciences	Physical Education	(Choiri, Basuki, Bagus A, Sukaridhoto, & Jannah, 2017; Pan, 2015)	Skill Training / Interactivity / Safety	HMD VR to imitate real training situations and compensate for lack of equipment. Enhance an athlete's mental concentration.
Health Sciences	Psychology	(Gutierrez-Maldonado et al., 2015)	Skill Training	Experiment: HMD VR compared to non-immersive stereoscopic computer while performing a virtual interview on a virtual client who was diagnosed with an eating disorder. No difference found.
Health Sciences	Psychology	(Gutierrez-Maldonado et al., 2017)	Skill Training / Engagement	Experiment: Follow-up. HMD VR compared to non-immersive stereoscopic computer while performing a virtual interview on a virtual client who was diagnosed with an eating disorder. No difference found. No difference in learning. HMD VR more engaging.
Health Sciences	Psychology	(Lin, 2017)	Interactivity	VR goggles for users in a survival horror game to analyze fear coping strategies.
Health Sciences	Psychology	(Gupta & Chadha, 2015)	Skill Training / Suggestion	HMD VR to overcoming physical withdrawal symptoms from cigarette and drug addictions.
Health Sciences	Psychology	(Parsons & Courtney, 2014)	Interactivity	Experiment: Compared HMD VR version of the Paced Auditory Serial Addition Test (PASAT) with paper-and-pencil version. HMD VR has extra capability over paper-and-pencil. VR-PASAT unanimously preferred.
Health Sciences	Psychology	(Kalyvioti & Mikropoulos, 2013)	Skill Training	HMD VR for testing/training short-term memory of dyslexic users featuring environments with household objects, geometric shapes and virtual art galleries.
Health Sciences	Psychology	(Kniffin et al., 2014)	Safety / Skill Training	Experiment: Used HMD VR to compare diaphragmatic breathing to attention control training for the enhancement of self-regulatory skills in female students exposed to virtual aggressive males. Concluded that

				HMD VR effective for training self-regulatory skills.
Health Sciences	Psychology	(Jouriles, Kleinsasser, Rosenfield, & McDonald, 2016)	Interactivity / Safety	Experiment: VR (goggles) Measure bystander behaviour in response to sexual violence. Concluded that immersive VR allows researchers to determine behavioural effectiveness.
Health Sciences	Psychology	(Lamb, Antonenko, Etopio, & Seccia, 2018)	Interactivity	Experiment: VR goggles were compared with desktop educational games, video recorded lecture and hands-on paper cut-outs to determine user blood-brain hemodynamic responses while interacting/learning about DNA structures. Hemodynamic responses were analyzed with functional near-infrared spectroscopy. Results suggested that greater cognitive processing, attention and engagement occurred in VR goggle and desktop education game conditions.
Health Sciences	Psychology	(Parong & Mayer, 2018)	Skill Training	Experiment: Immersive VR (The Body VR) compared with desktop slideshow to determine student cellular biology learning ability and interest. Segmented VR learning was compared to continuous VR learning. Desktop slideshow showed greater learning ability, yet lower interest level. Segmented VR showed greater learning ability than continuous.
Health Sciences	Psychology	(Fominykh, Prasolova-Førland, Stiles, Krogh, & Linde, 2018)	Convenience	This paper presents a detailed conceptual framework for therapeutic practice with VR. A virtual environment of a beach scene relaxation scenario will change from calm to stormy, depending on the user's heart rate. Results showed the system may be useful for implementation of therapeutic training with biofeedback.
Health Sciences	Psychology	(Wiederhold, Miller, & Wiederhold, 2018)	Convenience	Mentions immersive VR use to supplement treatments for low-back pain, anxiety, PTSD, stroke, post-surgery palliation, etc.
Health Sciences	Psychology	(Leader, 2018)	Interactivity / Highlighting	Immersive VR and AR for psychotherapy, featuring adjustable clinic designs to optimize therapy for clients.
Health Sciences	Psychology	(Singh et al., 2018)	Engagement / Interactivity	Electroencephalogram measures of cognitive processes were recorded as a user's avatar hands were switched between varying levels of realism. The realistic virtual hands led to users noticing more tracking inaccuracies.
Health Sciences	Psychology	(Formosa, Morrison, Hill, & Stone, 2018)	Skill Training / Engagement	HMD VR (Oculus) allowed users to enter a lounge room to experience positive symptoms associated with schizophrenic spectrum, complete with auditory and visual hallucination. Results showed an increase in user knowledge and empathetic understanding).
Health Sciences	Public Health	(Real, DeBlasio, Beck et al., 2017)	Skill Training / Suggestion	Experiment: Compare HMD VR with control group for training best-practice communication skills in paediatricians, working with clients who refused vaccinations. HMD VR found valid for

				training communication skills and reducing vaccine refusal.
Health Sciences	Public Health	(Real, DeBlasio, Ollberding et al., 2017)	Skill Training / Suggestion	A curriculum featuring immersive VR to address influenza vaccine hesitancy was developed. User's verbally spoke with vaccine-hesitant caregiver avatars (controlled by another user) with open-ended questioning, empathy and education without medical jargon. VR showed promising results.
Health Sciences	Rehab.	(Wen, Duan, Yu, Tan, & Cheng, 2014)	Interactivity / Convenience	VR to monitor stroke patients (motion capture) during exercise while under the guidance of a therapist (HMD VR) who may provide electrical stimulation, despite being in a different location than patient.
Health Sciences	Rehab.	(Chen, Liu, & Ren, 2018)	Skill Training / Engagement	Patients used HMD VR (HTC Vive) to perform upper body tasks for rehabilitation. Virtual environment allowed users to move objects in four different arm positions, which could detect up to 5-degrees of freedom.
Health Sciences	Surgical Education - General	(Oyasiji, Thirunavukarasu, & Nurkin, 2014)	Highlighting	Google Glass to guide surgeons by providing AR images of portal and hepatic vessels in patients' surgical sites.
Health Sciences	Surgical Education - General	(Mathur, 2015)	Convenience / Skill Training	HMD VR low-cost surgery-based training for engineering education to enhance student learning.
Health Sciences	Surgical Education - General	(Nakayama et al., 2016)	Interactivity / Skill Training / Suggestion	Motivate student attitude toward surgical education in urology.
Health Sciences	Surgical Education - General	(Huang, Cheng, Bureau, Agrawal, & Ladak, 2015)	Skill Training / Interactivity	VR to simulate myringotomy procedures.
Health Sciences	Surgical Education - General	(Olasky et al., 2015)	Skill Training	Practice surgical peg-transfer tasks while in an adjustable environment.
Health Sciences	Surgical Education - General	(Harrington et al., 2018)	Engagement / Skill Training	Experiment: Single-blinded randomized cross-over study compared 360-video HMD VR (Samsung Gear) with two-dimensional video, depicting laparoscopy procedures, to determine attention, information retention and appraisal. HMD VR condition showed greater user engagement and attention with no difference in retention.
Health Sciences	Surgical Education - General	(Yoganathan, Finch, Parkin, & Pollard, 2018)	Skill Training	Experiment: Prospective randomized controlled study compared 360-video HMD VR with two-dimensional video, depicting a surgical reef knot, to enhance surgical student knot tying skill. VR condition showed greater knot tying success rates.
Health Sciences	Surgical Education - General	(Andersen, Foghsgaard, Caye-Thomasen, & Sorensen, 2018)	Skill Training	Experiment: An educational interventional cohort study offered additional immersive VR training over the control group, during mastoidectomy dissection training. Results showed that skills acquired in VR further increased student performance.

Health Sciences	Surgical Education - General	(Benabou, Raker, & Wohlrab, 2018)	Skill Training	Experiment: Prospective randomized controlled trial compared HMD VR (Sony Playstation 4 VR) with controls to determine surgical (laparoscopic) two-handed efficiency. VR group showed greater dominant and non-dominant hand speed while also increasing user perceived task performance.
Health Sciences	Surgical Education - Neuro	(Schirmer, Mocco, & Elder, 2013) (Gallagher & Cates, 2004)	Skill Training	Review: VR applications in neuroscience were found to be focused on skill acquisition, technical task-based applications and team/collaboration.
Health Sciences	Surgical Education - Neuro	(Shakur et al., 2015)	Skill Training / Highlighting	Users performed neurosurgical tasks such as ventriculostomy; bone drilling, pedicle screw placement, vertebroplasty and lumbar puncture on virtual patients.
Health Sciences	Surgical Education - Neuro	(Schirmer, Elder, Roitberg, & Lobel, 2013)	Skill Training	Experiment: Repeated measures assessing the knowledge of neurosurgery trainees both before and after experiencing a stereoscopic ventriculostomy simulator. VR shown to increase knowledge across all simulation tasks.
Health Sciences	Veterinary Education	(Seo et al., 2017; Seo et al., 2018)	Skill Training / Engagement	Experiment: HMD VR compared to traditional box method for users to create and manipulate canine skeletons. HMD VR shown to increase user interest.
Military and Aerospace	Aerospace	(Bucceroni, Lecakes, Lalovic-Hand, & Mandayam, 2016)	Safety / Skill Training	Users pilot a virtual unmanned aerial system (UAS) within a simulated environment that resembles a real-world location.
Military and Aerospace	Military	(Champney et al., 2017)	Skill Training	Experiment: Room-clearing task training conditions, ranging from high fidelity HMD VR to training video only, showed HMD VR may have faster skill acquisition.
Military and Aerospace	Military	(Greunke & Sadagic, 2016)	Skill Training / Convenience / Interactivity	HMD VR systems were used to train Landing Signal Officers (LSOs), outside of formal training facilities (2H111), the skills necessary to help pilots land their aircraft safely.
Science and Tech	Agriculture	(Thompson, Krienke, Ferguson, & Luck, 2018)	Skill Training / Safety	360-degree video recordings from high-clearance applicator cabs during nitrogen fertilizer management were shown to users with HMD. Details for optimal recording of 360-degree video were mentioned.
Science and Tech	Architecture	(Newton & Lowe, 2015)	Skill Training	Used open-sourced software (Simulation Engine) to allow students perform various building construction tasks.
Science and Tech	Architecture	(Sun, Xu, Daria, & Tao, 2017)	Skill Training	Proposal: “Bounded Adoption” strategy for HMD VR to learn skills such as component recognition, construction phases and adjusting traffic parameters.
Science and Tech	Astronomy	(Tajiri & Setozaki, 2016)	Interactivity / Skill Training	Experiment: Compared HMD VR to desktop computers for enhancing college students’ understanding of position and direction of celestial bodies. HMD VR claimed to have extra capability.
Science and Tech	Astronomy	(Rosenfield et al., 2018)	Interactivity	A report on The America Astronomical Society’s WorldWide Telescope (WWT)

				project, allowing astronomical images to be projected into planetariums and HMD VR.
Science and Tech	Chemistry	(Lau et al., 2017)	Skill Training / Convenience / Safety	3D VR glasses were implemented to enhance students' abilities in a textile chemical coloring virtual environment.
Science and Tech	Computer Science	(Liang et al., 2017)	Interactivity	Experiment: Compared user's personal experience level between HMDs and monoscopic desktop-display-screens for VR puppet story; child-operated with hand-gesture controls. HMDs outperformed the monoscopic displays.
Science and Tech	Computer Science	(Liarokapis, Petridis, Lister, & White, 2002; Stigall & Sharma, 2017) (Wang, 2017)	Skill Training / Highlighting	HMD AR was used to create training markers and provide" gamification strategies" in software development.
Science and Tech	Computer Science	(Timcenko et al., 2017)	Team Building	Experiment: Mediaology students used HMD VR to promote team collaboration in game design. When compared to no VR, no difference found in team building ability between users.
Science and Tech	Computer Science	(Teranishi & Yamagishi, 2018)	Interactivity / Skill Training	VR learning application that allows users to assemble personal computer hardware, with Leap Motion and HMD, with improved visual systems that reduced user eye fatigue.
Science and Tech	Computer Science	(Hahn, 2018)	Team Building	HMD VR (HTC Vive) was used for text browsing in a digital library, where both librarian and students users worked together.
Science and Tech	Education	(Akçayır & Akçayır, 2017) (Potkonjak et al., 2016)	Various	Review: AR usage found to have increased in educational curricula and promotes enhanced learning achievement. VR of laboratories was noted to have increased capability and safety outside of real world.
Science and Tech	Education	(Jensen & Konradsen, 2018)	Various	Review: Performed a quality assessment and analysis on 21 experimental studies, featuring the use of immersive VR in education and training.
Science and Tech	Education	(Yang et al., 2018)	Skill Training	Experiment: HMD VR compared with paper-and-pencil condition to determine effect on student creativity, flow, attention and stress. VR condition showed greater quality, creativity, attention. VR environment allowed for 3D drawing and painting on a human model to create gear.
Science and Tech	Education	(Dolgunsöz, Yildirim, & Yildirim, 2018)	Skill Training / Engagement	Experiment: VR Goggles were compared with two-dimensional video (about Chernobyl or Bear Habitat) to enhance EFL writing performance. VR was shown to possibly improve writing performance in the long term (1-month later) and be more engaging.
Science and Tech	Education	(Tepe, Kaleci, & Tuzun, 2018)	Safety	VR Goggles, depicting a warehouse environment, allowed users to perform tasks in response to a fire.
Science and Tech	Education	(Alfalah, 2018)	Various	A report detailing institutional supports, motivations for adoption and teaching staff perceptions for the incorporation of VR into education curricula.

