Final Report for OCJS Project: 2017-JG-A02-V6351

Cory Haberman, Heejin Lee, Ming Tang, Rachel Kail, Clay Driscoll, Dongrui Zhu, Ruby Qiu, Snigdha Bhattiprolu, Rishyak Kommineni, and J.C. Barnes

University of Cincinnati

February 2022

Table of Contents

Executive Summary

Active shooter situations are uncommon, but when they occur they cause asymmetric harm. Ohio law enforcement have various training regimens that can be deployed to prepare officers for these situations. To date, however, there has been little research that can speak to the efficacy of those training programs. Moreover, there is almost no research available that can identify the training needs of Ohio law enforcement regarding active shooting incidents specifically. And there has been no research that can speak to the efficacy of virtual reality as a training tool for these situations.

This project had three objectives: 1) identify the training needs for Ohio law enforcement in regard to active shooting incidents; 2) develop a novel virtual reality training program that could be used by Ohio law enforcement; 3) assess the efficacy of that virtual reality application while considering the goals, needs, and responses to the current standards of training that Ohio law enforcement receive.

This project was a success in all three areas. First, the University of Cincinnati research team visited several law enforcement training facilities across the state of Ohio. During these visits, researchers interviewed training officials/agents and learned that virtual reality programs are already being used in many jurisdictions for various types of training applications. More expensive options like "simunitions" and "shoot houses" are often used to simulate active shooting events. Yet, there are few coordinated efforts across jurisdictions and there is no consistent set of training goals that are being assessed.

Second, the University of Cincinnati team successfully developed a virtual reality application that can be implemented using off-the shelf, inexpensive virtual reality hardware. This application is customizable in many respects, such as allowing officers to respond in different ways, tracking progress through the scenario and in shooting accuracy.

Third, the University of Cincinnati team was successful in gaining IRB approval to conduct an empirical study regarding the efficacy of the above-described virtual reality application. The research team will collect data from Ohio law enforcement officers. IRB approval allows the UC team to build on the current efforts by collecting pilot data from Ohio law enforcement agencies who participate in the virtual reality training scenario that was created for this project.

The success of the current project has opened the door for next steps in the research agenda that will speak to the efficacy and effectiveness of virtual reality programs for law enforcement training. The University of Cincinnati team has already secured internal funding to carry out pilot data collection so that we can, in the near future, speak to the efficacy of the novel virtual reality application that was created as part of this project.

Introduction

Active shootings are increasingly gaining attention from Ohio residents and lawmakers (Pelzer, 2021; WHIO Staff, 2021) and they are becoming one of the most commonly cited concerns about public safety in the US (Graf, 2018; *Guns*, 2021). Active shooters pose many life-threatening challenges to law enforcement who are in charge of responding. The decision-making points that responders must navigate are far more complex than simply neutralizing the threat. Every decision made, both on the way to the scene and upon arrival, can potentially impact the harm caused and the overall outcome.

Active shooting scenes are chaotic. Sensory overload can easily occur due to a multitude of variables such as the lighting, the presence of multiple victims who are seriously wounded, fire alarms, secondary explosions, and many other events that compound onto one another. Ohio law enforcement officers are, therefore, in need of modern training modalities that will appropriately simulate the chaos and randomness that characterize these events so they can respond effectively whenever and wherever an active shooting takes place.

Prior research has shown that virtual reality (VR) is an effective training tool for high-risk jobs in the military (e.g., the Air Force), for medical procedures (e.g., surgeons learning new procedures), and in manufacturing (e.g., operating heavy machinery). Yet, to date, there is no research that tests whether VR can be applied to law enforcement training for high-risk events like an active shooting.

There are companies that offer VR training for law enforcement, but given the lack of data and research, these systems are not evidence-based. Additionally, existing systems are expensive (some with costs near $1 million), making them unaffordable for most midsized (or smaller) agencies.

We believe fully immersive 3D virtual reality can provide a realistic simulation of the stress, chaos, and randomness that takes place during an active shooting. We also believe we can work with Ohio law enforcement to develop solutions that will be evidence-based, affordable, and scalable.

This project began with three research objectives. First, we proposed to collect, aggregate, and analyze data around decision-making points, training tactics, training effectiveness, and stress responses expected of Ohio law enforcement who respond to an active shooting. This project allowed our team to gather information about how Ohio law enforcement trainers currently train officers for active shooting scenarios so that we could better prepare and develop a fully immersive 3D VR simulation scenario that could be used by Ohio law enforcement trainers in the future.

Second, our team proposed designing an active shooter training system using VR technology. Our team was successful in achieving this second research objective as we developed a fully immersive 3D VR active shooter scenario that can run on cost-effective, commercially available, VR hardware. We will describe this research objective, and the application that came out of it, more fully below.

Third, our research team planned to test our VR shooter scenario on Ohio law enforcement personnel to determine whether the VR scenario elicits the stress response(s) (e.g., heart rate) that would be expected for an actual active shooting scenario. As will be explained in more detail below, the project team was successful in gaining institutional review board approval to carry out data collection on human subjects and we have begun to pilot test the system with live subjects. Due to significant delays caused by the COVID-19 pandemic, we were unable to collect the full range of empirical data necessary to conduct statistical analyses prior to the project's closing date. Preliminary pilot data indicated the VR program performs as expected and that it is effective in eliciting the anticipated stress responses.

Our multidisciplinary team will continue to work with local law enforcement agencies (primarily the Cincinnati (OH) Police Department) to enhance our current application and to develop new applications that will allow Ohio law enforcement agencies to have access to cutting edge VR training technology. Moreover, because our team begins with an evidence-based research approach, we believe the application that resulted from this partnership—along with any future applications—will prove to be informative and useful.

The remaining sections of this final report include the following: 1) a literature review outlining the various use-cases of VR training technology that informed our approach to application development; 2) a detailed overview of the research objectives from our original proposal; 3) a detailed overview of the findings, organized by research objective, and 4) discussion of the key substantive findings from this project, along with a description of next steps that we recommend be taken to keep Ohio on the leading edge of law enforcement training development.

Literature Review

In recent years, virtual reality technology has increased in fidelity and portability, drastically increasing its general practicality. Because of this, instructors, teachers, and trainers have begun conceptualizing methods to implement the technology into their educational strategies. These strategies have expanded into a wide range of applications and fields, ranging from the examination of dangerous volcanoes to veterinary and human surgeries to escaping burning buildings (Tibaldi et al., 2020; Hunt et al., 2020; Alaraj et al., 2015; Singh et al., 2015; Liang et al., 2020). In response to this proliferation, researchers across many fields have begun to examine VR technology and bring evidence to support or oppose its practical applications. The bulk of this research has focused on two major fronts: (1) training for common activities and (2) preparing for emergency situations.