Science and Tech	Education	(Makransky & Lilleholt, 2018)	Engagement	Experiment: Crossover repeated-measures compared HMD VR (Samsung Gear) with desktop, depicting a laboratory simulation, to determine several factors, including user enjoyment and perceived learning. VR was found to be preferred over desktop for various reasons as detailed in report.
Science and Tech	Education	(Murcia-Lopez & Steed, 2018)	Interactivity	Experiment: Efficiency of bimanual 3D block puzzles was measured between HMD VR (Oculus) and physical assembly exercises. VR users showed results that were similar to physical assembly. VR performance was promising.
Science and Tech	Education	(Al-Azawi & Shakkah, 2018)	Suggestion	Report summarizes VR concepts in education, with the goal to motivate instructors to adopt its use in their teaching methods.
Science and Tech	Education	(See, Lee, Brimo, Thwaites, & Goodman, 2018)	Convenience / Highlighting	Report summarizes VR concepts in massive open online course education, detailing potential obstacles, issues with adoption, practices and requirements.
Science and Tech	Education	(Bryan, Campbell, & Mangina, 2018)	Engagement / Highlighting / Skill Training	Report details gamification strategies with Google Maps. The objective is for users to find a country flag by answering questions about each location they encounter.
Science and Tech	Education	(Misbhauddin, 2018)	Engagement / Interactivity	Proposal: A VR framework to enhance learning experiences in classroom settings. Framework includes recording of lecture, visualization of instructor communication, user input for verbal note-taking.
Science and Tech	Education	(Hickman & Akdere, 2017)	Skill Training / Engagement / Team Building	Proposal: Compare 360-video recorded images with computer generated avatars in HMD VR, desktop with HMD VR, high-cost and low-cost hardware, to determine student engagement and learning outcomes. Modules includes intercultural business exchanges, where user contributions affect project success.
Science and Tech	Education	(Chin et al., 2017)	Engagement	HMD VR (Google Cardboard) for education is briefly described and exemplified with SplashSim- users experience stages of the water cycle from the perspective of a water droplet.
Science and Tech	Education	(Zaphiris & Ioannou, 2017)	Skill Training	Book: Conference presentations of immersive VR systems for training in teacher education (bullying prevention).
Science and Tech	Education / Psychology	(Hashimura, Shimakawa, & Kajiwara, 2018)	Interactivity	Experiment: Used HMD VR (Oculus) and motion controls to determine attention capacity (head, eye and hand movement) while under cognitive load (sort English words in VR space). VR showed possible ability to measure a user's cognitive load.
Science and Tech	Engineering – Civil	(Wang, Li, & Kho, 2018)	Skill Training	The construction of 3D building information models for quantity surveying practice in immersive VR were detailed in this report.
Science and Tech	Engineering – Civil / Driving	(Veronez et al., 2018)	Convenience / Safety /	Driving setup (Oculus HMD and Logitech G27 Racing Wheel system) to enhance

			Skill Training	learning for road design. Users can test-drive their roads during development.
Science and Tech	Engineering – Civil / Driving	(Likitweerawong & Palee, 2018)	Safety / Skill Training	Immersive VR driving setup (Oculus) to provide users with basic driving lessons and rules before actual road-tests. User skill evaluated by completion of checkpoints on a virtual driving course including parking, speed and cornering.
Science and Tech	Engineering – Computer	(Alhalabi, 2016)	Skill Training	Experiment: Effectiveness of four different VR setups analyzed to determine student performance on engineering tests. All forms of VR found to improve performance. HMD VR with tracking shown to excel over CAVE, no-tracking HMD VR and no VR.
Science and Tech	Engineering – Computer	(Akbulut, Catal, & Yıldız, 2018)	Skill Training	Experiment: MultiPeer Immersive VR compared with traditional teaching material to determine student performance on sorting algorithms .VR system showed an improvement on student test results over traditional methods.
Science and Tech	Engineering – Electrical	(Liang & Xiaoming, 2013)	Skill Training / Convenience	Students used VR workbench software to design analog and digital circuits, encouraging autonomous exploration.
Science and Tech	Engineering – General	(Haefner et al., 2013)	Various	Curricula: Recommendations on how to implement practical VR coursework in engineering education by encompassing skill development, interdisciplinary teamwork and time management training.
Science and Tech	Engineering - General	(Ndez-Ferreira, Fuente, Mez, & Camacho, 2017)	Team Building / Suggestion	Virtual Mobility: The UbiCamp Experience is a 3D immersive virtual environment that allows groups of users to visit iconic buildings, monuments and universities, promoting cultural and language learning.
Science and Tech	Engineering - General	(Lemley, Kar, & Corcoran, 2018)	Highlighting	Deep learning achieved by eye-tracking was tested by comparing a standard eye tracker with AR/VR eye-tracking datasets across high-res HMD VR and low-res smart devices.
Science and Tech	Engineering - General	(Starkey, Spencer, Lesniak, Tucker, & Miller, 2017)	Skill Training	Experiment: Systematic disassembly of a product was performed across three interfaces (computer desktop, iPad, immersive VR). Student learning was found to be the same for each condition, yet immersive VR showed greater student satisfaction and perceived learning.
Science and Tech	Engineering – Mech	(Muller, Panzoli, Galaup, Lagarrigue, & Jessel, 2017)	Skill Training / Interactivity	Immersive VR workshops were reported to allow mechanical engineering students to expedite the learning process by interacting with virtual workbenches.
Science and Tech	Engineering – Mech	(Im, An, Kwon, & Kim, 2017)	Skill Training / Engagement	Proposal: HMD VR (Oculus) and Leap Motion allowed users to disassemble and reassemble engines. Results showed high user interest, immersion, satisfaction, perceived learning and effectiveness.
Science and Tech	Engineering - Numerical Control	(Hu & Wang, 2015)	Skill Training	Proposal: Incorporating VR technology courses for environment shape design, animation, interactive functions and internet related content.

Science and Tech	Engineering – Pneumatic	(dela Cruz & Mendoza, 2018)	Convenience / Skill Training	HMD VR, depicting a lab environment, allowed users to operate pneumatic components.
Science and Tech	Forensics	(Liu, Campbell, & Gladyshev, 2017)	Skill Training	Proof of Concept: Details on the development of a crime scene simulation were provided, complete with virtual suspects who would run away if the user failed to maintain line of sight. The project aims to teach users how to prevent damaging crime scene evidence.
Science and Tech	Geology	(Ables, 2017)	Skill Training / Interactivity	Dynamic topographic data was digitally rendered onto a virtual 'sandbox,' showing different types of terrain within the virtual environment. Users were able to interact with the terrain.
Science and Tech	Industrial Plant Operation	(Nazir, Sorensen, Øvergård, & Manca, 2015)	Skill Training / Safety	Experiment: Power Point was compared to immersive VR (stereoscopic glasses) for Distributed Situation Awareness (DSA) skill training for industrial plant operators. Immersive VR showed enhanced dynamic security assessment ability in students over PowerPoint method.
Science and Tech	Information Interfaces	(Khuong et al., 2014)	Highlighting	HMD VR assisted in constructing a block structure with one of two different highlighting guidance information systems: overlay and adjacent.
Science and Tech	Physics	(Kozhevnikov, Gurlitt, & Kozhevnikov, 2013)	Skill Training	Experiment: HMD VR compared with non-immersive VR to determine which would enhance students' ability to solve two-dimensional relative motion problems. HMD VR performed better than non-immersive VR on solving 2D relative motion problems.
Science and Tech	Physics	(Matsutomo, Manabe, Cingoski, & Noguchi, 2017)	Highlighting	VR was used to show real-time graphics of magnetic fields between objects.
Science and Tech	Physics	(Kuhn et al., 2015)	Highlighting	Immersive VR (Google Glass) was used to determine water-level in a glass to achieve specific tones in physics (acoustics) education.
Various	Various	(Dunbar et al., 2017)	Highlighting / Safety	Visionless Interfacing Exploration Wearable (VIEW) substitutes the vision sense with wearable haptic feedback, assisting individuals with recognizing obstacles and avoiding walls when navigating a space.
Various	Various	(Suh & Prophet, 2018)	Various	Review: Determined the trends, theoretical foundations and research methods of immersive VR studies.
Various	Various	(Zikky, Fathoni, & Firdaus, 2018)	Various	Report briefly mentions immersive VR programs for distance learning including social media, military skydiving, university campus, lab safety, chemistry and solar systems.
Various	Various	(De Paolis, Bourdot, & Mongelli, 2017)	Various	Book: Conference presentations of immersive VR systems for training in industrial processes, tannery processes, motor fine skills rehabilitation, industrial heritage, collaboration, safety training, automotive mechanics and journalism.

Table 2.6

Summary of educational theories associated with immersive Virtual Reality

Theory	Description	References
Cognitive Load Theory	Learning and instruction that optimizes the amount of cognitive load a user experiences within the capacity of working memory. Immersive VR features multiple modes of information that is simultaneously processed by multiple sensory modalities including sounds, images, texts, tactile cues.	(Liu, Dede, Huang, & Richards, 2017; Paas, Renkl, & Sweller, 2016)
Conceptual Blending Theory	Recommends AR users to move "fluidly" between the physical and virtual world. This creates a conceptual blend as users layer multiple, distinct "conceptual spaces," or different "source domains," which enhances learning.	(Enyedy, Danish, & DeLiema, 2015)
Constructivist Learning Theory	Assumes that knowledge development occurs best through the building of "artifacts" (physical or digital), which can be experienced and shared. Constructivist strategies in VR are effective, because they empower learners to author their own scenarios in which they have an emotional investment.	(D. Liu et al., 2017; Papert & Harel, 1991)
Flow Theory	A positive experience associated with immersive VR leads to optimal learning states induced by intrinsic motivation, well-defined goals, appropriate levels of challenge and feedback.	(Csikszentmihalyi, 1990; D. Liu et al., 2017)
Generative Learning Theory	Practice of learning information by transforming it into usable form by selecting (spending attention on relevant information), organizing (arranging information into coherent structure), and integrating (connecting verbal/image representations with each other and with prior knowledge from long-term memory).	(Parong & Mayer, 2018)
Interest Theory	Users learn better when they perceive value in the learning material, either intrinsically (individual interest) or as elicited by the situation (situational interest).	(Parong & Mayer, 2018; Wigfield, Tonks, & Klauda, 2016)
Jefferies Simulation Theory	The development process of simulations includes context, background and design characteristics, resulting in dynamic interactions between the facilitator and learner through the use of appropriate educational strategies.	(Aebersold, 2018; Jeffries & Jeffries, 2012)
Kolb's Experiential Learning Theory	A four step theory (concrete experience, reflective observation, abstract conceptualization and active experimentation) that form a continuous cycle- reminiscent as users experience immersive VR.	(Aebersold, 2018; Kolb, 1984)
Motivation Theory	VR learning may enhance user focus, due to an increase in engagement, resulting in further investment of energy to allocate cognitive resources during difficult parts of the lesson.	(Parong & Mayer, 2018)
Presence Theory	Based on the following immersions: *Actional* - VR empowers users to experience new capabilities as actions are performed with novel/intriguing consequences, *Symbolic/Narrative* – Users learn semantic associations from content of experience, *Sensory* – Immersive VR's ability to encourage a user to imagine being in a different actual location, *Social* – Interactions among other users (or perhaps artificially intelligent avatars) deepens sense of being part of the setting.	(Dede, 2009; D. Liu et al., 2017)
Situated Learning	Virtual environments allow users to interact with objects and apply them within the setting itself, fostering tacit skills through experience and modeling.	(D. Liu et al., 2017)
Stimuli – Organism – Response	The stimuli found in virtual environments affect both a user's cognitive and affective states, which in turn leads to behavioural changes (technology adoption behaviour).	(Mehrabian & Russell, 1974; Suh & Prophet, 2018)

Control Value Theory of Achievement Emotions (CVTAE)	Learning can be facilitated through positive achievement emotions, such as enjoyment, especially when instructional design elicits and promotes appraisal of student autonomy and intrinsic value.	(Makransky & Lilleholt, 2018; Pekrun, 2016)

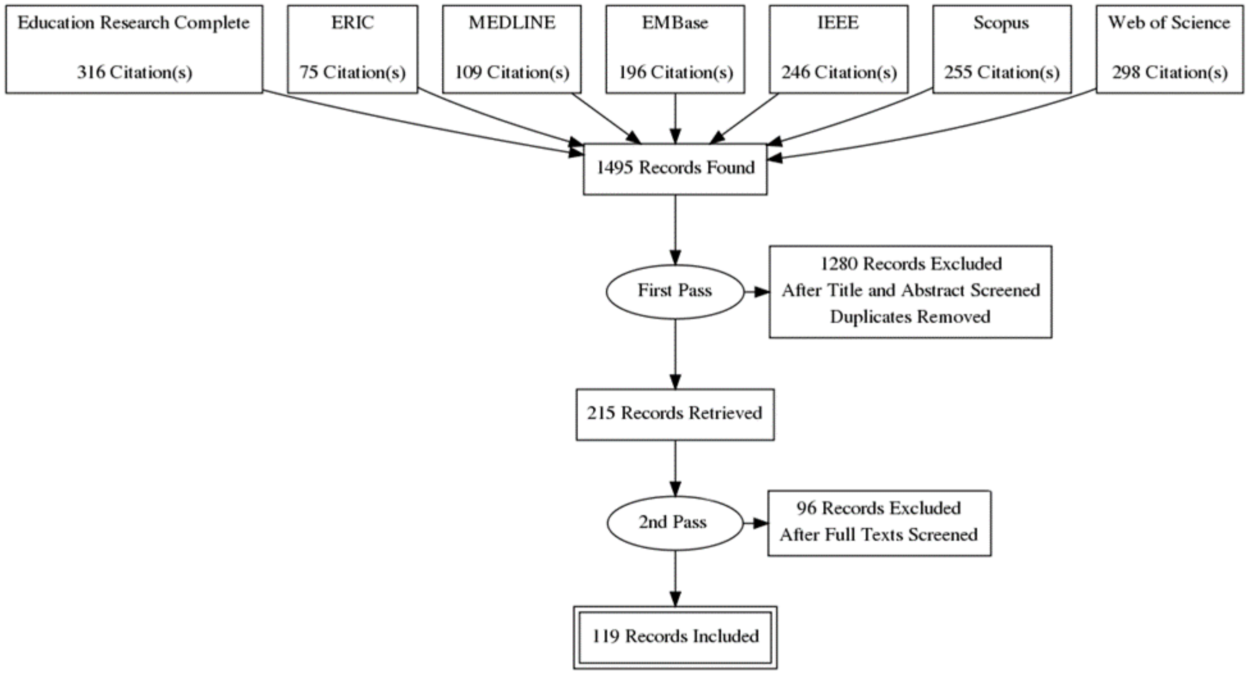

Figure 2.1. *PRISMA* flow diagram of search results.

Chapter 3 - Immersive Virtual Reality for the Reduction of State Anxiety in Occupational Therapy Students Preparing for Objective Structured Clinical Exams

Abstract

Background: Immersive head-mounted display virtual reality (VR) was used to determine if clinical interview simulations had an effect on first-year occupational therapy (OT) student anxiety levels as they prepared for an upcoming Objective Structured Clinical Exam (OSCE). Anxiety in Health-Science students is a potential problem that may diminish performance during OSCEs. This investigation aimed to fill the gap in the literature, regarding the effectiveness of VR to reduce anxiety in OT students.

Methods: A prospective experimental nonrandomized control trial compared two groups of first-year OT students' state anxiety, test anxiety and academic self-efficacy levels, measured at four different timepoints by self-reported psychometric scales, analyzed with a mixed factorial ANOVA. Groups consisted of VR simulation (YesVR) and control (NoVR). VR simulation featured a virtual clinic and standardized patient who students could interview in natural language. Measures of student study strategies and previous experience with VR were also recorded.

Results: 49 participants (29 for NoVR, 20 for YesVR) showed state anxiety had a rise-then-fall trend, peaking at the time point just before the OSCE. At that point, YesVR students showed significantly less state anxiety than NoVR. In similar trends for both groups, student test anxiety remained relatively static across the timepoints while academic self-efficacy continually increased. A moderate positive correlation was found for total time spent studying and peak state anxiety, while a moderate negative correlation was found for academic self-efficacy and total peak state anxiety. Top study strategies used by the students were hands on practice group (mean=44.99%), individual (mean = 18.28%) and note review (mean=21.34%).

Conclusion: This investigation shows evidence of immersive VR's capability to reduce state anxiety in OT students. Immersive VR simulation, used for the reduction of anxiety in Health Science

students, can potentially lead to a future of positive mental health change from the virtual to real world.

Introduction

This investigation used immersive virtual reality (VR) to reduce anxiety in Occupational Therapy (OT) students who were preparing for a clinical practical exam. VR is as a useful tool that can positively shape mental health. It utilizes a human-machine interface that immerses people into digitally rendered illusions, multi-sensory in composition, projected by computer hardware. These illusions act as virtual environments, allowing people to condition themselves against symptoms of anxiety, by undergoing Virtual Reality Exposure Therapy (VRET), a form of systematic desensitization that facilitates mental fortification against a feared stimulus (Grochowska, Jarema, & Wichniak, 2019). VRET allows for the training of affective regulation, while people are subjected to situational contexts that induce anxiety (Grochowska et al., 2019; Kniffin et al., 2014). VRET can safely provide answers to inaccessible and intangible concepts, by observing the responses of people who are subjected to fear and anxiety-inducing stimuli, which would otherwise be considered too dangerous or unethical to perform in the real world (Grenier et al., 2015). Depending on the extent of a virtual system's designed capability, a person immersed within the virtual environment acts as a user who may encounter, interact, control and modify the virtual world. The user's experience is "evoked" to improve their mental proficiency and habituate against fear and anxiety (Grochowska et al., 2019). In this investigation, the anxiety under analysis is of the type that students may experience while preparing for clinical practical exams in Health Science programs.

Campus Anxiety – A National Epidemic

Anxiety is a feeling of uneasiness and worry, usually generalized and unfocused as an overreaction to a situation that is subjectively seen as menacing (Bouras & Gs, 2007). It is a theoretical construct, capable of being triggered in either general or specific situations, with "proneness" (trait anxiety) representing the frequency and/or intensity of the response and "transitory" (state anxiety) representing the momentary response at a specific point in time

(Spielberger, C. D., Gorsuch, Lushene, Vagg, & Jacobs, 2015). Trait anxiety is a stable construct that is associated with personality traits, influencing the potential of a person's state anxiety response that occurs at a specific point in time (Spielberger et al., 2015). Spielberger and colleagues (1972 and 1978) developed a measure for test anxiety, which detects differences in test specific personality traits between individuals.

Test anxiety is situation-specific and associated with two components: 1) Cognitive components that manifest symptoms of worry (due to student concerns regarding the outcome of an assessment) and task-irrelevant thinking (causing interference and shifting of attention to irrelevant content), 2) Affective components are what manifest physiological reactions (such as increased heart rate and headache), nervousness and tension (emotionality) (Sommer & Arendasy, 2015). Self-centered worry cognitions and emotionality responses, which students may experience during testing situations, are potentially distracting and may disrupt concentration and attention, resulting in reduced performance on cognitive-intellectual tasks (Liebert & Morris, 1967).

It is important to note that anxiety while under academic evaluation (test anxiety) is normal, especially in situations where students have invested urgent and preparatory activities to win an ideal outcome. However, severe anxiety that causes students to "lock-up," panic or show an unexpected reduction in performance is a serious problem. Anxiety symptoms are expected to have a negative impact on student academic achievement, self-efficacy and self-concept (Dobson, 2012). In a survey with 1,099 responses from a Canadian university: 38.5% of university students self-reported that they had suffered from test anxiety at some point during their studies, 20.5% of surveyed students believed that professors were unable/unwilling to help and 11.3% of the students indicated they would not seek help as this would act against social desirability (Gerwing, Rash, Allen Gerwing, Bramble, & Landine, 2015). Test anxiety on university campuses is associated with student burnout and increased rates of attrition (Vanstone & Hicks, 2019).

Self-efficacy is the subjective belief in one's ability to successfully perform a given task (Bandura, 1997). Academic self-efficacy is of a specific type that pertains to academic situations, with greater levels being correlated with increased student class participation and exam performance at the higher grade-point average levels (Galyon, Blondin, Yaw, Nalls, & Williams, 2012). The relationship between academic self-efficacy and student anxiety, where the retention of academic self-efficacy is maintained by the suppression of state anxiety, was a primary outcome of interest in this investigation.

Virtual Reality vs Anxiety

VR is defined as a human-machine interface that allows users to "project" themselves into a computer generated virtual environment, where specific objectives can be achieved (Zhang, 2014). A potential method for reducing anxiety involves the use of immersive VR, which allows people to learn how they would feel and respond (physiologically, tactfully, and procedurally) while interacting with virtual situations that the brain treats as real. Immersive VR can change a user's fear structure into an adapted one, removing the pathological kind that distorts reality and increases escapist tendencies (Bissonnette, Dubé, Provencher, & Sala, 2016). The objective is to create an immersive virtual environment that simulates a specific testing situation, allowing users to learn how to adapt. This objective allows users the ability to develop anxiety tolerance by facilitating *inhibitory learning*, at both voluntary and involuntary levels, granting them resiliency after developing habituation from specific virtual situations to utilize in real-world situations (Craske et al., 2008). *Inhibitory learning* is theorized to occur when anxiety suppression is achieved by neurobiological conditioning of the prefrontal motor cortex, amygdala and hippocampus within the brain (Sotres-Bayon, Cain, & LeDoux, 2006).

A fully immersive virtual environment allows users to accept and respond to artificial stimuli in a natural manner (Zhang, 2014). The component of VR that determines a user's perception of their surrounding virtual environment is their physical level of "immersion," ranging from non-immersive (e.g., desktop computer showing the environment) to fully immersive (e.g., head-mounted display VR) (Gutiérrez Alonso, Vexo, & Thalmann, 2008; Parsons, 2015; Rebelo, Noriega, Duarte, & Soares, 2012). Interactivity, the degree a user's actions result in applicable responses within the virtual environment, is the second component of VR (Rebelo et al., 2012). The third component is imagination; the degree a user feels is within the virtual environment (Rebelo et al., 2012). These components influence VR's level of fidelity, the capability of a virtual environment to reflect the real world. High fidelity is achieved when a user's actions, senses and thought-processes in a virtual world closely or exactly resemble what would be transferrable to a similar situation in the real world.

In Gaggiloi and colleagues (2014) report on the use of VR to reduce workplace stress for teachers and nurses, VR was found to be more effective in treating anxiety than the traditionally accepted gold standard for psychological stress treatment- cognitive behavioural therapy (Gaggioli et al., 2014). Sports psychologists have developed immersive VR environments that train an athlete's mental concentration for sprinting events, depicting crowd-filled stadiums and competitors (Choiri, Basuki, Bagus A, Sukaridhoto, & Jannah, 2017). Designs of virtual hospital waiting rooms allow older-adults the opportunity to be treated against anxiety-inducing stimuli, such as loud noises from distressed patients or crying infants (Grenier et al., 2015). This exposure could be employed to improve the efficacy of psycho-social therapy, such as cognitive behavioural therapy, with VR simulations resembling anxiety-inducing situations (Grenier et al., 2015). Kniffin and colleagues (2014) reported on diaphragmatic breathing training for the retention of attentional control to enhance self-regulatory skills, experimented on female students who were exposed to virtual avatars of aggressive males (Kniffin et al., 2014). It was concluded that immersive VR was effective for the training of self-regulatory skills in this manner (Kniffin et al., 2014).

Test anxiety is often explained by the Deficit Model, stating that a student's increased awareness of their deficit in perceived cognitive ability, occurring during exams, causes attentional control processes to become compromised (Sommer & Arendasy, 2015). During exams that feature evaluators and student-to-client interactions, social anxiety is another potential problem.

VR in Occupational Therapy

The use of VR simulation in the field of Health Sciences has become increasingly considered in disciplines such as Physiotherapy, Speech-language Pathology and Occupational Therapy (Yeung, Dubrowski, & Carnahan, 2013). In a Canadian survey with 1,071 respondents from Physical Therapy and Occupational Therapy disciplines, located across the country, client VR-based therapy was provided for those diagnosed with stroke/hemiparesis, musculoskeletal injury, brain injury, cerebral palsy, neurodevelopment disorders, geriatric limitation, mental health and complex/chronic pain (Levac, Glegg, Colquhoun, Miller, & Noubary, 2017). In that same Canadian survey, most of the VR and active-gaming activities featured those that train balance, exercise, mobility, participation/engagement and cognition (Levac et al., 2017). Note that most of the reportedly used hardware configurations in the survey, detailed by Levac and colleagues (2017), featured non-immersive or semi-immersive VR.

Occupational Therapy has recognized VR as a potential tool for treating clients, yet reports of VR's role in curricula for training interprofessional skills in students are typically peripheral in comparison (Bennett, Rodger, Fitzgerald, & Gibson, 2017). Occupational Therapy will often employ Objective Structured Clinical Examinations (OSCEs), clinical practical exams that assess student core competencies including procedural, clinical encounter and history taking skills (Ravikirti & Gopalakrishnan M., 2018). OSCEs often feature standardized patients, who are actors trained to portray the characteristics of patients, giving students the opportunity to demonstrate their technical and non-technical skills while in a controlled environment.

There are reports detailing the use of virtual standardized patients in medical education, allowing students to practice history-taking skills with reasonable differential diagnosis results

(Maicher et al., 2017). However, there is a gap in the literature regarding the use of immersive VR systems for the reduction of anxiety in Occupational Therapy students. Occupational Therapy students are often expected to interview standardized patients during OSCEs, while under formal evaluation by observers, resulting in them potentially experiencing increased levels of state anxiety if characteristics of the Deficit Model begin to manifest.

Test anxiety's trait characteristics that influence state anxiety responses, within academic settings, have been stated to negatively affect student self-efficacy (Dobson, 2012). It is expected that an immersive VR simulation of a clinical practical exam will facilitate *inhibitory learning* in Occupational Therapy students, resulting in the suppression of their anxiety symptoms. These anxiety symptoms, which may impact student performance on clinical practical exams, are expected to be conditioned by immersive VR simulation, resulting in a reduction of student state anxiety levels and retention of academic self-efficacy levels. Immersive VR in this investigation is expected to demonstrate these positive changes in Occupational Therapy students and fill the gap in the literature regarding these conditions. The results of this investigation may inform future decisions of educational disciplines, which may consider the implementation of immersive VR for the reduction of performance anxiety that is associated with clinical practical exams. In addition to immersive VR as a study option for Occupational Therapy students, it is important for OT students to utilize "deep and strategic" approaches for the development of self-efficacy (Bonsaksen, Sadeghi, & Thørrisen, 2017). "Deep and strategic" study strategies feature activities that allow students to "discover concepts and their inter-relationships," while also forming a personal meaning (Bonsaksen et al., 2017). "Deep and strategic" learning approaches are associated with better academic performance and higher general self-efficacy (Bonsaksen et al., 2017) while "surface" approaches, which feature students completing exams only by remembering content while checking-off requirements, is associated with reduced academic performance (Brodersen, 2007).

Aim of this Investigation

This investigation aimed to uncover immersive VR's effectiveness for reducing anxiety in Occupational Therapy students, who were preparing for an OSCE. The human-machine interface utilized a head-mounted display to achieve a fully immersive experience, complete with speech recognition software to allow the use of natural language for conversing with a virtual standardized patient, resulting in a system of high-fidelity. This high-fidelity system was expected to optimize *inhibitory learning* for the facilitation of anxiety toleration as detailed by Craske and colleagues (2008) report. Academic self-efficacy was also measured to determine its relation with peak state anxiety. In addition, an increased awareness of study strategies that Occupational Therapy students utilized, during their clinical exam preparatory process, would uncover additional study options that future students could utilize for the establishment of personal meaning during the learning process.

Research Questions

This investigation was designed to answer the following research questions:

1. Does immersive VR simulation of a clinical practical exam (OSCE) effectively reduce state anxiety in Occupational Therapy students, when compared to a control group?
2. What degree of academic self-efficacy is retained in Occupational Therapy students, if state anxiety is successfully reduced by immersive VR simulation of a clinical practical exam (OSCE), when compared to a control group?
3. What is the relationship between total study time and peak state anxiety in Occupational Therapy students as they prepare for an upcoming clinical practical exam and what study strategies are used?

Expectations

This investigation expected to observe the following:

- A significant reduction in state anxiety scores between Phases at the time point 1-week prior to the OSCE; this point includes the availability of the immersive VR simulation for the purpose of mitigating anxiety for this event alone.
- State anxiety levels to peak at the time point closest to the OSCE; a significant reduction in state anxiety levels for the students who had access to the VR simulation as opposed to those who did not have access.
- An inverse relationship between student anxiety levels and their academic self-efficacy, with academic self-efficacy being decreased as state anxiety levels increased. This inverse relationship was expected due to Dobson's (2012) report stating that anxiety symptoms are expected to have a negative effect on student academic achievement, self-efficacy and self-concept.

Methods

Experimental Design

This investigation was a prospective experimental nonrandomized control trial, involving two groups of participants, each comprised of Occupational Therapy (OT) students who were in the first year of their program. The first group was designated as Phase 1 (NoVR), which acted as the control group since it did not have access to the immersive virtual reality (VR) simulation- it was incomplete and still under development at that time. Phase 1 was used to establish baseline measures. The second group was formed in the next year and was designated as Phase 2 (YesVR), which was the experimental group that had access to the VR simulation.

Unlike a completely randomized design, this investigation allowed each group of participants to be aware of their status in the experimental process. Due to the single critical opportunity for when the OSCE became available, it was not possible for this investigation to feature a block controlled trial. Had a standard randomized control trial been utilized, there would have been difficulties with randomizing the students to their designated conditions; withholding an intervention that has the potential to positively impact student performance and well-being is unethical. To compensate, the participants of Phase 1 (NoVR) were offered first priority of the simulation when it became available in the second year of their studies. By maintaining intact cohorts as separate control and intervention groups between the years, this acted as a strategy to reduce treatment diffusion, which may have occurred if both groups had been analyzed at the same time.

Recruitment

Announcements providing details of the investigation were made by an announcer who was neutral to the investigation's outcome. The announcer was the same for each Phase and was not a professor of the faculty; this was to minimize the compulsory pressure on students to participate. Announcements were made in-lecture to an OT class of 120-students for each Phase. All OT students for each Phase, who were in the first year of their program, were invited and eligible to participate. While both Phases were informed of the availability of a survey package that became available for them to obtain and complete, Phase 2's announcement included additional information to explain the risks associated with the use of immersive VR hardware.

Ethics

This investigation was approved by the research ethics office of Research and Innovation, University of Alberta, Canada. After inspection, this investigation was deemed ineligible to record participant age and sex variables. This was to ensure each participant's recorded measure would not be traceable by professors of the faculty, especially if that datum belonged to participants who were unique to the student population and could thus risk becoming identified. All the participants were to remain completely anonymous and thus no signatures were to be taken. Instead, consent to participate was indicated by survey package submission. Census data pertaining to demographics of the student body were allowable.

Experimental Process

Students were requested to obtain and complete a survey package that contained four separate sections, each to be completed at different time points (TP). Each section contained questionnaires that recorded primary and secondary outcome measures of this investigation. Once each section was complete, the participants were informed to drop-off each section at a secure mailbox as indicated within the package information guide. Note that Phase 2's (YesVR) package contained additional information about sign-up timeslots for immersive VR sessions, which would become available 2-weeks prior to their OSCE date. Tutorials on how to operate the VR hardware were provided by assistants, neutral to the investigation outcome, who remained on stand by at each appointed sign-up session. Each package section had been labelled with a specific completion date as follows:

- TP1 (3-weeks pre OSCE)
- VR sign-up became available for Phase 2 (YesVR) students only (2-weeks pre OSCE)
- TP2 (1-week pre OSCE)
- TP3 (1-week post OCSE)
- TP4 (1-month post OSCE)

Refer to Figure 1 for a summary of this investigation's experimental process.