Most of the available research on virtual reality technology focuses on use-cases that are not directed at law enforcement. These applications include situations within a wide range of domains, including regular surgeries, science classrooms, and dental training. In these situations, both experts and students have reported positive experiences while training with virtual reality (Alaraj et al., 2015; Pfeil et al., 2021; Torda et al., 2020). Additionally, students who used VR technologies in classrooms were found to be more engaged with the classrooms and expressed more confidence and deeper understanding in their studies (Makranksy et al., 2019; Takagi, 2019; Pfeil et al., 2021). Additionally, the use of virtual reality technology for instruction for routine situations resulted in the retention of both skills and knowledge that was either better or comparable to conventional methods (Chan et al., 2021; Hunt et al., 2020; Singh et al., 2015). Overall, while there are some caveats to the results of these studies, which will be discussed below, research examining the opinions and effectiveness of VR-based education for routine training are supportive of its use.

Although more limited, research testing the applicability of VR-based trainings for non-routine and emergency events have results that are similar to those examining the routine situations. Examples of these situations include trainings for medical triage or identifying mining accidents as they occur. Due to the stressful, sporadic nature and infrequency that is inherent to most emergency events that are trained for, these trainings serve to be the most opportune application for implementing VR technologies. Despite the stress that may be inherent to these emergency trainings, both trainers and trainees who used VR reported positive experiences and opinions of the technology (Buttussi & Chittaro, 2021; Liang et al. 2020; Li et al., 2020). When compared to conventional emergency safety trainings, VR trainings have been found to be associated with higher levels of procedural knowledge than the conventional means (Buttussi & Chittaro, 2021). Similar to evidence on routine events, trainees in emergency events reported higher engagement with the VR technologies, opposing arguments that using VR technologies in emergencies may be unauthentic and ineffective (Buttussi & Chittaro, 2021).

There is also evidence to suggest that using VR technologies is comparable to “live” simulations of emergency situations that use real-life actors. When the experiences of student nurses were compared, no significant differences in information retention were found between those who participated in the VR simulation versus the “live” simulation (Wiese et al., 2021). Additionally, students in both groups reported comparable increases in confidence in their abilities regardless of the type of simulation used (Wiese et al., 2021). As with the research on education for routine events, VR's applications in emergency trainings is well supported, albeit numerically limited.

The primary limitation associated with VR research is the small number of studies examining its practical applications in preparing for emergency situations. Additionally, most research focused on *perceptions* of the emergency trainings rather than skill or knowledge retention. Limitations in VR technology are not limited to research on its applications in emergency trainings. One of the primary drawbacks of the use of VR technologies as a whole were glitches, which participants reported as a large reason VR technology may not be reliable (Torda, 2020). Additionally, there is some evidence to suggest that over-using VR can overstimulate students and cause less learning and retention (Makranksy et al., 2019). Conversely, students who had a disproportionately low amount of study time to use the VR technologies compared to conventional studying techniques had test results that were essentially indistinguishable from students who only had access to conventional studying techniques (Hunt et al. 2020). This suggests that the effectiveness of VR as a teaching tool may be related to the amount of time that one spends using the technology. This adds further evidence to support VR's use as a supplement to conventional learning techniques and devices, rather than a full replacement.

Overall, virtual reality technology is poised to become a key teaching and training modality. Although additional research is needed to determine exactly how effective the technology is for training, initial evidence suggests that virtual reality scenarios can be effective tools that are comparable or better than conventional methods when used in the proper way. Additionally, both experts and students appear to be extremely supportive of VR technology. Lastly, an important gap in research focusing on modern VR technologies has been identified: the practical applications of VR as training equipment for non-routine and emergency situations. This gap is both a negative and a positive, as it is difficult to draw conclusions about the true effectiveness of VR technologies yet opens the door for the current research to play an important role.

Research Objectives

In this section, we outline the three research objectives that were addressed with this project. We then provide an overview of the findings that emerged during each phase of the study.

Research Objective #1

Our first research objective was to:

> 1a) validate the needs and training goals of law enforcement tactical trainers within the context of their current capabilities and training systems;
>
> 1b) determine key indicators of effectiveness (i.e., tactical skills, stress responses, and situational awareness factors) for law enforcement tactical training.

Prior to this project, the training goals and outcomes for Ohio law enforcement had not been assessed in terms of their application to active shooter training. The goal of our first objective was to identify the needs and goals as expressed by tactical trainers across the state of Ohio. To achieve this goal, members of the research team conducted interviews with trainers from the Cincinnati Police Department, the Columbus Police Department Training Academy, the Great Oaks Police Academy, and the Ohio Peace Officer Training Academy.

During the site visits, research team members interviewed trainers and law enforcement officers to gain insight into the training applications that are currently in use, to better understand the goals of law enforcement training, and to gain insight into law enforcement training needs.

Synthesizing the information gleaned from the site visits resulted in the following summary findings:

- Law enforcement training in Ohio already uses—to varying degrees—virtual training technologies.

  Here, we use the term "virtual" more liberally, as the research team found that law enforcement considered popular 2D training tools like the FATS system and Milo Range virtual training options.

- Trainers believed currently used systems, like Milo Range, were beneficial, but lacked "realism".

- Trainers expressed concern that currently used systems encouraged trainees to be ready to "shoot" and that there was not enough emphasis on de-escalation or situations other than shoot/don't shoot decision-making.

- Trainers were concerned that currently used systems lacked evidence-based validation.

- Trainers noted that collecting performance data during training sessions was either not done or difficult to do in a robust and reliable way.

- No standardized form of outcome data is collected within- or across agencies. In other words, different approaches to training for active shooting scenarios are currently in use and trainers are confident they are effective. But there are currently no standardized outcome data collection instruments, making it difficult to say how effective different trainings or trainers are relative to others.

- Trainers expressed concern that currently used systems were not effective in eliciting the types of physiological responses that officers experience when encountering an actual active shooter event, such as stress-induced heart rate acceleration and the presence of stress-related hormones.

- In addition to popular 2D virtual reality options (like Milo Range), Ohio law enforcement trainers believed live-action training (e.g., shoot houses) were the best tool for eliciting the types of physiological responses that officers experience when encountering an actual active shooter event.

- Trainers expressed concern that while live-action training (e.g., shoot houses) are the best tool to train for various events, these techniques are not convenient or flexible enough to conduct with regularity.

Summary of Research Objective #1

The research team visited and conducted interviews with law enforcement training professionals from across the state of Ohio. Active shooting training is a standard part of Ohio law enforcement training. Some training sites use various forms of virtual training and all agencies are open to using fully-immersive 3D virtual reality training. No consistent, standardized data collection is currently in place to track training outcomes.

Research Objective #2

The second research objective for this study was to develop a fully immersive 3D virtual reality active shooter scenario that can experienced on cost-effective and commercially available VR hardware.

The UC team successfully developed a customized and fully immersive 3D VR active shooter scenario. Led by Professor Ming Tang, the design team developed a virtual reality application called "Active Shooter Simulation": an immersive training program for the police force to respond to an active shooter situation in a school environment. The goal was to create a VR prototype that allows the research team to conduct testing with the Cincinnati Police Department (CPD), collect users' biometric data, and test various hypotheses.