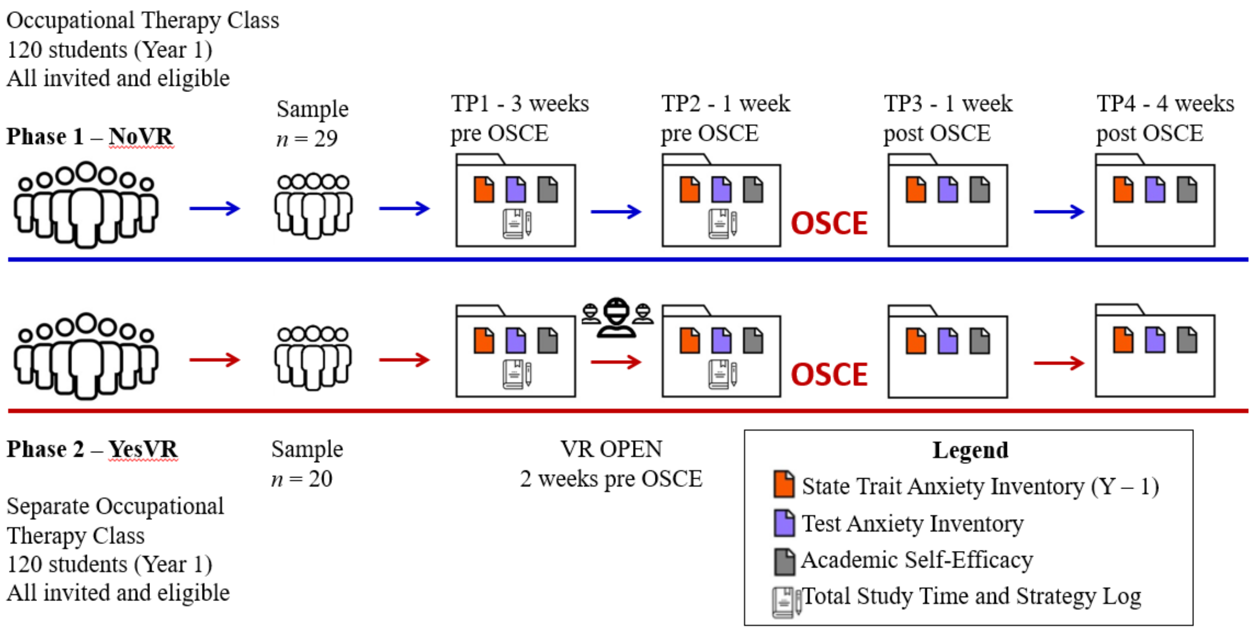

Figure 3.1. Prospective experimental nonrandomized control trial comparing NoVR with YesVR in Occupational Therapy students who were preparing for an Objective Structured Clinical Exam (OSCE).

Both Phases – Primary Outcome Measures

Information – State-Trait Anxiety Inventory Form (Y-1)

The State-Trait Anxiety Inventory (STAI) form consists of two scales each comprised of 20-items that measure anxiety in adults, scored as a value ranging from 20 – 80, with higher scores being associated with stronger symptoms of anxiety (Spielberger, C. D. et al., 2015). This investigation utilized form Y-1 (S-Anxiety scale), which measures a participant's level of anxiety at a specific moment in time. The S-Anxiety scale has been found to be a "sensitive indicator of changes in transitory anxiety" as experienced by students exposed to stressors such as job interviews or important school tests (Spielberger, C. D. et al., 2015). The STAI S-Anxiety scale was developed for use with college students and has shown a reliability stability of $r < .62$. Although reliability coefficients for the STAI have shown low to moderate scores, these stability coefficients are assumed for a state-anxiety scale of this type, due to its expected ability to reflect differences in participant anxiety levels that are unique between each retesting situation (Spielberger, C. D. et al., 2015). For validity, the STAI S-Anxiety scale has been compared to other existing measures of state/trait anxiety in addition to contrasted groups, personality and adjustment tests, correlations with measures of academic aptitude, achievement and investigations of the effects of different amounts and types of stress on S-Anxiety scores (Spielberger, C. D. et al., 2015). For college students, the Institute of Personality and Ability Testing (IPAT) Anxiety scale was compared to the STAI and showed validity correlation coefficients of $r = .75$ and $r = .76$ for females and males respectively, while the STAI to Taylor Manifest Anxiety Scale (TMAS) showed validity correlation coefficients of $r = .80$ and $r = .79$ for females and males respectively (Spielberger, C. D. et al., 2015). The STAI has shown consistency in measuring essential qualities of anxiety, including apprehension, tension, nervousness and worry (Spielberger, C. D. et al., 2015). Form Y-2 (T-Anxiety scale) measures a participant's general and long-standing level of anxiety, which was not featured in this investigation. Overall, the STAI has shown to be both a reliable and valid instrument for measuring state anxiety levels in college students.

Information – Test Anxiety Inventory

The Test Anxiety Inventory, also known as the Test Attitude Inventory (TAI), is a self-reporting psychometric scale that measures individual differences in test anxiety as a situation-specific personality trait. It is comprised of 20-items that measure anxiety attributable to test situations and scored as a value ranging from 20 – 80, with higher scores being associated with stronger symptoms. TAI subscales include worry and emotionality as major qualities of test anxiety (Spielberger, C. D. et al., 1980). Although most normative data for TAI usage is based on general purpose or multiple-choice tests, it allows for modification about specific tests or time periods accordingly (Spielberger, C. D. et al., 1980). The TAI is also useful as a measure of outcome for studies featuring test anxiety treatment (Algaze, 1980; Gonzalez, H. P., 1976; Gonzalez, Hector P., 1978). The TAI scale was developed for use with college and graduate students and has shown a reliability stability of $r = .80$ for time periods varying between two weeks to six month (Spielberger, C. D. et al., 1980). For validity, the TAI scale has been compared to other existing measures of test anxiety including the Test Anxiety Scale (TAS) and Worry Emotionality Questionnaire (WEQ) (Spielberger, C. D. et al., 1980). For college students, the TAS and TAI comparison showed validity correlation coefficients of $r = .83$ and $r = .82$ for females and males respectively, while the TAI and WEQ-Emotionality comparison showed validity correlation coefficients of $r = .85$ and $r = .77$ for females and males respectively (Spielberger, C. D. et al., 1980). Although there have been moderate positive correlations found when comparing the TAI with the STAI ($r = .67$ in males and $r = .34$ females), the TAI was concluded not to measure or be comparable to state anxiety (Spielberger, C. D. et al., 1980). Overall, the TAI has shown to be both a reliable and valid instrument for measuring test anxiety levels in college students.

Information – Academic Self-Efficacy

In this investigation, academic self-efficacy was measured with the German Academic Self-efficacy Scale instrument, developed by authors Jerusalem and Satow in 1999, as part of an extensive test-battery to implement self-efficacy theory in schools of various grade levels up to and including trade-school. Their instrument was developed by a combination of empirically proven concepts as outlined by Albert Bandura's Self-Efficacy Theory (1995 and 1997) and Jerusalem, Mittage and Satow's research (1999). Their academic self-efficacy instrument is comprised of 7-items, showing internal consistency of Cronbach's $\alpha = .73$ when compared with the other tests that measured theoretically related constructs such as optimism, helplessness and social requirement expectations (Schwarzer & Jerusalem, 1999). These theoretically related constructs were and were not related to academic self-efficacy (r values ranged from .27 to .51), resulting in theoretical correlations speaking for the criterion-oriented validity of the scale (Jerusalem & Mittag, 1999; Schwarzer & Jerusalem, 1999).

Both Phases – Secondary Outcome Measures

Information – Total Study Time and Strategy Log

Each survey package contained a log template providing instructions on how to note total study activities and durations in preparation for the OSCE. Participants were encouraged by the instructions to log each study activity and its duration on an ongoing basis. Participants were requested to provide only the times and activities that were outside their normal class or lecture sessions. Phase 2 (YesVR) participants were also requested to include their VR Simulation session in their log and, if applicable, provide special notes as to why their VR session was incomplete had it ended prematurely.

Phase 2 (YesVR) Only – Secondary Outcome Measures

Information – Previous Experience VR Survey

This brief 5-item survey was an additional document available in the Phase 2 (YesVR) survey package, which allowed participants to define the amount of familiarity and ownership (if applicable) of immersive VR hardware they had experienced prior to the simulation as featured in this investigation. This survey established participant opinions regarding the following characteristics of VR environments: a) VR features that they perceived to be the most important for establishing feelings of realism, b) Their preferred activities while using immersive VR and c) Their prediction of immersive VR's potential as an educational tool for the future of education. It was important for the survey to specify the type of VR in each question and provide examples of VR headsets (Oculus Rift, HTC Vive, Playstation VR, Samsung Gear VR or Google Cardboard) so that potential discrepancy between the interpretation of immersive and non-immersive VR types was minimized. A copy of this survey is available in Appendix A. Overall, this survey was used to establish a baseline understanding of participant attitude toward immersive VR, prior to their involvement in the simulation as featured in this investigation.

Simulation Design

The simulation in this investigation included the following components:

(1) A virtual environment depicting a Health Sciences clinic, rendered with Unity game engine software, (2) Two virtual avatars: The first being a virtual standardized patient who was located within the virtual environment and would respond to a user's questions, the second being a virtual exam evaluator who observed the user and would write notes into a clipboard during the interview process, (3) Speech recognition software provided by IBM Watson, a question-answering engine linked with the virtual standardized patient and (4) VR (HTC Vive) and computer hardware that ran the software, allowing users to operate within the virtual environment itself.

Health Sciences Clinic

Experts from the discipline of Computer Science were given a tour of the real-world Health Sciences clinic, allowing them to develop a virtual environment that closely resembled the OSCE setting as accurately as possible. The virtual environment was rendered with Unity game engine software and had two rooms: A hallway and examination room (doctor's office) that were separated by a door. The setting allowed users to move through the hallway, open the door and walk into the doctor's office to meet the virtual standardized patient. The doctor's office included a patient examination table and a computer desk that was outfitted with a desktop computer and miniature clock. At this point, a buzzer was sounded to signal the start of the OSCE and the miniature clock began to countdown from 8-minutes. The avatar representing the exam evaluator was standing discretely in the corner of the room, writing notes into a clipboard throughout the interview process. The avatar representing the standardized patient was sitting in a chair, next to the patient examination table. Both the avatars were programmed to maintain eye contact with the user. Refer to Figure 3.2 for a sample screenshot of the virtual Health Sciences clinic.

According to the Medical Council of Canada (2019):

OSCEs are typically station oriented, attempting to resemble clinical scenarios with as much realism as possible. They are repeatable, controlled and often feature trained actors who portray specific clinical patients in health related situations. Although OSCE stations assess a variety of clinical competencies in students, assessments often focus on a student's ability to communicate with the patient, typically in an interview process with a history taking approach. OSCE stations are timed and formally observed by evaluators who assess the student's performance.

Figure 3.2. An Occupational Therapy student (left) is interviewing a virtual standardized patient (right) while being observed by a virtual evaluator (middle).

Virtual Standardized Patient

The avatar representing the standardized patient was modelled to act as either one of three different patients: Alex, Sam or Jordan. They each had a different cause for their physical injury.

The user could select a specific virtual patient or have one assigned randomly. They were voiced by the same voice actress and could respond to user questions or commands, recognized and processed by IBM Watson's voice recognition software. The avatar would raise her arms above her head when asked to do so, having a noticeable reduction in her range of motion for whichever limb that was injured. She would respond in a respective manner to other physical actions such as when asked to reach behind her back or touch her head.

Speech Recognition Software

IBM Watson was linked to Unity, via Application Programming Interface (API), with a script that contained programming code to access the microphone located on the VR hardware. The script then streamed audio data to the Watson speech-to-text service, allowing the virtual standardized patient to convert the verbal question of a user to text and check it with a list of applicable responses. If a user's verbal question matched an applicable response, the avatar would respond with an answer as previously voice-acted during her development. Her responses would vary depending on if she was Alex, Sam or Jordan. Overall, the avatar was programmed to respond to an array of hard-coded questions that were divergent across the six components of health including the physical, social, environmental, emotional, spiritual and intellectual domains. She would also respond to other medical history questions, such as when asked for the reasoning of her doctor's referral or if we was prescribed medication. She would respond appropriately when greeted. She would state she didn't understand a question when a user issued a verbal command that did not match any line-of-text from the list of applicable responses. Note that she was not programmed to understand or respond to convergent questions such as, "Can you tell me more?"

A detailed list of questions that Alex, Sam or Jordan could understand and respond to is available in Appendix B.

VR and Computer Hardware

This investigation's VR hardware consisted of the HTC Vive, a consumer headset model with built-in microphone, which allowed participants to interact within the virtual health-sciences clinic and converse with the virtual standardized patient. The headset was supplemented with noise-cancellation headphones to reduce any real-world noise that could potentially contaminate the virtual clinic experience. The computer hardware was built using a 3.60 GHz CPU, 8GB GPU and 16GB RAM.

Statistical Analysis

A 2 x 4 mixed factorial analysis of variance (ANOVA) was used to evaluate differences between and within each Phase's STAI, TAI and ASE ratings. Statistical significance was evaluated at $\alpha = 0.05$ and a two-sided P value of .05 or less was considered to be statistically significant. Partial eta-squared (ηp^2) effect size was checked to determine the ratio of variance accounted for by each effect and that effect plus its associated error variance within this ANOVA investigation. A ηp^2 effect was considered meaningful if the value was found to be 0.06 or greater, indicating the effect explained 6% of the variance in the dependent variable. Protected *t*-tests were used to compare each specific time point between Phases as well as total time spent preparing for the OSCE between Phases. Cohen's *d* effect size was checked for protected *t* – tests between Phases. To account for conceivable events where immersive VR may have shown results that were opposite in direction to the expected results, such as state anxiety being increased in students due to the VR intervention itself, analysis checks for differences were two-tailed. Pearson correlation coefficients were performed between both Phases' peak anxiety time points and total study times, plus total peak anxiety and total academic self-efficacy. The peak anxiety TP was expected to be TP2 as it had the closest temporal distance to the OSCE of 1-week.

Power Analysis

A power analysis was used to predict the number of participants needed for this investigation. A power analysis of 0.8 with $\alpha = 0.05$, expecting a large effect size for an ANOVA ($f = .40$), required a minimum sample size of 26. With the same parameters, yet an effect size of $f = .50$, the investigation would have required a minimum sample size of 17.

Results

A total of 49 OT students participated in the study (29 for Phase 1 (NoVR) and 20 for Phase 2 (YesVR)). Although the response rate was 100% for package submissions, there were some missing sections: Phase 2 (YesVR) had one participant fail to submit completed TAI surveys while both Phase 1 and Phase 2 each had one participant fail to submit Study Strategy Logs. From those Logs, only one participant from Phase 2 (YesVR) reported to have suffered from simulation sickness, yet was still able to complete the simulation. Although this investigation was unable to ethically obtain participant demographics, census data from the OT student body was found to be the following**:** For Phase 1, [86.2%], [10.6%], [2.4%] and [0.8%] of the students made up the age groups of [25 – 30], [30 – 35], [36 – 40] and [45-50] respectively. 11.4% were male. For Phase 2, [16.5%], [72.7%], [9.9%], and [0.8%] of the students made up the age groups of [20 – 24], [25 – 30], [30 – 35] and [36 – 40] respectively. 9.1% were male. Main statistical analysis results has been provided in Table 3.1.

Table 3.1

Statistical Analysis Results

Variables		Phase (mean values)			ANOVA			*t* - Test	
		NoVR (*SD*)	YesVR (*SD*)	df	*F*	*p*	*ηp²*	*t*	*p (d)*
STAI (Y-1)	TP1	44.34 (12.38)	40.70 (11.06)	47				1.06	.296
	TP2	**48.03 (12.67)**	**41.25 (7.54)**	**46.19[a]**				**2.34**	**.023 (0.65)**
	TP3	39.55 (10.60)	41.45 (11.69)	47				-.59	.557
	TP4	31.17 (9.17)	34.75 (8.76)	47				-1.37	.178
STAI (Phase)				47	.28	.602	.006		
STAI (Time)				**3**	**18.40**	**<.001**	**.281**		
STAI (Intercept)				**3**	**4.12**	**.008**	**.081**		
TAI	TP1	41.59 (14.07)	41.89 (12.99)	46 [b]				-.77	.939
	TP2	42.72 (13.55)	41.21 (11.58)	46 [b]				.40	.691
	TP3	40.62 (13.62)	41.68 (11.48)	46 [b]				-.28	.780
	TP4	40.52 (14.40)	41.79 (12.50)	46 [b]				-.32	.754
TAI (Phase)				46 [b]	.01	.941	<.001		
TAI (Time)				3	.67	.569	.014		
TAI (Intercept)				3	1.57	.199	.033		
ASE	TP1	18.90 (2.43)	19.20 (3.12)	47				-.38	.704
	TP2	18.93 (2.37)	19.45 (3.10)	47				-.66	.511
	TP3	19.79 (2.64)	19.80 (2.93)	47				-.01	.993
	TP4	20.03 (2.76)	20.55 (2.72)	47				-.65	.521
ASE (Phase)				47	.22	.643	.005		
ASE (Time)				**2.62[c]**	**8.98**	**<.001**	**.160**		
ASE (Intercept)				2.62[c]	.40	.728	.008		

[a]Levene's Test for Equality of Variances found equal variances not assumed, thus df was changed accordingly.
[b]Phase 2 (YesVR) had one participant fail to complete TAI surveys.
[c]Macuhly's test found sphericity assumption violated, thus df was corrected using Greenhouse-Geisser (ε = .88).

Results – State Anxiety

Figures 3.3 and 3.4 shows student state anxiety across time. The results of the 2 x 4 Mixed ANOVA showed there was no significant main effect for Phase ($F(1, 47) = .276$, $p = .602$, $\eta p^2 =$

.006) on state anxiety scores, with NoVR (mean = 40.78) and YesVR (mean = 39.54) performing similarly overall. However, there was a significant difference in state anxiety scores between Phases at TP2 with NoVR showing greater anxiety scores (mean = 48.03, *SD* = 12.67) than YesVR (41.25, *SD* = 7.54) at $t(46.19) = 2.34$, $p = .023$, Cohen's $d = 0.65$, $\eta p^2 = .105$. The mean difference was 6.78 units (95% confidence interval .96 – 12.61).

There was a significant effect for time on state anxiety scores ($F(3, 141) = 18.40$, $p < .001$, $\eta p^2 = .281$) with participants showing a rise-then-fall trend in mean state anxiety scores across the time points (TP1 = 42.86, TP2 = 45.27, TP3 = 40.33, TP4 = 32.63). Pairwise comparisons that were corrected with Bonferroni *t*-tests and confidence interval adjustments showed a significant difference between TP1 (mean = 42.86, *SD* = 11.88) and TP4 (mean = 32.63, *SD* = 9.09) at $p < .001$, with a mean difference of 9.56 units (95% confidence interval 5.12 – 14.00). There was also a significant difference between TP2 (mean = 45.27, *SD* = 11.29) and TP4 at $p < .001$, with a mean difference of 11.68 units (95% confidence interval 7.30 – 16.06). Lastly, a significant difference was found between TP3 (40.33, *SD* = 10.98) and TP4 at $p < .001$, with a mean difference of 7.54 units (95% confidence interval 2.94 – 12.14).

There was a significant interaction between time and phase in terms of state anxiety scores ($F(3, 141) = 4.12$, $p = .008$, $\eta p^2 = .081$). Descriptive statistics showed that while NoVR participants showed greater state anxiety scores for TP1 (mean = 44.34, *SD* = 12.38) and TP2 (mean = 48.03, *SD* = 12.67) than YesVR participants' TP1 (mean = 40.70, *SD* = 11.06) and TP2 (mean = 41.25, *SD* = 7.54) respectively, the opposite pattern occurred at TP3 and TP4 with NoVR participants showing lesser state anxiety scores (mean = 39.55, *SD* = 10.60 and mean = 31.17, *SD* = 9.17 respectively) than YesVR (mean = 41.45, *SD* = 11.69 and mean = 34.75, *SD* = 8.76 respectively).

These results show that student state anxiety had a rise-then-fall trend, peaking at the time point just before the OSCE. At this point, students who had access to the VR clinical simulation showed less anxiety than the controls.

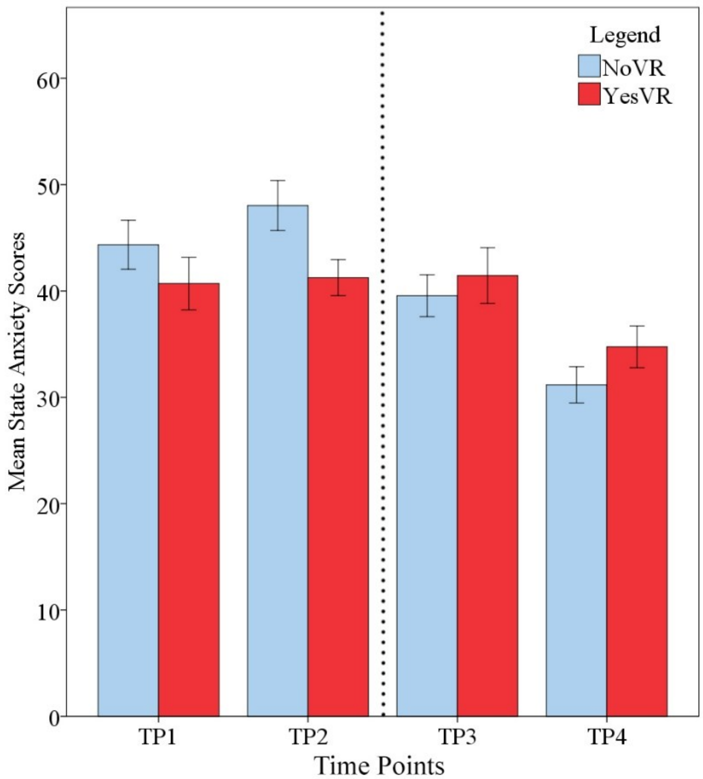

Figure 3.3. Mean state anxiety scores between NoVR with YesVR Phases in Occupational Therapy students preparing for an Objective Structured Clinical Exam (OSCE). The dotted line represents when the actual OSCE took place. TP1, TP2, TP3 and TP4 each represent 3-weeks pre OSCE, 1-week pre OSCE, 1-week post OSCE and 4-weeks post OSCE respectively. Error bars represent standard errors.

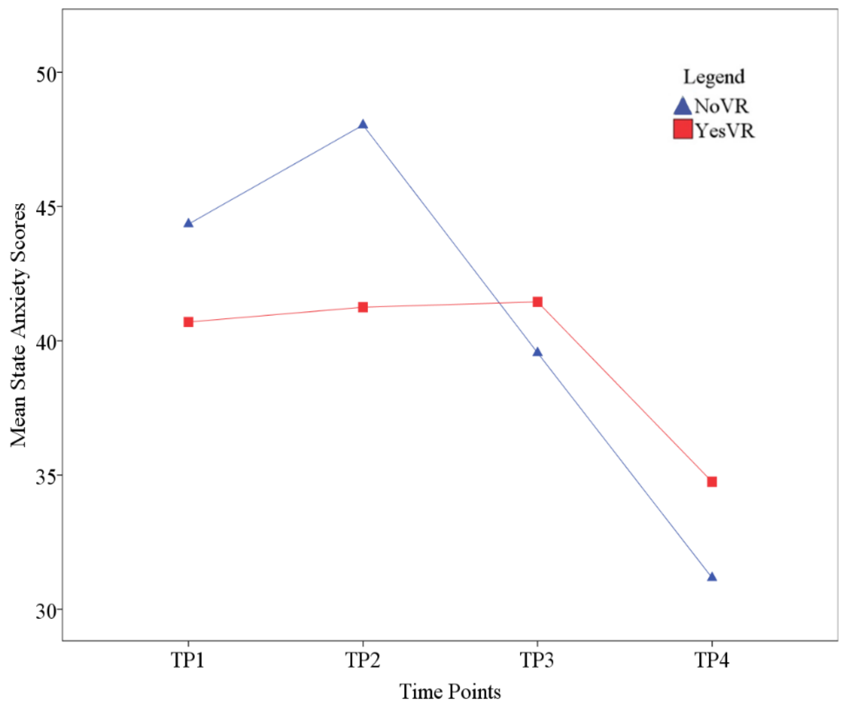

Figure 3.4. Mean state anxiety scores between NoVR with YesVR Phases in Occupational Therapy students preparing for an Objective Structured Clinical Exam (OSCE). TP1, TP2, TP3 and TP4 each represent 3-weeks pre OSCE, 1-week pre OSCE, 1-week post OSCE and 4-weeks post OSCE respectively.

Results – Test Anxiety

Figure 3.5 shows student test anxiety across time. The results of the 2 x 4 Mixed ANOVA showed there was no significant main effect for phase ($F(1, 46) = .005$, $p = .941$, $\eta p^2 < .001$) on test anxiety inventory scores, with NoVR (mean = 41.36) and YesVR (mean = 41.65) performing similarly overall. There was no significant effect for time on test anxiety inventory scores ($F(3, 138) = .674$, $p = .57$, $\eta p^2 = .014$), with participants showing a similar level of scores across the time points (TP1 = 41.71, TP2 = 42.13 TP3 = 41.04, TP4 = 41.02). There was no significant interaction between time and phase in terms of test anxiety inventory scores ($F(3, 138) = 1.57$, $p = .20$, $\eta p^2 = .033$).

These results show that student test anxiety scores had remained relatively static throughout their participation in the OT program, whether they had access to VR or not.

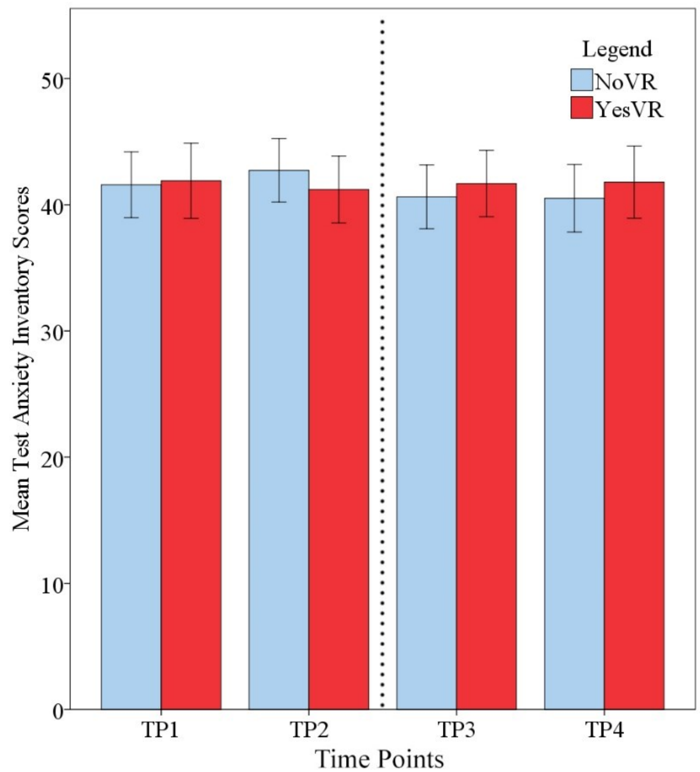

Figure 3.5. Mean test anxiety scores between NoVR with YesVR Phases in Occupational Therapy students preparing for an Objective Structured Clinical Exam (OSCE). The dotted line represents when the actual OSCE took place. TP1, TP2, TP3 and TP4 each represent 3-weeks pre OSCE, 1-week pre OSCE, 1-week post OSCE and 4-weeks post OSCE respectively. Error bars represent standard errors.

Results – Academic Self-Efficacy

Figure 3.6 shows student academic self-efficacy across time. The results of the 2 x 4 Mixed ANOVA showed there was no significant main effect for phase ($F(1, 47) = .217$, $p = .643$, $\eta p^2 = .005$) on academic self-efficacy scores, with NoVR (mean = 19.41) and YesVR (mean = 19.75) performing similarly overall.

Mauchly's test indicated that the assumption of sphericity had been violated for the main effects of time, $x^2(5) = 13.32$, $p = .021$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .88$). There was a significant effect for time on academic self-efficacy scores ($F(2.62, 123.32) = 8.98$, $p < .001$, $\eta p^2 = .160$), with participants showing an increase in mean academic self-efficacy scores across the time points (TP1 = 19.02, TP2 = 19.14, TP3 = 19.80, TP4 = 20.24). Pairwise comparisons that were corrected with Bonferroni *t*-tests and confidence interval adjustments showed a significant difference between TP1 (mean = 19.02, *SD* = 2.70) and TP4 (mean = 20.24, *SD* = 2.73) at $p = .001$, with a mean difference of 1.24 units (95% confidence interval .45 – 2.04). There was also a significant difference between TP2 (mean = 19.14, *SD* = 2.68) and TP4 at $p = .002$, with a mean difference of 1.10 units (95% confidence interval .32 – 1.89).

There was no significant interaction between time and phase in terms of academic self-efficacy scores ($F(2.62, 123.32) = .40$, $p = .73$, $\eta p^2 = .008$).

There was a significant moderate negative correlation between total mean academic self-efficacy (mean total = 19.14; *SD* = 2.68) and mean total peak state anxiety scores at TP2 (mean = 45.27, *SD* = 11.30) at $r = -.42$, $n = 49$, $p = .003$.

These results show that student academic self-efficacy had continually increased throughout their participation in the OT program, whether they had access to VR or not, yet it was inversely related to state anxiety at the peak anxiety time point.