Hardware

After extensive research of available VR headsets in the market, the design team decided to develop the VR app for the Oculus Quest platform. As a standalone mobile VR system, Quest has gained a significant market share and popularity in recent years. The potential to be integrated with Metaverse and sustain the long-term life circle in the rapid technology field was also an important reason for our selection. The Quest motion controllers can be customized to simulate various weapons allowing the realistic experience of haptic and locomotion compared to actual handguns.

Figure 1. Hardware tools used in study.

Development Tools

The team used the Epic Unreal game engine to develop the VR app, including user interfaces (UI), scripts, and interactive content. The team used 3D modeling and animation tools to create 3D content, including environments, characters, and various props. The design process is organized based on the following components.

Design Process

User Interface

The design team developed three types of UI features to allow users' inputs in the VR environment. First, the laser pointer allows the user to click the menu system to navigate from the entry lobby to the training range and the active shooter scenarios (Figure 2, left). In the shooting scenario, the UI is designed to provide a virtual handgun and navigation through motion controllers (Figure 2, center). At the ending event, a digital billboard will present the score, record, and the "Try Again" button, interacting directly with the virtual hand (Figure 2, right).

Figure 2. Left: menu system. Center: handgun UI. Right: Billboard system

Levels and Scenarios

The training simulation is organized with multiple levels. Users can navigate between these levels using a menu system, trigger zone, or timed event. For example, users can use the lobby level menu system to navigate into a "Practice Range" level to get familiar with the handgun interaction. Users can also move into the main "exterior level" by entering a cutscene that will brief the office of the situation before entering the school. At the "interior level," the user can make decisions and navigate in the virtual building. The game will automatically pause and display the billboard score when the user neutralizes the active shooter or the user is injured. The user can then navigate back to the lobby or replay the "interior level" directly.

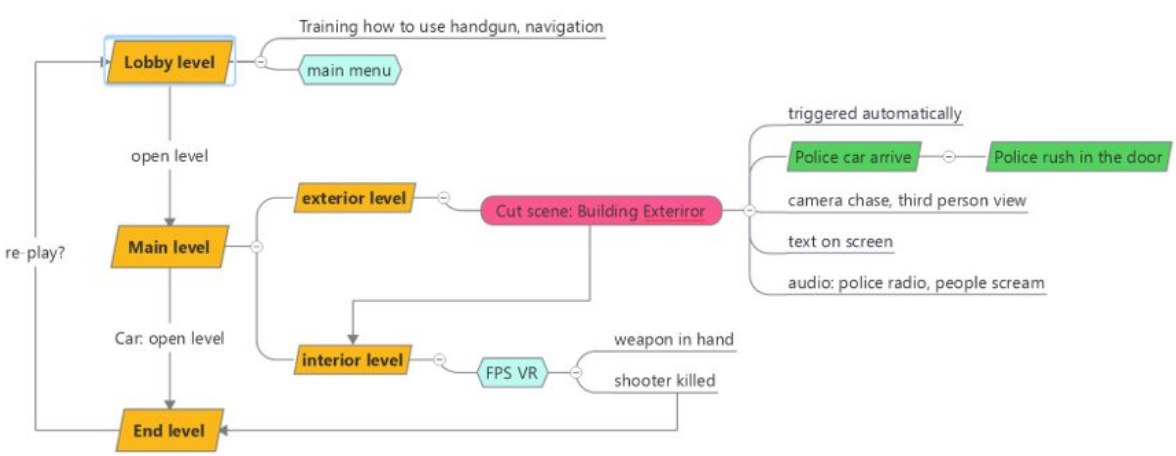

Figure 3. Diagram of levels and connections.

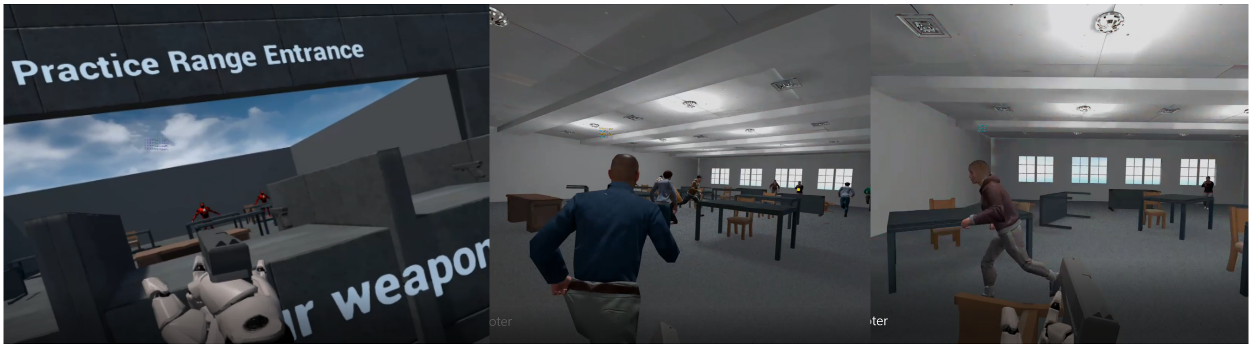

Figure 4. Practice Range level and Interior level.

Cutscene Design

The team designed the animated characters, soundtracks, and camera flythrough to illustrate the context of the active shooting scenario. The exterior of a school building is modeled and rendered to "immerse" the user in the chaotic situation.


Figure 5. Left: School exterior. Right: Animated civilian asking for help.

Weapon System

To simulate the active shooter, the design team programmed the weapon system, including fire rate, projectile, and bullet speed. This allows the virtual active shooter to fire an automatic rifle with bullets that will interact with players and civilians to generate damage (Figure 6).

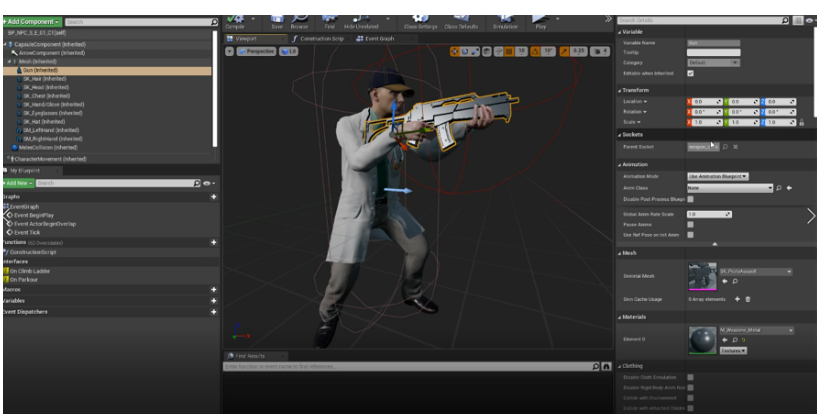
Figure 6. Weapon system designed for the active shooter.

The team designed a similar weapon system to simulate the handgun for the player, including the sound effects, fire, and particle system based on the first-person shooting in VR (Figure 7, left and center). With a script, statistics including the number of shots and number of civilians killed are automatically recorded and displayed at the end (Figure 7, right).

Figure 7. Left and right: First-person shooting system. Below: The number of shots is displayed on a billboard at the end.

Motion-Controller with Customized Pistol Add-On

The design team customized the visual of the simulation’s handgun to match the look of the Glock 19 (Figure 8, left and center). The hand grabbing animation, as well as the animation of gun recoil, was included. The handgun add-on for the Quest motion controller is attached to create the right weight and haptic sensation of holding a real weapon (Figure 8, right).

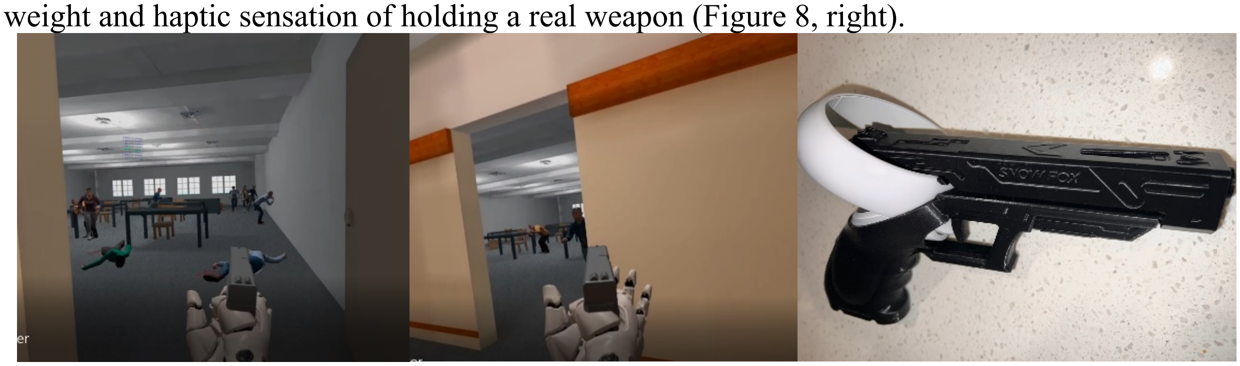

Figure 8. Handgun customization within the simulation (left and center) and in-person (right).

Environment Design

The VR environment was molded to match a real building at the University of Cincinnati. The below diagram illustrates the floor plan with a hallway and multiple doors leading to several classrooms. The active shooter (represented by the red dot) is hiding behind a group of civilians in one of the classrooms (Figure 9). Both classroom doors are open.

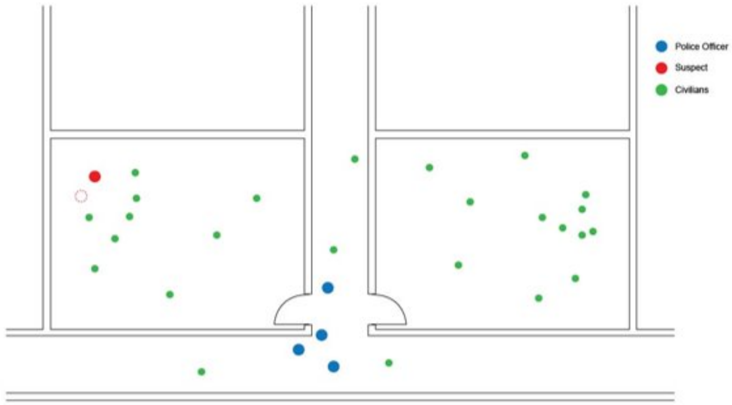

Figure 9. Floor plan diagram of the interior level.

Using a real-world reference (Figure 10), the design team created a 3D model of the hallway and classroom, with light fixtures, doors, and furniture (Figures 11-14).

Figure 10. Photo of a hallway (left and center) and classroom (right) as reference.

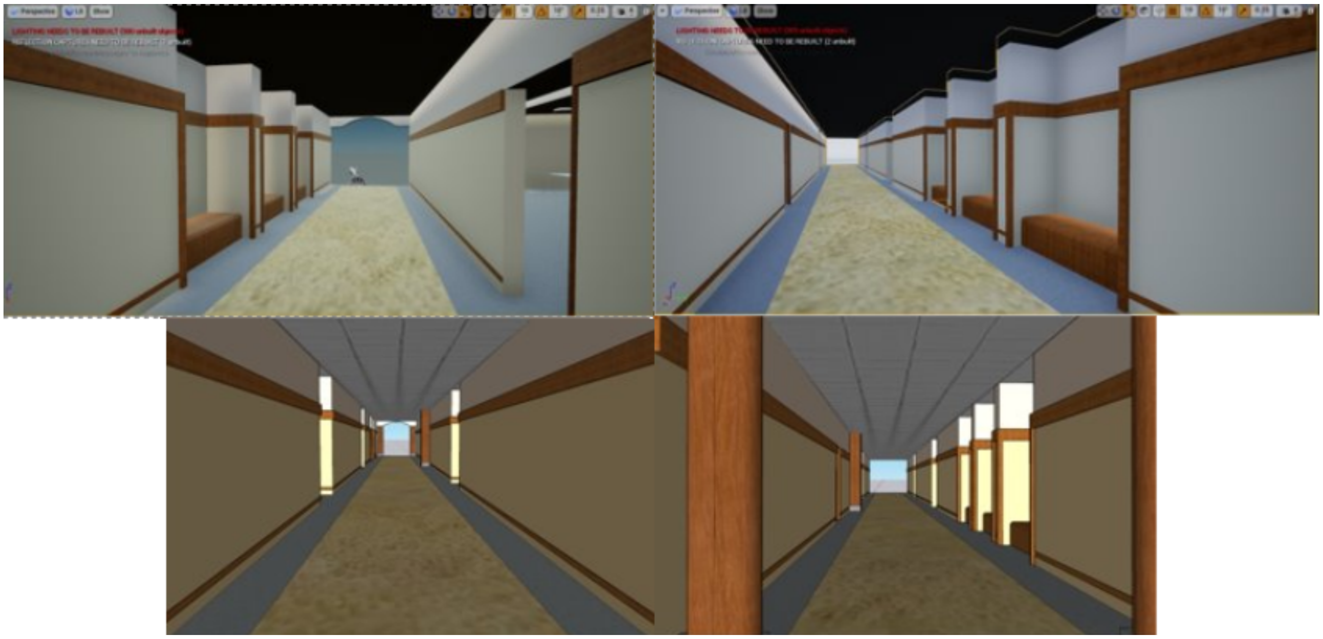

Figure 11. Corridor space and classrooms created from reference.

Figure 12. Doors and entrance of the classroom.

Figure 13. Virtual classroom with furniture in the 3D modeling program.

Figure 14. Testing rendering of a classroom in VR.

Non-player Character (NPC)

The design team has created various realistic, human nonplayer characters (NPC) including figures such as active shooters, police, and civilians. The team also created several mannequins for the training range and other testing purposes.

Character Modeling

The character model includes a full-body inverse kinematic (IK) system to simulate the skeleton and joint movement of an NPC. The customizable cloth and weapon system was attached to generate a library of NPCs (Figure 15).

Figure 15. NPC library with a customizable look.