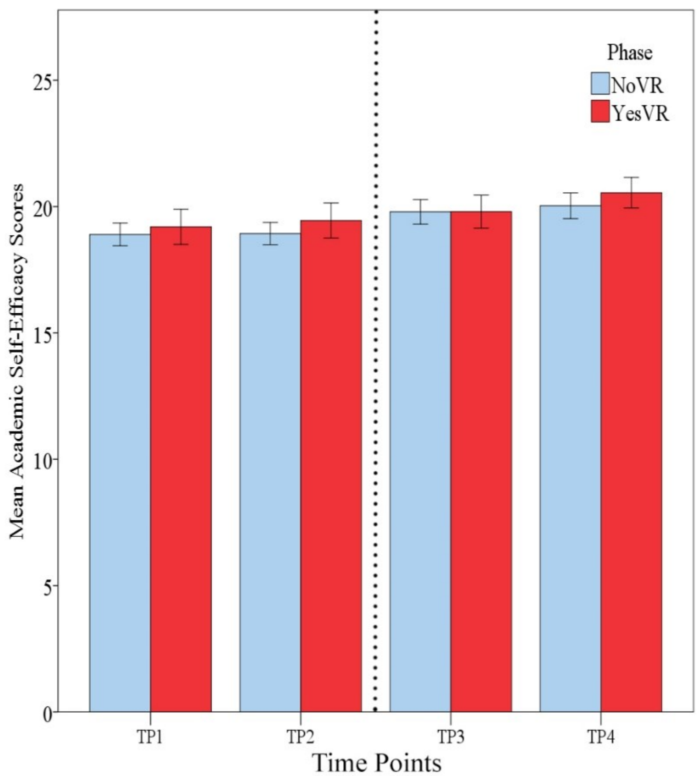

Figure 3.6. Mean academic self-efficacy scores between NoVR with YesVR Phases in Occupational Therapy students preparing for an Objective Structured Clinical Exam (OSCE). The dotted line represents when the actual OSCE took place. TP1, TP2, TP3 and TP4 each represent 3-weeks pre OSCE, 1-week pre OSCE, 1-week post OSCE and 4-weeks post OSCE respectively. Error bars represent standard errors.

Results – State Anxiety and Total Study Time

Figure 3.7 and Figure 3.8 show respective NoVR and YesVR Phase correlations of student peak anxiety levels in relation to their total study times. Note that these total study times were reported by the students themselves outside of their normal lecture and lab hours. For the NoVR participants, there was a significant moderate positive correlation between total study time (mean = 1151.79; *SD* = 572.44 minutes) and student state anxiety scores at TP2 (mean = 48.03, *SD* = 12.67) at $r = .46$, $n = 28$, $p = .013$. For the YesVR participants, there was a significant moderate positive correlation between total study time (mean = 1577.37; *SD* = 830.03 minutes) and student state anxiety scores at TP2 (mean = 41.25, *SD* = 7.54) at $r = .52$, $n = 19$, $p = .024$.

There was no significant difference in total study time per week between NoVR (mean = 383 minutes/week, *SD* = 191 minutes/week) and YesVR (mean = 315 minutes/week, *SD* = 166 minutes/week) at $t(45) = 1.27$, $p = .210$, Cohen's $d = 0.38$.

The results show that excess time spent studying and preparing for clinical practical examinations was related to an increase in state anxiety.

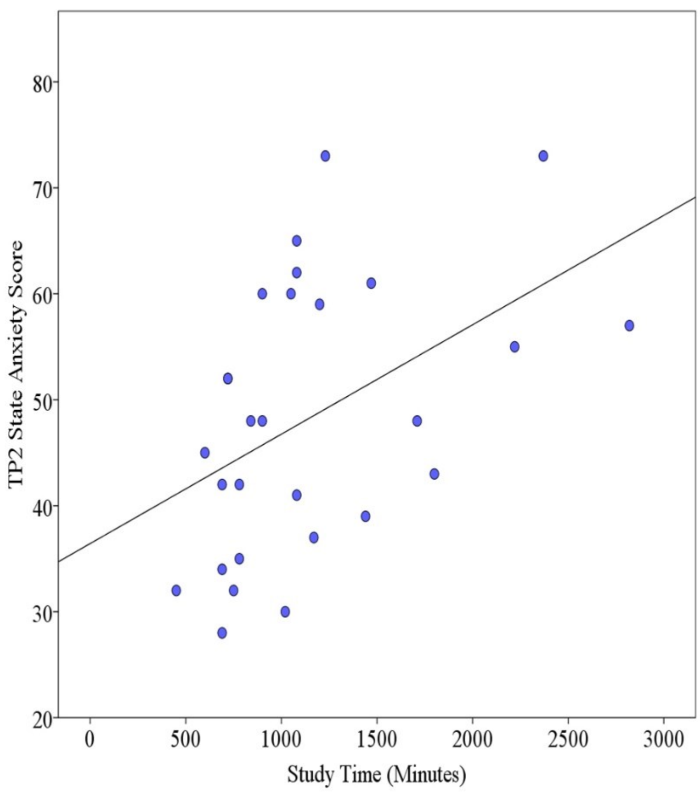

Figure 3.7. Relationship between Phase 1 (NoVR) student state anxiety scores and their total study time in preparation for an Objective Structured Clinical Exam (OSCE). Peak state anxiety scores measured 1-week prior (TP2) to OSCE. Pearson's $r = .46$.

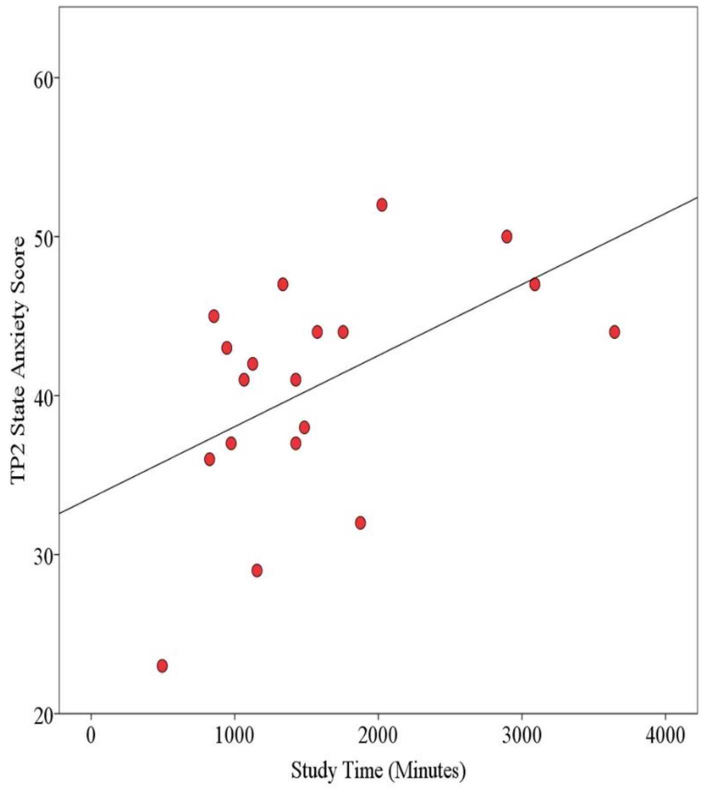

Figure 3.8. Relationship between Phase 2 (YesVR) student state anxiety scores and their total study time in preparation for an Objective Structured Clinical Exam (OSCE). Peak state anxiety scores measured 1-week prior (TP2) to OSCE. Pearson's $r = .52$.

Results – Study Strategies

Figure 3.9 shows the various study strategies the students used while preparing for their OSCE. Note that these study strategies were reported by the students themselves outside of their normal lecture and lab hours. The topmost strategies used by the students were hands-on practice – group (mean = 44.99%), note review (mean = 21.34%) and hands-on practice – individual (mean = 18.28%). The three least used strategies were internet sources (mean = 0.23%), tutelage from experienced students (mean = 0.10%) and office hours (mean = 0.09%). The majority of students in Phase 2 utilized the VR simulation for a single 15-minute session, with some having multiple sessions which made the mean VR simulation time per student at 17-minutes.

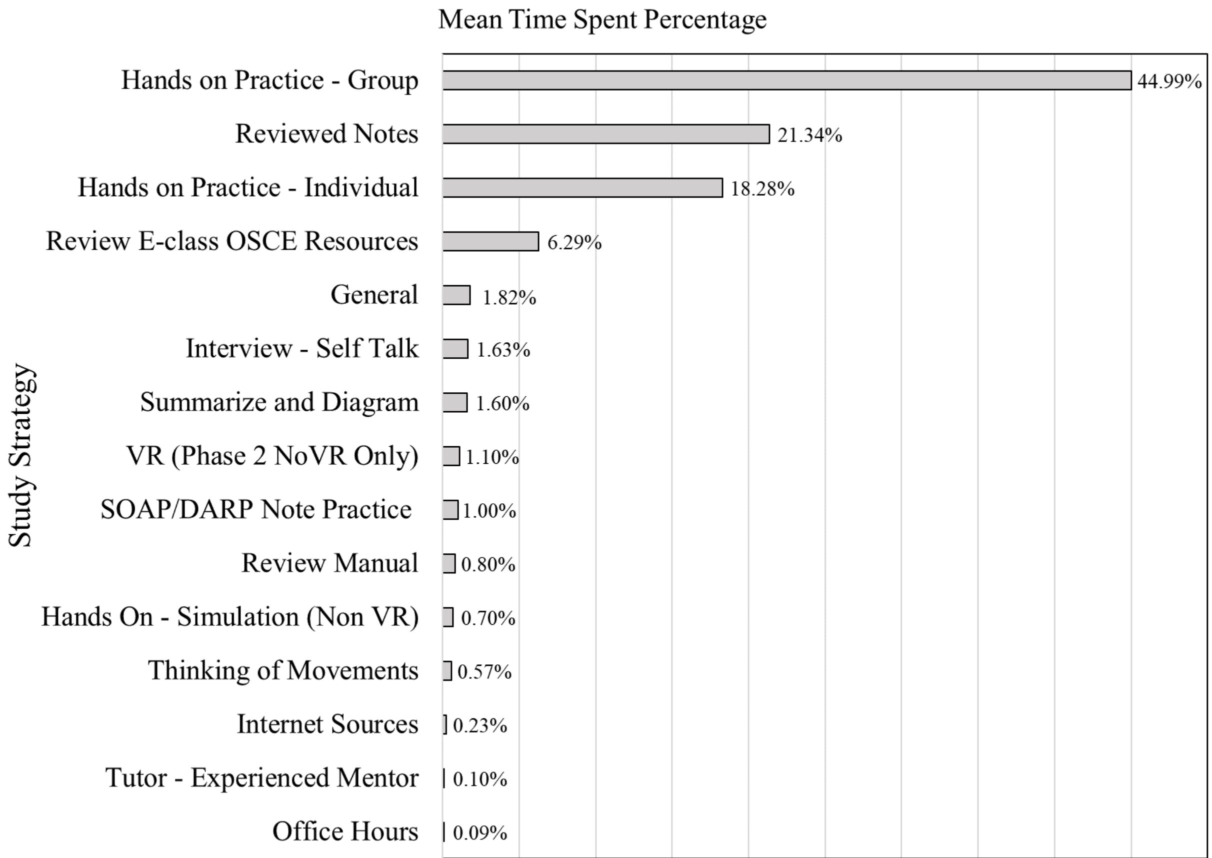

Figure 3.9. Mean percentages of time spent by students on their study strategies as they prepared for an Objective Structured Clinical Exam (OSCE). These study strategies were outside of normal lecture and lab hours.

Results – Previous Experience VR Survey

Phase 2 (YesVR) participants provided the following majority responses:

- 60% stated that they had no previous experience with immersive VR.
- 85% stated that they had neither themselves or their friends/coworkers owned an immersive VR system.
- 65% stated that their main interest for immersive VR was Training and Education.

- 90% stated that quality of the graphics was the most important requirement for making virtual environments feel the most realistic (85% stated ease of use and interaction with the environment in addition to graphic quality).
- 95% stated that they would prefer to use immersive VR for professional work/education (70% stated learning a new skill in addition to professional work/education).
- 50% stated that immersive VR would have moderate potential as an educational tool within the next 10-years (35% stated that immersive VR would be the way of the future).

Discussion

This investigation shows evidence of immersive VR's potential to reduce anxiety in OT students, during their peak state anxiety time point as they prepared for an upcoming OSCE. However, this investigation did not fulfill the requirements of a rigorous randomized control trial. Thus, causation of immersive VR's effectiveness for the reduction of anxiety in OT students in-training cannot be inferred. Favourable demonstrations of immersive VR's ability to reduce anxiety must consider that cognitive and affective responses, within the confines of a virtual world, could vary from those observed in the real world. The artificial nature of OSCEs are designated to act as simulations themselves, and despite their attempts to represent situations within the real world, they are not the real world (Downing & Haladyna, 2004). Such can be stated for immersive VR simulation and its potential to optimize mental preparedness in medical students for the real world. Despite these remarks, previous research on immersive VR has demonstrated its capability for reducing state anxiety, within the field of Health Sciences (Gaggioli et al., 2014). The results of this investigation reflected those trends.

Main Findings

State anxiety in the OT students was found to be different between Phases at only the time point located 1-week prior to the OSCE, which encompassed the VR intervention for the purpose of *inhibitory learning* to occur. The VR intervention was designed for the purpose of reducing anxiety during that window of time alone, 1-week prior to the OSCE, thus no significant differences were expected or observed in each of the other time points. It cannot be ruled-out that differences in participant characteristics, covariates, coursework or even the qualities of the students themselves, who agreed to participate, may have been responsible for the difference in state anxiety observed. It also cannot be stated that student performance anxiety levels were reduced, during their actual performance in the OSCE event itself, since no measures were taken at that time. Gaggioli and colleagues' workplace stress report (2014) showed a main effect for the reduction of anxiety in their VR experimental group, yet their study featured multiple VR sessions (eight treatment sessions) while the mode of this investigation featured only one.

According to Spielberger's manual (2015), normative mean state anxiety levels in military recruits (Air Force and Navy personnel in Texas and Florida respectively) were found to be 44.05, *SD* = 12.18 and 47.01, *SD* = 14.42 for males and females respectively. This investigation's peak mean state anxiety scores (48.03, *SD* = 12.67 and 41.25, *SD* = 7.54 for NoVR and YesVR respectively) resembled those military recruits' state anxiety levels. During the students' 3-week preparation window for their upcoming OSCE, this investigation showed greater mean state anxiety levels than Spielberger's reported normative data (2015) of college students (Psychology students in Florida at 36.47, *SD* = 10.02 and 38.76, *SD* = 11.95 for males and females respectively). The implication of these anxiety levels implies that OT departments, considering the incorporation of OSCEs for performance assessments, should expect students to experience increasing levels of state anxiety, especially when their OSCE appointments draw near. Systems should be implemented to mitigate this increase in state anxiety.

Test anxiety in OT students was not found to be different between Phases or time points. Spielberger's manual (1980) states the TAI was developed as a tool to measure test anxiety as a "situation-specific personality trait." This could potentially be less sensitive to changes over time than the Form Y – 1 of the STAI, which is a measure that is sensitive to changes in state anxiety. Note that test-retest reliability of TAI scores for college and graduate students for time spans of 3-weeks and 2-weeks respectively have each been found to be strong (*r* = .80) (Spielberger et al., 1980). Personality traits are expected to be stable and unlikely to change over time (Soldz & Vaillant, 1999). Despite this lack of difference, there are two points to consider: 1) Having no significant difference in test anxiety scores between Phases at the first time point, prior to the VR simulation intervention, further establishes similarity between Phases of OT students for test anxiety specific personality traits, prior to their shown differences in state anxiety at TP2. 2) The implication of test anxiety specific personality traits, being the same across the time points, means that student attitudes of clinical practical exams are unlikely to change as they participate in an OT program. If students suffer debilitating symptoms of test anxiety, this is unlikely to change as they continue with their OT program. OT programs are recommended to be equipped with separate and dedicated activities to mitigate test anxiety in students.