Animations

The team designed various animations such as running, falling, dodging, and death. The animation sequence is triggered and programmed under the control of the NPC's perception system and AI (Figure 16).

Figure 16. Create bloodstain mask material

AI, Perception, and Behaviors

The NPC's perception system includes a vision and hearing sensor system (Figure 17, left), which allows the NPC to choose the various decisions (Figure 17, right) based on the proximity to the active shooter or the human player (Figures 18 and 19) (Tang. 2021).

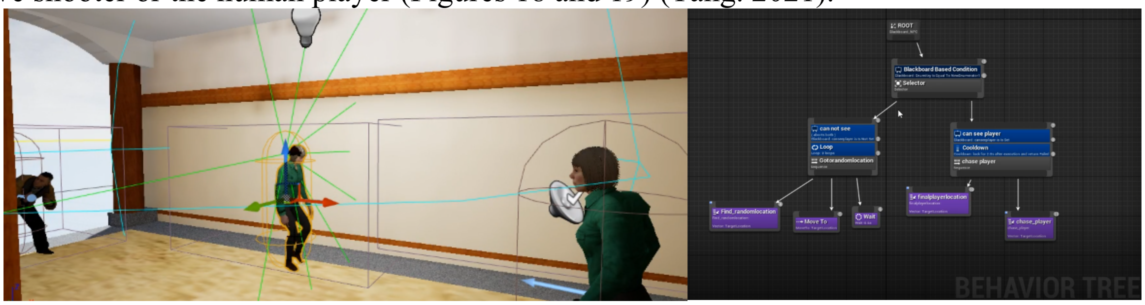

Figure 17. Left: The green cone represents the visual perception system of an NPC. Right: Behavior tree of an NPC.

Figure 18. The panic NPC crowd scattered during the active shooting simulation. Some NPCs will hide or freeze based on their own A.I.'s reaction.

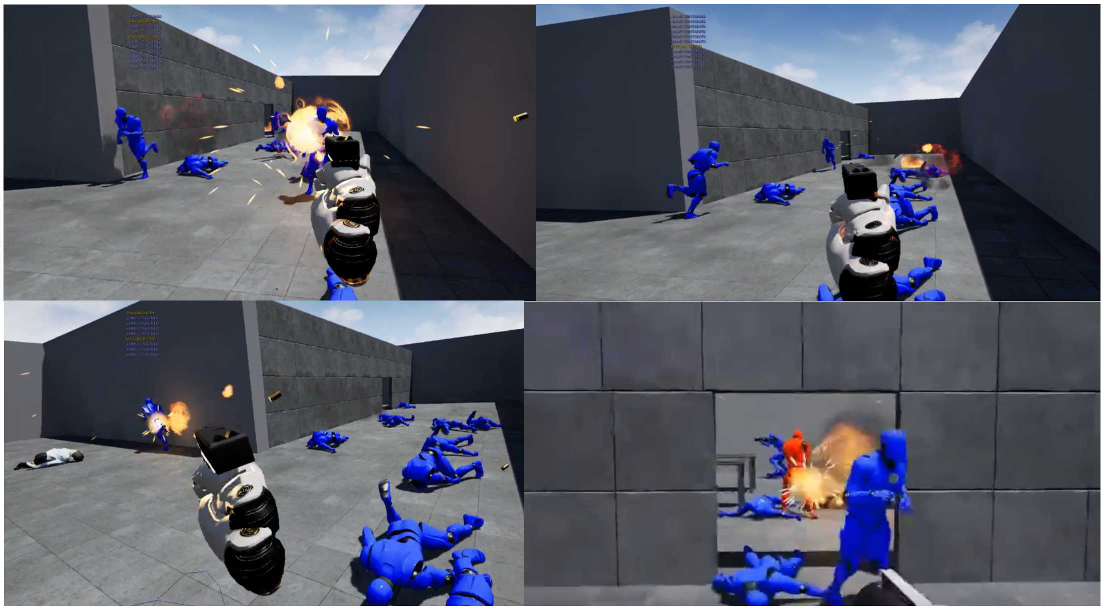

Figure 19. Test with mannequins in VR. NPC can be killed by the friendly fire from the player without knowing who the active shooter is.

Dialogue and Sound effects

The level of presence in VR is created by introducing the audio. The team designed the police communication dialogue, built an alarm system and sound effects of the shooting.

Figure 20: NPC crowd reacting to sounds created by user and active shooter.

Summary of Research Objective #2

The research team successfully developed a fully immersive 3D virtual reality active shooter scenario that can be used with cost-effective and commercially available VR hardware. The scenario was developed with the intention to arouse users physiologically in ways that would be expected of an active shooting situation.

Research Objective #3

Our third research objective was to determine if the fully immersive 3D VR application developed as part of **Research Objective #2** (see above) elicits the anticipated stress response(s) (e.g., accelerated heart rate) expected from an actual active shooting event. In doing so, we sought to assess the level of realism, as perceived by Ohio law enforcement officers, for the 3D VR active shooting scenario.

The motivation behind this objective was to clarify whether fully immersive 3D VR will be an effective tool for Ohio law enforcement training purposes. Our plan was to partner with the Cincinnati Police Department to assess stress responses and their perception of the realism of the VR scenario.

The research team has made progress toward achieving this objective. We received IRB approval for data collection on human subjects (FWA #: 00003152). To date, we have conducted preliminary pilot testing with members of the CPD leadership team (Figure 21) and we have received feedback regarding the viability of the 3D VR application that was developed in **Research Objective #2** (see above).