In order for immersive VR to have potential in reducing trait-based anxiety, it would require an established treatment protocol, similar to what Gaggioli and colleagues stated in their workplace stress report in 2014. Their treatment protocol followed the stress management training program as established by Kaluza and Meichenbaum, which consisted of 10 one-hour sessions in 5 weeks, administered by clinical psychologists (Kaluza, 2000; Meichenbaum, 1985; Pallavicini et al., 2013). A stress management training program utilizing VR in this manner would be expected to reduce chronic workplace trait-anxiety by 12%, greater than the results found when compared to a cognitive behavioural therapy control group (Gaggioli et al., 2014).

This investigation unexpectedly found academic self-efficacy to gradually increase across the time points for both Phases, despite an expected moderate inverse relationship being found at the peak state anxiety point. Greater academic self-efficacy being associated with lower state anxiety is congruent to Dobson's report (2012), which was reflected in this investigation's peak anxiety time point. In a report featuring writing anxiety in graduate students, self-efficacy was found to have a large and inverse relationship with writing anxiety (Huerta, Goodson, Beigi, & Chlup, 2017). However, it has been stated in previous reports that low to moderate levels of emotionality, affective physiological reactions to anxiety, may actually enhance a student's performance, while excessive levels may cause a reduction in performance (Cassady & Johnson, 2002; Spielberger, Charles D. & Vagg, 1995). The peak state anxiety levels in the OT students within this investigation were not strong enough to show a noticeable reduction in their academic self-efficacy scores, possibly due to extraneous variables such as mental resiliency and previous experience. Enjoyment in the learning material and student pride have been found to have positive associations for self-efficacy (Villavicencio & Bernardo, 2016). Future research that compares OT student's peak state anxiety levels and their actual OSCE performance scores would allow further conclusions to be made for academic self-efficacy, state anxiety and performance relationships.

There is a conceivable argument to be made for the necessity of students to endure anxiety symptoms as they progress through OT programs. By overcoming situations that induce anxiety, it is arguable that students will learn necessary coping skills to apply in practice for the real world. However, this investigation showed no difference in the rate of academic self-efficacy development between the YesVR and NoVR groups of OT students, despite their significant difference in peak state anxiety scores. Thus, it is presumable that OT students will not have their academic self-efficacy development compromised when VR interventions significantly reduce state anxiety levels. VR interventions that are designed to reduce state anxiety do not result in OT students missing out on academic self-efficacy development.

For the association between total study time and peak state anxiety, it is to be assumed that greater time spent in preparation for an upcoming OSCE is equivalent to students placing greater amounts of perceived importance into the successful outcome of the evaluation. Students who appraise exams with high importance are associated with increased state test anxiety levels before the exam, which determines higher anxiety levels after the exam (Roick & Ringeisen, 2017). This association could also mean that facilitative aspects of anxiety may have compelled the students to spend greater amounts of time in preparation for the OSCE.

The OT students in this investigation showed a variety of study strategies as they prepared for their OSCE. While the majority of students in this investigation utilized hands-on practice – group, hands-on practice – individual and note review, there are several other strategies that were less utilized. The implication is that students should adopt learning strategies that form a personal meaning with themselves, which requires having a greater awareness of study options available. OT programs are encouraged to make students aware of the various study strategies available, enabling students to discover those that establish personal meaning.

Based on student response from the Previous Experience VR Survey, it appears that views regarding the adoption of VR simulation into OT programs are favourable, especially for use in professional work and education. The majority of students stated that quality of graphics was the most important consideration for achieving realistic virtual environments, while also stating that ease of use and interaction was also important. In this investigation, the virtual standardized patients were programmed to maintain eye contact with the user throughout the simulation, yet this extent of nonverbal communication cues could be improved upon. In future designs, kinesics such as posture, gesture and facial expression are encouraged to be implemented into virtual avatars to optimize quality of communicative experiences (Steptoe, 2010). The communicative properties of an avatar's eyes (oculesics) such as gaze, pupil dilation and eyelid movements are considered to have a major impact on a user's perceived sense of realism (Steptoe, 2010) Based on Steptoe's (2010) report, varying these oculesics parameters in virtual standardized patients, to match those of varying personality types or truth/deception responses, may result in avatars that students may perceive to be socially real. A virtual environment that simulates having an interview with a patient, based mainly on social communication interactions, allows users to establish a sense of what is expected in the real world. Incorporating oculesic properties into virtual patients may instill a greater sense of immersion for the user to enhance their communicative experience.

Strengths and Limitations

This investigation is potentially the first to implement an immersive VR intervention, within the discipline of OT, for the reduction of state anxiety in students who were preparing for an OSCE. This investigation aimed to minimize researcher bias by having minimal contact with the participants. The primary outcome measures for state and test anxiety, in addition to academic self-efficacy, were taken by established theory-based tools. This investigation was supplemented by secondary outcome measures including student total study time, strategies and previous experience with immersive VR, which were deduced with the primary measures.

However, this investigation had the following limitations: Measures of student performance anxiety were not taken during the actual OSCE event, which did not allow inferences to be made about immersive VR's effectiveness for that specific occasion. There were no follow-up measures taken, such as during the students' next year of preparation for their second OSCE, determining if immersive VR had an effect on long-term memory development for *inhibitory learning*. Physiological stress markers such as blood cortisol levels, saliva, urine or heart rate were not measured to determine possible changes in affective anxiety components. The sample size of this investigation was satisfied for within-subject measures, but sample size would need to be increased for establishing greater confidence in the between-subject measures. This investigation was unable to check for student covariates between the Phases and did not perform the rigors of a randomized control trial. The total cost for the software, hardware and development of the simulation itself was estimated to be over $50,000 US, which may discourage the adoption of such a system in other OT facilities. It is important to note that technological improvements in immersive VR hardware and software development is becoming increasingly efficient, however, resulting in an increase of accessibility to this platform.

Future Recommendations

In addition to implementing design changes for the rectification of limitations as stated in this investigation, future designs may consider the use of general or workplace based self-efficacy questionnaires, establishing student perceived levels of competency for the professional world. A comparison of immersive VR's performance, developed with improved artificial intelligence for interview skill-training, evaluated with formal Clinical Performance Assessments, could be implemented to establish student levels of performance for the professional world. Virtual standardized patients could also be developed to have unique traits, allowing for students to train for scenarios that would otherwise be difficult or possibly dangerous.

Conclusion

This investigation shows evidence of immersive VR's capability to reduce anxiety in OT students, who communicated with virtual standardized patients, using natural language. Although test anxiety potentially leads to worry cognitions, which can disrupt students' attention, this investigation showed that academic self-efficacy continually increased in Health Science students as they persevered in their program. A combination of optimal study strategies and immersive VR simulation, for the reduction of anxiety in Health Science students, preparing for clinical practical exams, can lead to a future of positive mental health change from the virtual to real world. Will your next clinical interview take place in the virtual world?

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A

Previous Experience with Virtual Reality Technology

Virtual Reality (Definition): An artificial environment or simulation which is experienced through sensory stimuli (e.g., as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment" (Merriam Webster, 2017).

Instructions: Please answer the following letter-options for each question below:

1. Aside from the OSCE Preparation VR sessions, have you tried the latest VR headsets such as the Oculus Rift, HTC Vive, Playstation VR, Samsung Gear VR or Google Cardboard?
    a. Never tried
    b. Once
    c. A few times
    d. Regularly
2. Do you own any of the latest VR headsets or apps for systems such as the Oculus Rift, HTC Vive, Playstation VR, Samsung Gear VR or Google Cardboard?
    a. No, not even my friends/coworkers do
    b. No, but one or more of my friends/coworkers do
    c. Yes, I own one
    d. Yes, I own more than one
3. My interest in virtual reality includes (may circle more than one):
    a. Entertainment and gaming
    b. Touring and shopping
    c. Training and education

d. No interest

e. Other (please specify): _____________

4. Which of the following is the most important for making a virtual environment feel the most realistic (may circle more than one):

    a. Quality of the graphics

    b. Relatable content

    c. Ease of use and interaction with the environment

    d. Music and sound effects

    e. Other (please specify): _____________

5. What would you like to be doing in virtual reality? (may circle more than one)

    a. Professional work/education

    b. Entertainment and gaming

    c. Arts / design

    d. Learning a new skill

    e. Other (please specify): _____________

6. Between now and 10-years from now, how much potential do you think virtual reality has as an educational tool?

    a. None

    b. Minor

    c. Moderate

d. Way of the future

e. Other (please specify) : ___________________

Appendix B

Topic	User Questions that VR is Programmed to Respond to:
Greeting	Greetings
	Hello
	Hey
	Hey there
	Hi
	Howdy
Greeting: Question	Hi, how are ya?
	How are you?
	How are you doing today?
	How are you feeling?
	How's it going?
Introduction	What is your name?
	Tell me about yourself
	Can you tell me a bit yourself?
	What can you tell me about yourself?
	Can you help me to understand who you are as a person?
Consent	Are you all right if we do a quick interview?
	Are you okay if we do an interview together?
	Are you okay with me writing this information down?
	Are you open to having a coversation about your injury?
	Are you open to me asking you some questions?
	Before we begin, I just need to make sure you are okay with this interview, is that okay?
	Can I ask you some questions?
	Can I ask you some questions about how you are doing?
	Can we talk a bit about your injury?
	Can you follow along with the movements I am asking you to do?
	Do you consent to this assessment?
	I am going to ask you to do some movements for me, is that okay?
	I am going to assess how you are moving, is that okay?
	I am going to see how your injury is impacting your ability to move, is that okay?
	I am going to ask you some questions about your injury, is that okay?
	Is it okay for us to do an interview?
	Is it okay with you if I take down some notes?
	I want to learn more about your injury and how it is impacting you. Can we chat about that for a bit?
	I was hoping to do an interview with you, is that okay?
Purpose	Do you know why you are here today?
	I read on your referral that you injured your arm...

	Is there anything I can help you with?
	What brings you here today?
Injury: When	Approximately how long ago did you get hurt?
	How long ago did you get injured?
	How long ago did you hurt yourself?
	I heard that you hurt yourself, when was that?
	Mmm that suchs, when did this happen?
	When did that happen?
	When did this happen?
	When did you hurt yourself?
	When did you injure yourself?
	When did you sustain the injury?
Injury: How	Can you tell me how you injured yourself?
	How did the injury occur?
	How did this happen?
	How did you get hurt?
	How did you hurt yourself?
	How did you injure yourself?
	What happened when you hurt yourself?
	What happened when you injured yourself?
Injury: Where	Heard you had an injury, where does it hurt?
	Was it your left or right side?
	Where are you injured?
	Where did you hurt yourself?
	Where did you injure yourself?
	Where do you feel discomfort?
	Which shoulder did you hurt?
	Which shoulder hurts today?
	Which side does it hurt on?
	Which side is your injury on?
Pain: Now	Are you currently in pain?
	Are you in pain right now?
	Are you in pain today?
	Does it hurt right now?
	Does your shoulder hurt if you are just sitting there?
	How does it feel?
	How does your injury feel now?
	How does your shoulder feel now?
	How's the pain now?
	Is it painful right now?
	Is there any pain or discomfort in your shoulder now?

Pain: Type	Does the pain radiate?
	How would you describe the pain?
	Is it a sharp pain?
	Is it a throbbing pain?
	What kind of pain is it?
Pain: When	Does it hurt at night?
	Does it hurt in the morning?
	Does it hurt more in the morning or at night?
	Does it hurt more when you've been sitting for a while?
	Does it hurt with activity or with rest?
	Does it worsen with activity?
	Does the pain increase with anything?
	Does the pain wake you up at night?
	Is there an activity that makes the pain worse?
	What time of day does it hurt the most?
	What time of day does it usually hurt?
	What types of activities make the pain worse?
	When does it hurt the most?
	Is there usually a time of day that the pain happens?
Pain: Severity	Are you in a lot of pain?
	How badly does it hurt right now?
	How much does it hurt?
	How much pain are you in?
	How severe is the pain?
	On a scale of 1-10 how bad is the pain?
	On a scale of 1-10 how would you rate your pain?
	On a scale of one to ten how much would you rate your pain?
	On a scale of one to ten how severe would you rate your pain?
	What is your pain severity?
	When you are sitting, how severe is the pain?
	When you're working, what would you rate your pain?
Medication: Use	Are you currently taking any medications?
	Are you taking anything for your other medical conditions
	Do you ever find it hard to remember to take your medications?
	Do you have any difficulties with your medications?
	Do you take any prescription medications now?
	Have you been prescribed any medications?
	How many medications are you taking?
Medication: Adherence	Do you have any difficulties with your medications?
	Do you have any trouble managing your medications?
	How many medications are you taking?

Past Medical History	Are there any medical conditions that I need to know about?
	Do you have any concenrs other than your shoulder injury?
	Do you have any other conditions that may be relevant for me to know?
	Do you have any other health concerns?
	Do you have any other medical conditions?
	Have you had any past injuries?
	Have you had any past medical history?
	Have you had this type of injury before?
	Have you injured your shoulder in the past?
	How was your health before the injury?
OT Knowledge	Are you familiar with what occupational therapists do?
	Before we get started, I was just wondering if you know what occupational therapy is about?
	Do you know what occupational therapists do?
	Do you know what occupational therpay is about?
	Do you know what occupational therpay is all about?
	Do you understand occupational therapy?
	Do you understand what occupational therapy is?
	Have you ever worked with an occupational therapist before?
	Have you heard of occupational therapy before?
	What do you know about occupational therapy?
Mood: General	How do you feel your emotional health is?
	How have you been feeling lately?
	How would you describe your mood lately?
	What's your mood like today?
Mood Yes/No	Are you more angry or irritable since your injury?
	Are you more prone to anger or sadness now?
	Do you find the pain affects your mood at all?
	Do you have any concerns with your mood or how you have been feeling lately?
	Do you think that you are more prone to irritability or frustration now?
	Do you think your mood has been affected by the injury?
	Has the pain affected your mood at all?
	Has your mood changed?
	Have people around you commented on changes in your mood?
	Have you been feeling down or depressed lately?
	Have you been feeling emotional lately?
	Have you been feeling sad or angry lately?

	Have you experienced more sadness than usual?
	Have you felt a change in your mood? Maybe you get angry more easily? Or sad?
	Have you felt more angry or sad emotions since your injury?
	Have you felt more negative emotions since your injury?
	Have you felt that your emotions fluctuate more so than before?
	Have you noticed any changes in your mood?
	Have you noticed anything different about your mood?
	Have your family or friends noticed any changes in your mood?
	Is your mood lower compared to what it was like before?
	Would you describe your mood as same as always, or different than before?
	Would you say that your mood has changed due to the injury?
	Would you say that your mood is still the same as it was before?
Fatigue	Do you feel as energetic as before?
	Do you feel that fatigue is an issue for you?
	Do you feel tired or fatigued more often than usual?
	Do you find that you tire more easily now?
	Have you noticed a change in your energy levels?
Fatigue Difficulties	Do you feel tired after a specific activity?
	Do you find working really fatiguing?
	Do you think there is any activity that really tires you out?
	Is there anything activity that makes you tired?
	Is there anything you find that really drains your energy?
	What activities make you tired?
	What makes you more fatigued?
Pain: Cognition	Can you focus or concentrate on tasks like you were able to before?
	Does the pain affect your concentration?
	Does the pain affect your concentration at all?
	Does the pain affect your concentration or memory?
	Does the pain affect your memory?
	Do you find it hard to concentrate sometimes because of the pain?
	Do you find it hard to focus sometimes due to the pain?
	Do you think your focus or attention has been impacted by the pain?
	Has it been difficult to pay attention or focus on tasks?
	Has pain impacted your ability to pay attention to things?
	Has the pain impacted your concentration?
	Has the pain impacted your memory?
	Has you concentration or memory suffered because of the pain?
	Have the pain affected your ability to concentrate in your daily tasks?
	Have you found it hard to concentrate lately?
	Have you noticed any changes in your ability to concentrate or rememeber things?
	Is you concentration or attention the same as it was before?

	Sometimes pain affects a person's ability to concentrate or remember. Do you feel that is affecting you in this way?
	Sometimes pain can cause you to have changes in your concentration or memory; have you noticed this at all?
	What has your concentration been like?
	Would you say your ability to focus and concentrate has been the same, or different?
Pain: Sleep Disturbances	Are you having troubles falling asleep at night?
	Does it hurt when you go to sleep?
	Does the pain disturb your sleep?
	Do you find the pain disturbs your sleep at all?
	Do you have difficulty falling asleeping or staying asleep?
	Has the pain prevented you from having a good night's rest?
	Has your sleep been affected at all?
	Have you been sleeping ok?
	Would you say that the pain is interrupting your sleep?
Occupation: General	Has the injury impacted your ability to do anything?
	Has your injury affected your ability to do what is important to you?
	Have you found any activities difficult to do since your injury?
	How has your injury affected your daily activities?
	How has your pain affected your daily activities?
	What do you find difficult to do?
Self-Care	Are you able to do things like dress yourself or brush your teeth?
	Are you able to put on clothes and shoes yourself?
	Are you having any difficulties with brushing your hair?
	Are you having any difficulties with brushing your teeth?
	Are you having any difficulties with dressing?
	Are you still able to clean up after using the toilet?
	Did your injury impact your ability to do any of your self-care activities? So things like grooming, hygiene, dressing, etc.
	Does your shoulder injury make it difficult for you to get dressed or use a toothbrush?
	Do you find it difficult to brush your hair
	Do you find it difficult to brush your teeth
	Do you find it difficult to dress yourself
	Do you find it hard for you to get ready in the morning now?
	Do you find that you have any concerns with brushing your hair
	Do you find that you have any concerns with brushing your teeth
	Do you find that you have any concerns with dressing yourself
	Do you have difficulties taking a shower?
	Do you think that your injury has affected your ability to complete your morning routine?
	Has your injury made it difficult for you to take care of yourself? For example, brush teeth, eat, etc.

	Has it been difficult for you to wipe your bottom after using the toilet?
	Have you had any difficulties using a spoon or fork to feed yourself?
	Have you needed any help to dress or shower yourself?
	Is it difficult for you to get up from bed?
	Is it hard for you to eat with your shoulder injured?
Productivity: What	Are you engaged in any volunteer work?
	Are you engaged in paid employment?
	Are you in school?
	Are you still working?
	What do you do for a living?
	What kind of work do you do?
	Where do you work?
Productivity: Work Difficulties	Are there any aspects of your work that you find difficult?
	Do you find it hard to do your job because of your injuries?
	Do you have any current difficulties completing your work?
	How are you finding work?
	Is there any parts of your work that it's tough for you to do right now?
Productivity: Household (Who)	Who does the cleaning around the house?
	Who does the cooking?
	Who does the yardwork?
	Who takes care of the household chores?
	Who takes care of your children?
Productivity: Household Yes/No	Are there things around the house that you are unable to do now?
	Are you able to use the vacuum or dust?
	Are you currently able to shop for groceries?
	Are you still able to manage household chores and activities?
	Are you still able to manage your household tasks?
	Can you lift heavy items, like garbage bags or groceries?
	Do you have any concerns with household chores?
	Do you have any difficulties doing laundry?
	Do you have any difficulties with cleaning or doing the laundry?
	Do you have any household chores that you find difficult to do?
	Do you have difficulties reaching higher-up places in your home? Like when you want to dust on bookshelves or clean the window
	Has the injury made it difficult for you to spend time with your children?
	Has the injury made it difficult for you to play with your kids?
	Has your injury impacted your ability to do the cooking or cleaning?

	Has your injury impacted your ability to manage household tasks?
	Is doing the laundry difficult for you now that your arm is injured?
	Is it difficult for you to do the cleaning/cooking/laundry?
	Is it difficult to lift grocery bags with your shoulder injury?
Productivity: Household Difficulties	Are there any concerns with finance management?
	Do you find it hard to concentrate when paying your bills?
	Do you find managing your own finances okay, or somewhat difficult?
	Has it been difficult to manage your finances since the injury?
	Has your arm injury made it tough to manage your finances?
	Has your injury made it difficult for you to pay your bills?
Productivity: Finances (Who)	Do you pay your own bills at home, or does someone else take care of that?
	Do you take care of the money, or does someone else?
	Who is responsible for paying the bills and filing taxes in your household?
	Who keeps the books at home?
	Who manages the money at home?
	Who takes care of the finances?
Productivity: Finances Difficulties	Are there any concerns with finance management?
	Do you find it hard to concentrate when paying your bills?
	Do you find managing your own finances okay, or somewhat difficult?
	Has it been difficult to manage your finances since the injury?
	Has your arm injury made it tough to manage your finances?
	Has your injury made it difficult for you to pay your bills?
Productivity: Transportation (How)	Are you able to get to where you need to go?
	Do you drive or do you take the bus?
	How do you get around?
Productivity: Transportation Difficulties	Do you find it difficult to navigate the buses?
	Do you have any concerns with driving?
	Do you have anyone who is able to drive you around?
	Is there anyone else who is able to help you get to where you need to go?
	Have you noticed any difficulties driving?
Leisure: What	In your spare time, what do you do to occupy the time?
	Tell me about some of your hobbies?
	What are some of your favourite activities?
	What are some of your hobbies?
	What do you do for fun?
	What do you do in your free time?
	What do you like to do?
	What do you like to do for fun?
	What do you like to do in your spare time?
	What would you say some of your interests are?
Leisure: Difficulties	Do you find that you are able to do your leisure activities?

	Do you have any difficulties or concerns with that?
	Has your injury made it difficult for you to game?
	Has your injury made it difficult to do your hobbies?
	Has your shoulder impacted your ability to play badminton?
	Have you been able to play badminton with your shoulder?
	Have you had any difficulties reaching for the TV remote?
	Is it tough to play video games with your shoulder injured?
	Is your TV-watching impacted by your shoulder injury?
Spirituality: Yes/No	Can you tell me a bit about what spirituality means to you?
	Do you have any religious practices?
	Is spirituality an important part of your life?
	Would you say that you are affiliated with any religions?
Spirituality: General	Can you tell me a bit about what spirituality means to you?
	What do you hope to achieve in life?
	What do you value in life?
	What gives your life meaning?
	What is the most important thing to you in life?
	What prompts you to get up in the morning?
Physical: Describe	Can you describe what your home looks like?
	How many stairs do you have in your home?
	Is your bathroom and bedroom on the same floor?
	What kind of a house do you live in?
Physical: Reaching	Are there any high places that you need to reach?
	Are there any high up places in your home that are hard for you to reach?
	Can you reach everything you need comfortably in your home?
	Do you find it difficult to reach certain things in your home?
	Do you have cabinets that are hard to reach?
	Do you have problems reaching things in your kitchen?
	Is everything in your home placed at a level that you can reach?
	Is there anything in your home that you find difficult to reach?
	Is your house set-up so that you can reach everything you need?
Social: Yes/No	Can anyone in your family help you with that?
	Can you get help if you needed it?
	Do you feel comfortable asking someone for help if you need?
	Do you have supports to help you?
	Do you think there is someone who can help you?
	Is your spouse able to help you out with that?
Social: General	Are your family or friends available to help you with the cooking or cleaning?
	Are your friends and family able to help you if you need?

	Can anyone in your family help you with that?
	Can someone drive you around?
	Can you ask anyone to help you if you need?
	Do you have anyone who can drive you if needed?
	Do you have anyone who is able to help you out?
	Do you have anyone who is able to help you out?
	If you aren't able to do something, can you access supports?
	If you needed help in the shower, is there someone you can ask to help?
	If you needed help with showering or cleaning, would you have someone to ask?
	How would you describe your support system?
	If you need help showering or cleaning, can someone help you with that?
	If you need, is there someone who can offer you support?
	Is anyone available to assist you with groceries or cleaning?
	Is there anyone who can help you with household chores?
	Is there anyone whom you live with?
	Is there someone who is able to come and assist you?
	Is there someone whom you can turn to for help?
	Is your husband/children/family able to assist you?
	Who can support you when you need?
	Who can you ask to help you?
	Who would you say are your supports?
Intimacy	Are you sexually involved with a partner now?
	Do you have any problems with sex or intimacy?
	Have you been sexually involved with a partner in the past?
	How has your injury or disability affected your sexuality?
Intimacy: Consent	People may experience sexual concerns related to their illness or disability so I am going to ask you a few questions around that now Sometimes an injury or disability may impact people's ability to have sexual intercourse. Would it be okay for me to ask you some questions on that subject?
Movement Screening related	*The verbs in the questions below can be interchanged with appropriate words such as "raise, reach up with, reach down with, reach back with, rotate(ing) forward/backward"*
Movement: Ask Anatomical	Can you abduct your shoulder?
	Can you extend your shoulder?
	Can you externally rotate your shoulder?
	Can you flex your shoulder?
	Can you horizontally abduct your shoulder?
	Can you horizontally adduct your shoulder?
	Can you internally rotate your shoulder?
Injury: Confirm Location	Are you having trouble moving your arm towards the ceiling?
	Are you having trouble moving your shoulder?
	Is it hard to lift your arm above your head?

Is it your right shoulder that is injured?
It looks like the problem is in your right shoulder...
It looks like you are having a hard time with shoulder flexion, is that correct?
It looks like you are having difficulty moving your shoulder above your head, is that correct?
It seems like it's your shoulder that is injured...
It seems like you injured your shoulder, is that right?
It seems that you can't lift your arm all the way up
You appear to be having a hard time moving your shoulder, is that correct?
You seem to be having problems with your shoulder, do you agree?

Chapter 4 – General Discussion

Justifying the Adoption of Virtual Reality into Health Sciences Education

If virtual reality (VR) is to embed itself into educational systems as a skill training tool, it will need to be evaluated in order to justify its existence. VR will need to continually demonstrate its effectiveness within educational systems, while stakeholders measure these contributions and look for ways to enhance VR's performance. While the adoption of VR into educational systems continues to increase, the methods pertaining to how stakeholders measure its performance becomes important for determining VR's future. According to Donald and James' Kirkpatrick (2006) model for the evaluation of skill training programs, a successful training program will contribute as many of the following levels as possible:

1) Reaction – Positive attitude; user satisfaction with the training experience should be deemed preferable as well as enjoyable.
2) Learning – Skill acquisition; user knowledge and skill-sets should improve throughout the training experience.
3) Behavior – Skill transferability; user skills that are learned in the training situation must carryover to associated real-world behavior.
4) Results – Real-world effectiveness; the user's behavior should result in significant improvements of workplace efficiency at a reasonable cost. Associated clients should show an improvement in satisfaction. This is arguably the most important level.

The Kirkpatrick model (Kirkpatrick & Kirkpatrick, 2006) has been used to assess VR's capability within Health Science skill training programs, but due to the model's categorical nature, systematic reviews tend to only provide descriptive results (Wang, DeMaria, Goldberg, & Katz, 2016). Systematic reviews of past investigations that featured skill training VR programs, within Health Sciences, have shown the following: a) A very strong representation of user engagement and satisfaction, resulting in positive affective reaction being well-established (Bracq, Michinov, &

Jannin, 2019; Wang et al., 2016), b) A strong representation of learning and skill development in trainees, resulting in skill acquisition being established (Bracq et al., 2019; Wang et al., 2016), c) A weak representation of skill transferability, resulting in further analysis being required to determine if VR has the capability to prepare Health Science students for the real world (Bracq et al., 2019), d) A very weak representation of cost-effective outcomes, resulting in further analysis being required to determine if VR can positively shape healthcare systems, resulting in safer and happier clientele (Bracq et al., 2019; Wang et al., 2016).

Strong representation of VR's ability to demonstrate positive affective reaction and skill acquisition, Kirkpatrick levels 1 and 2 respectively, could possibly be due to VR's movement through its initial stages of research. Early investigations of VR in Health Sciences often focused on these levels, featuring discussions mainly about the simulators themselves, as standalone events, with the main goal to discern if the platforms could successfully establish positive affective reactions and skill acquisition (Bracq et al., 2019). In order for VR to demonstrate skill transferability and cost-effective outcomes, satisfying Kirkpatrick levels 3 and 4 respectively, the tools used to assess VR's performance will need to establish greater validity, reliability and comparability. VR's previously used assessments for the determination of technical and non-technical skill development have often not been uniform, preventing the results from being comparable with one another (Aïm, Lonjon, Hannouche, & Nizard, 2016; Bracq et al., 2019; Moglia et al., 2016; Shin & Kim, 2015). It is expected that future research in VR will establish greater standardization of its training assessments, allowing virtual results to be compared with real-world performances, to discern transferability of skills. Some reviews have already begun to show transferability of VR surgical skill training to the real world (Aïm et al., 2016; Gallagher et al., 2013). Transfer effectiveness ratios, typically affiliated with airplane VR, is the proportion of time saved in the real world to the time spent in the virtual world (Gallagher et al., 2013). For example, reports on surgical VR's real-world resuts have been found to show a reduction in surgical procedural error by 32-42% (Gallagher et al., 2013). Overall, it is the increased awareness of VR's capability, standardization of its training assessments and demonstration of its cost-effectiveness that will increase the likelihood of it being adopted into Health Sciences education.

Strengths and Limitations of this Report

This report provides an extensive overview of VR applications in education, while considering the technical, non-technical and affective skill regulation it provides. This report covered the use of VR across a wide array of educational disciplines, considering the multidisciplinary contributions each has made towards VR's role in education. Chapters 2 and 3 both identified gaps in the literature, respectively determining how immersive VR has affected post-secondary education and performance anxiety in Occupational Therapy. However, this report does not extensively cover the VR hardware that was used, nor does it discuss the actual simulation design, programming lingo and technical development process of VR applications. Although Chapter 2 shows a list of educational theories/frameworks that each explain how VR can aid in the skill training process, these theories were not elaborated on extensively. Despite these shortcomings, it is arguable that the most important factor, determining VR's future in Health Sciences education, is the necessity of a tool that can determine how well it can transfer skills from the virtual to real world. This report is has shown that experts in the field are aware of this issue, eager to join the others in the effort to increase this awareness.

Conclusion

Under consideration of the four levels in the Kirkpatrick model, VR is expected to continually demonstrate positive affective reaction, while enabling skill acquisition in Health Science trainees. It is also expected for future Health Science disciplines to report similar positive results as they find newfound ways to harness the power of VR into their training programs. However, skill transferability and cost-effectiveness of VR applications tend to be peripherally represented in the literature in comparison to the other established Kirkpatrick levels. In time, it is expected that greater standardization of valid, reliable and comparable tools will identify the transfer of training and effectiveness ratios of VR training programs, discerning if trainees are ready to take their skills from the virtual to real world. Will each satisfied client in the virtual world be representative of a satisfied client in the real world?

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