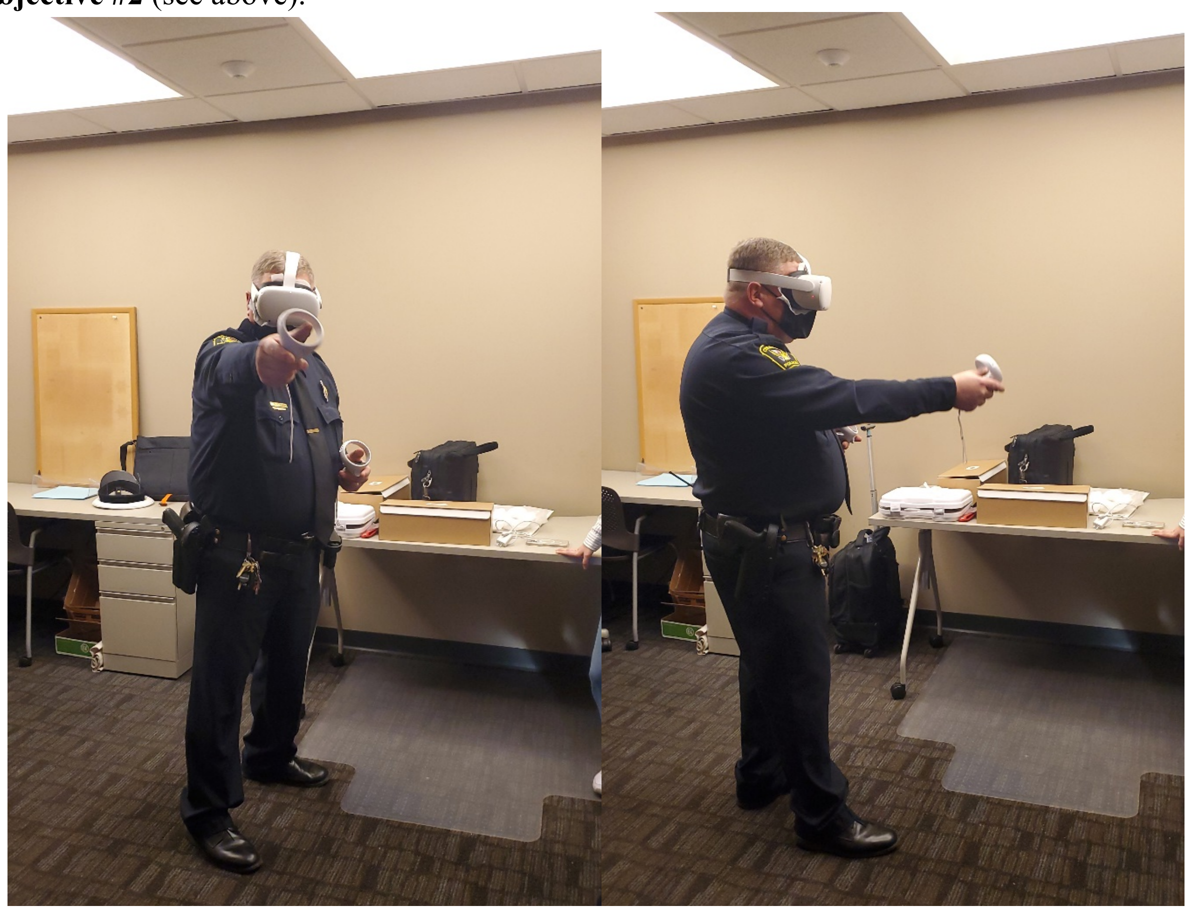

Figure 21. CPD Captain piloting VR Active Shooter Simulation

The preliminary feedback received by our CPD partner included:

- The setup of the virtual environment (a hallway and a classroom on campus) looks realistic. The visual and sound effects (crowd panicking and screaming) feel adequate to enhance the nervous tension before encountering the active shooter.

- The sensory monitors that are attached to some body parts (upper chest, wrist, fingers) during the simulation do not seem intrusive or interfering with officers' uniforms. There is little concern for study participants' noncompliance with wearing the monitors.

- Overall, the simulation is interesting and innovative. Although a different nature of control and movement in virtual reality requires some assisted training before the simulation, officers are expected to be intrigued by this novel modality of active shooter training.

Summary of Research Objective #3

Next steps for the research team include systematic data collection efforts to validate the physiological responses that are elicited from the VR application that was developed in **Research Objective #2**. Our data collection plans were impacted by the COVID-19 pandemic because of the need for several law enforcement personnel to share the VR headset. In response, our research team has developed a sanitary data collection protocol and, with vaccination rates increasing, we feel confident that full data collection will be possible in the near future.

Although the project period has closed for the current study, our research team is committed to collecting data from enough CPD officers to allow for full statistical analysis. Toward that end, our team has secured internal funding to cover the costs of data collection during the spring/summer 2022.

Research Team Biographies

Cory Haberman, Ph.D., is an Associate Professor in the School of Criminal Justice and Director of the Institute of Crime Science and Public Safety Research Center at the University of Cincinnati. Dr. Haberman provides technical assistance and evaluation services to agencies across the country implementing crime analysis and crime reduction strategies, such as hot spots policing, focused deterrence, and community-problem oriented policing. To date, Dr. Haberman's research program has been supported by roughly two million dollars in funding and resulted in one edited book and over 25 academic publications in the field's leading outlets. Dr. Haberman currently serves on the editorial boards for the *Journal of Research in Crime and Delinquency* and *Policing & Society* and the executive board for the Midwestern Criminal Justice Association. In 2019, Dr. Haberman was selected by the National Institute of Justice to be a LEADS Academic and was also awarded the American Society of Criminology Division of Policing's 2019 Early Career Award for his contributions to research on policing.

Heejin Lee, Ph.D., has served as a project manager in the School of Criminal Justice and is now pursuing a master's degree in Statistics at the University of Cincinnati. Her research interests include offender decision making, narrative identities and desistance, and the application of virtual reality technology in criminal justice. Her research has appeared in several journal outlets such as *Justice Quarterly*, *Criminal Justice and Behavior*, and *Crime & Delinquency*.

Ming Tang, M.F.A.; M. ARCH; M.A., is a registered architect and Associate Professor at the School of Architecture and Interior Design at UC. He is the Director of UC Extended Reality Lab and the founding partner of TYA Design. Before he taught at the University of Cincinnati, he was the Director of the Electronic Design program and a professor in the Architecture Department at the Savannah College of Art and Design. His multi-disciplinary research includes virtual reality & augmented reality, digital twins and BIM, game-based learning, computational design, digital fabrication, generative and performance-driven design, human behavior analysis, and simulation. He authored several books, including "Parametric Building Design" with Autodesk Maya (Routledge), and "Architectural Interventions: Design-build Collaboration on the Global Scale", and "Urban Paleontology: The Evolution of Urban Forms". His research and projects have been published and featured in various journals, books, and exhibitions.

Rachel Kail, M.S., is a Ph.D. student at the University of Cincinnati. Her research interests include offender decision-making, behavioral economics, and perception. She has experience in using emerging technologies in innovative ways to conduct research. Her research places a focus on causal inference, experimental design, and she has spearheaded multiple primary data collection projects.

Clay Driscoll, M.S., is a Ph.D. student at the University of Cincinnati with interests in policing and crime prevention. He also has a special interest in emerging technologies within the criminal justice system, including body-worn cameras and virtual reality training devices. His skills span a wide range of topics within the research world, including project management, crime mapping, and survey design.

J.C. Barnes, Ph.D., is Professor and Interim Director in the School of Criminal Justice at the University of Cincinnati where he teaches research design and advanced statistics at the doctoral level. He has expertise in various substantive areas of criminology and criminal justice such as offender decision-making and the interaction of individual differences and socio-cultural environments on offending behaviors. He has been recognized several times for his scholarly contributions, including a recent study that ranked him among the most productive criminologists in the world. Dr. Barnes has several affiliations outside of UC, including his role as an Associated Researcher with the Dunedin Multidisciplinary Health and Development Study, which is run out of the University of Otago in New Zealand. The Dunedin Study is one of the largest and longest running studies of human development that has ever been conducted. Recently, he was appointed by Ohio Governor DeWine to serve as a member of the Governor's School Safety Working Group. He received the Outstanding Educator Award from the Southern Criminal Justice Association in 2021.

Annotated Literature

Concepts

1. Tibaldi, A., Bonali, F. L., Vitello, F., Delage, E., Nomikou, P., Antoniou, V., Becciani, U., de Vries, B. Van Wyk, Krokos, M., & Whitworth, M. (2020). Real world–based immersive virtual reality for research, teaching and communication in volcanology. *Bulletin of Volcanology, 82*(5)https://doi.org/10.1007/s00445-020-01376-6
    - An interesting concept for the usage of VR technology. Volcanologists can create simulations of environments that are particularly dangerous or difficult to access. These environments are then used to teach students how to analyze or classify the volcano. Authors also used photographs from real-word areas to produce these environments, and allude to using more precise mapping techniques.

2. Torda, A. (2020). CLASSIE teaching - using virtual reality to incorporate medical ethics into clinical decision making. *BMC Medical Education, 20*(1), 326. https://doi.org/10.1186/s12909-020-02217-y
    - Students were presented with scenarios recorded by a 360-degree camera. These scenarios contained moral quandaries (e.g. dealing with parents who want to cut conventional therapies and switch to homeopathic remedies). Students were surveyed pre and post about their opinions and experiences, but unfortunately nothing about learning ability.
    - Study presents positive results about student engagement and "self-perceived knowledge gains". Study also discusses the negatives of VR training (e.g. glitches). End results suggest that using VR as a full replacement may be problematic, and suggests using VR more as a supplement to conventional learning techniques.

Routine/Common Events

1. Alaraj, A., Luciano, C., Bailey, D., Elsenousi, A., Roitberg, B., Bernardo, A., Banerjee, P., & Charbel, F. (2015). Virtual reality cerebral aneurysm clipping simulation with real-time haptic feedback. *Neurosurgery, 11 Suppl 2*(1), 52-58. https://doi.org/10.1227/NEU.0000000000000583
    - Study examines adding haptic feedback to a neural surgery. Asked actual surgeons what they thought about the technology and its applicability/authenticity/etc. Positive results about opinions on the technology and potential future applicability, but nothing gauging learning ability or knowledge retention.

2. Chan, H., Chang, H., & Huang, T. (2021). Virtual reality teaching in chemotherapy administration: Randomised controlled trial. *Journal of Clinical Nursing, 30*(13-14), 1874-1883. https://doi.org/10.1111/jocn.15701
    - Study used VR to train the administration of chemotherapy drugs, which are dangerous to train for using actual patients because of the toxicity of the drugs. Students were randomized into conventional and VR teachings, and were surveyed 7 days after training.
    - Students in the VR group had slightly higher (but statistically significant) knowledge about chemotherapy administration. VR students also had much more

positive opinions about administering chemotherapies. The authors also suggest that a full VR replacement is not the best idea, and that conventional and VR techniques should be combined to create a combination of both.

3. Hunt, J. A., Heydenburg, M., Anderson, S. L., & Thompson, R. R. (2020). Does virtual reality training improve veterinary students' first canine surgical performance? *Veterinary Record, 186*(17), 562. https://doi.org/10.1136/vr.105749
   - Students were randomized into groups, with one given conventional study techniques, and the other given 90-minutes to practice with a VR headset. Both were trained on how to perform canine surgery before performing their first live surgery.
   - Results suggest no significant differences between usage of VR and conventional training. The authors also mention that the ratio of VR to conventional training methods was large, with the students spending several hours on conventional methods and only 90 mins on the VR. Also, the study contains a very low sample size.

4. Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction, 60*, 225-236. https://doi.org/10.1016/j.learninstruc.2017.12.007
   - Students randomized into two groups in a standard university science classroom setting. Study used pre and post-test surveys and indicators of cognitive and neurological processes.
   - Results suggest that students had more positive opinions on the VR technology, but learned less. There are also results suggesting that using VR technology may put a "cognitive load" on the user that overwhelms them and limiting their ability to learn.

5. Pfeil, A., Marcus, F., Hoffmann, T., Klemm, P., Oelzner, P., Müller-Ladner, U., Hueber, A., Lange, U., Wolf, G., Schett, G., Simon, D., & Kleyer, A. (2021). OP0075 evaluation of a virtual reality teaching concept for medical students during the SARS-COV-2 pandemic. *Annals of the Rheumatic Diseases, 80*(Suppl 1), 40. https://doi.org/10.1136/annrheumdis-2021-eular.2578
   - Study used VR to walk students through how to diagnose arthritis. Study is survey about how much the students liked VR as a teaching method and does not include a comparison group.
   - The majority (79%) of students had positive opinions of the VR lecture, rating it as "good" or "very good". 87% of students reported an expanded knowledge of the lecture's topic after using the VR technology. Overall, positive results on both opinions and knowledge retention.

6. Singh, P., Aggarwal, R., Tahir, M., Pucher, P., & Darzi, A. (2015). A randomized controlled study to evaluate the role of video-based coaching in training laparoscopic skills. *Annals of Surgery, 261*(5), 862-869. https://doi.org/10.1097/SLA.0000000000000857
   - Students were asked to perform a routine surgery five times. Two initial groups split by usage of VR headsets and usage of pig muscles as placeholders. The two were then split into four, with half of each group receiving no feedback between

each surgery, and the second half getting feedback from an experienced surgeon who was watching through multiple cameras.

- Although the overall outcome is more comparing support from an expert to non-support, the study also found no significant differences in the pretest in those who used the VR vs those who used the pigs. This suggests that VR can be just as useful as "real-world" practice. Additionally, those with the support unsurprisingly did better across all scales. Combined, we could have experts watching "through the eyes" of the trainees as they use VR, can offer very specific feedback (since we can review the VR footage), etc. to offer advanced training.

7. Takagi, D., Hayashi, M., Iida, T., Tanaka, Y., Sugiyama, S., Nishizaki, H., & Morimoto, Y. (2019). Effects of dental students' training using immersive virtual reality technology for home dental practice. *Educational Gerontology, 45*(11), 670-680. https://doi.org/10.1080/03601277.2019.1686284
    - Study used VR technology to teach dental students, provided a pre and post survey. Unfortunately, it's examining opinions on VR, rather than effectiveness as a teaching tool.
    - After comparing pre and post surveys, results suggest that students had higher levels of knowledge confidence and in self-confidence regarding treatment assistance.

Non-routine/Emergency Events

1. Buttussi, F., & Chittaro, L. (2021). A comparison of procedural safety training in three conditions: Virtual reality headset, smartphone, and printed materials. *IEEE Transactions on Learning Technologies, 14*(1), 1-15. https://doi.org/10.1109/TLT.2020.3033766
    - Study compared different training techniques in aviation emergencies (opening the various emergency doors on a crashed aircraft): VR headset, smartphone, and conventional printed materials. Indicators were follow-up tests and surveys about the opinions of the instruction techniques as well as knowledge retention.
    - VR headset was found to be "significantly more usable" than printed materials, and participants were more interested in the VR headset compared to the smartphone option. Usage of VR headsets was also associated with the higher knowledge retention and confidence when compared to printed materials.
    - This study also contains an overview of comparisons of different specific VR training techniques (e.g. head-tracking vs no head-tracking).

2. Liang, H., Ge, C., Liang, F., & Sun, Y. (2020). VR-based training model for enhancing fire evacuee safety. *International Journal of Performability Engineering, 16*(1), 107. https://doi.org/10.23940/ijpe.20.01.p12.107117
    - Study used VR models to test people's abilities to find the safest pathway through a burning building while under time stresses. The study didn't look at the effectiveness of the program or VR tech, but participant's opinions on the effectiveness.
    - Results suggest that participants were very receptive of the tech, and thought that it would be an effective way to train people how to escape burning buildings.

3. Li, M., Sun, Z., Jiang, Z., Tan, Z., & Chen, J. (2020). A virtual reality platform for safety training in coal mines with AI and cloud computing. *Discrete Dynamics in Nature and Society, 2020.* https://doi.org/10.1155/2020/6243085
    - Study used VR, 3D environments, and an AI to recreate emergency events that could be experienced (e.g. gas explosions, roof collapses). Study only looks at opinions of the technology and software as a tool, rather than effectiveness. Overall, very positive reviews. Also reports that the tech has been used more than 20,000 times and has almost near-perfect reviews, though.

4. Wiese, L. K., Love, T., & Goodman, R. (2021). Responding to a simulated disaster in the virtual or live classroom: Is there a difference in BSN student learning? *Nurse Education in Practice, 55*, 103170. https://doi.org/10.1016/j.nepr.2021.103170
    - Study compared VR and "live" simulations using actors of triage and disaster response for nursing students. Students' abilities in various categories were scored and compared by nursing educators.
    - Overall, very few differences between VR and "live" simulations. Students using the VR option had higher scores in some categories, but comparable scores in others. Suggests that VR may be a legitimate replacement to using actors and "live" simulations. Students also reported various stresses associated with both types of simulations (e.g. "not being able to help everyone"), suggesting that VR simulations can mimic the emotional responses to actual events.

References

Alaraj, A., Luciano, C., Bailey, D., Elsenousi, A., Roitberg, B., Bernardo, A., Banerjee, P., & Charbel, F. (2015). Virtual reality cerebral aneurysm clipping simulation with real-time haptic feedback. *Neurosurgery, 11 Suppl 2*(1), 52-58. https://doi.org/10.1227/NEU.0000000000000583

Buttussi, F., & Chittaro, L. (2021). A comparison of procedural safety training in three conditions: Virtual reality headset, smartphone, and printed materials. *IEEE Transactions on Learning Technologies, 14*(1), 1-15. https://doi.org/10.1109/TLT.2020.3033766

Chan, H., Chang, H., & Huang, T. (2021). Virtual reality teaching in chemotherapy administration: Randomised controlled trial. *Journal of Clinical Nursing, 30*(13-14), 1874-1883. https://doi.org/10.1111/jocn.15701

Graf, N. (2018). *A majority of U.S. teens fear a shooting could happen at their school, and most parents share their concern*. Washington, D.C.: Pew Research Center. https://www.pewresearch.org/fact-tank/2018/04/18/a-majority-of-u-s-teens-fear-a-shooting-could-happen-at-their-school-and-most-parents-share-their-concern/

Guns (2021). Washington, D.C.: Gallup. https://news.gallup.com/poll/1645/guns.aspx

Hunt, J. A., Heydenburg, M., Anderson, S. L., & Thompson, R. R. (2020). Does virtual reality training improve veterinary students' first canine surgical performance? *Veterinary Record, 186*(17), 562. https://doi.org/10.1136/vr.105749

Li, M., Sun, Z., Jiang, Z., Tan, Z., & Chen, J. (2020). A virtual reality platform for safety training in coal mines with AI and cloud computing. *Discrete Dynamics in Nature and Society, 2020.* https://doi.org/10.1155/2020/6243085

Liang, H., Ge, C., Liang, F., & Sun, Y. (2020). VR-based training model for enhancing fire evacuee safety. *International Journal of Performability Engineering, 16*(1), 107. https://doi.org/10.23940/ijpe.20.01.p12.107117

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction, 60*, 225-236. https://doi.org/10.1016/j.learninstruc.2017.12.007

Pelzer, J. (2021). *Guns in schools: Ohio lawmakers advance bill allowing teachers to carry guns without any peace-officer training*. Cleveland, OH: Advance Local Media. https://www.cleveland.com/news/2021/11/guns-in-schools-ohio-lawmakers-advance-bill-allowing-teachers-to-carry-guns-without-any-peace-officer-training.html

Pfeil, A., Marcus, F., Hoffmann, T., Klemm, P., Oelzner, P., Müller-Ladner, U., Hueber, A., Lange, U., Wolf, G., Schett, G., Simon, D., & Kleyer, A. (2021). OP0075 evaluation of a virtual reality teaching concept for medical students during the SARS-COV-2 pandemic.

Annals of the Rheumatic Diseases, 80(Suppl 1), 40. https://doi.org/10.1136/annrheumdis-2021-eular.2578

Singh, P., Aggarwal, R., Tahir, M., Pucher, P., & Darzi, A. (2015). A randomized controlled study to evaluate the role of video-based coaching in training laparoscopic skills. *Annals of Surgery, 261*(5), 862-869. https://doi.org/10.1097/SLA.0000000000000857

Takagi, D., Hayashi, M., Iida, T., Tanaka, Y., Sugiyama, S., Nishizaki, H., & Morimoto, Y. (2019). Effects of dental students' training using immersive virtual reality technology for home dental practice. *Educational Gerontology, 45*(11), 670-680. https://doi.org/10.1080/03601277.2019.1686284

Tang, M. (2020). Active Shooter. http://ming3d.com/new/2020/08/03/vr-for-police-training/

Tang. M. (2021). Social distancing and behavior modeling with Agent-based simulation CAAD Future 2021 Conference. CAAD Futures 2021 Springer Proceedings. http://ming3d.com/new/wp-content/uploads/2021/07/CAADFUTURE21_Tang.pdf

Tibaldi, A., Bonali, F. L., Vitello, F., Delage, E., Nomikou, P., Antoniou, V., Becciani, U., de Vries, B. Van Wyk, Krokos, M., & Whitworth, M. (2020). Real world–based immersive virtual reality for research, teaching and communication in volcanology. *Bulletin of Volcanology, 82*(5) https://doi.org/10.1007/s00445-020-01376-6

Torda, A. (2020). CLASSIE teaching - using virtual reality to incorporate medical ethics into clinical decision making. *BMC Medical Education, 20*(1), 326. https://doi.org/10.1186/s12909-020-02217-y

WHIO Staff. (2021). *DeWine again urges lawmakers to consider gun reform proposals, warns of 'summer of violence'*. Dayton, OH: Cox Media Group. https://www.whio.com/news/crime-and-law/dewine-again-urges-lawmakers-consider-gun-reform-proposals-warns-summer-violence/J5CHP4H2FRDBNFQFNAEKMDO67A/

Wiese, L. K., Love, T., & Goodman, R. (2021). Responding to a simulated disaster in the virtual or live classroom: Is there a difference in BSN student learning? *Nurse Education in Practice, 55*, 103170. https://doi.org/10.1016/j.nepr.2021.103170