Immersive Active Shooter Response Training and Decision-Making Environment for a University Campus Building

Sharad Sharma(✉) and Pranav Abishai Moses

Department of Data Science, University of North Texas, Denton, TX, USA
sharad.sharma@unt.edu, pranavabishaimoses@my.unt.edu

Abstract. There is a critical need to improve emergency response, decision-making, and safety for the most critical threats to public spaces today. Active shooter events are one of the most critical threats that require training for high-pressure decisions that need to be made during such situations. This paper presents the prototype of an immersive active shooter response training and decision-making environment for a university campus building. The immersive active shooter response training environment is developed in Unity 3D and is based on run, hide, and fight modes for emergency response. We have presented a multi-user virtual reality (VR) platform where experiments for active shooter response can be conducted using computer-controlled (AI) agents and user-controlled agents. This platform can be used as a teaching and educational tool for navigation and performing VR evacuation drills for active shooter events. A user study was conducted to evaluate the immersive VR training environment with 195 participants. The experiment sought to examine how the proposed tool influenced participants' understanding of the safest actions to take during an active shooter situation. The evaluation includes Group Environment Questionnaire (GEQ), Presence Questionnaire (PQ), System Usability Scale (SUS), and Technology Acceptance Model (TAM) Questionnaire. The findings suggest that the participants' knowledge, intrinsic motivation, and self-efficacy showed a significant increase immediately after the training. The results show that the majority of users agreed that the sense of presence was increased when using the immersive emergency response training environment for an active shooter evacuation environment. Through the use of an immersive VR platform, trainees develop a heightened sense of spatial awareness and an understanding of how to navigate the building in high-stress situations, thus increasing the chances of survival and successful evacuation.

Keywords: Virtual reality · immersive VR · building evacuation · training simulation

1 Introduction

The use of immersive active shooter training drills allows for training for situations that could not be tested in real life due to legal issues and possible health risks to participants. The multi-user virtual reality (VR) environment goes beyond traditional or tabletop exercises by immersing participants in scenarios where they interact with realistic, dynamic,

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and often unpredictable situations. The use of an immersive active shooter response training environment improves the realism of the training by allowing participants to engage with each other in real-time scenarios, making decisions, responding to changes, and adapting to dynamic situations that mirror real-world challenges. VR enhances the spatial awareness of the users by allowing them to understand how best to navigate or make decisions based on the layout of the building. Sharma et al. [1–4] have developed an active shooter response training environment for a building evacuation in a collaborative virtual environment. They have presented an immersive security personnel training module and a civilian training module for an active shooter event in an indoor building. They have developed an experimental platform for conducting immersive training for performing virtual evacuation drills.

A multi-user VR environment places participants directly in the same environment using VR headset where each participant enters a fully immersive digital world. Participants can navigate around the space using VR headsets controllers, interact with objects in the environment, and respond to auditory cues, such as gunshots or cries for help. This increases the emotional and psychological engagement of the training which helps create a "sense of presence" in the environment. Traditional exercises for active shooter or fire evacuation drills often rely on pre-scripted events that unfold predictably. They allow for basic learning and repetition, but they don't fully replicate the complexity and unpredictability of real-world events. On the other hand, a multi-user VR environment allows for more advanced learning by replicating scenarios and user interactions that are dynamic and often unpredictable. The multi-user VR environment allows for the incorporation of dynamic and random elements such as an unexpected fire, a change in lighting, or the appearance of additional threats, keeping participants to critically think under pressure for various what-if scenarios. In a multi-user active shooter environment, participants can learn through experience, which aligns with a constructivist approach to learning. It allows for making choices and experiencing outcomes based on different what-if conditions, and replay scenarios, allowing participants to refine their decision-making and correct previous errors. In active shooter response training situations, VR can simulate the unpredictability of a threat. The active shooter's location can be changed forcing trainees to make on-the-spot dynamic decisions about how to react. Moreover, training in VR can replicate real-life emergencies such as sirens, loud gunshots, or the chaotic sounds of people in a disaster unfolding.

This paper presents a multi-user VR platform for conducting immersive training for an active shooter event for a university campus building. We have developed an immersive virtual reality training environment for active shooter events using the Unity game engine by integrating it with Meta Quest 3 hardware as shown in Fig. 1. The immersive nature of VR training and incorporation of fire and smoke creates a higher level of stress, which is necessary for learning how to manage anxiety and operate under pressure. The proposed multi-user VR platform can also be helpful for performance reviews such as decision speed, movement efficiency, and decision-making strategy. The data gathered from user participation can provide data-driven insights into how participants performed during a stressful and anxiety-inducing emergency situation.

Fig. 1. Immersive VR environment for active shooter response in a building on the university campus.

The rest of the paper is structured as follows. Section 2 briefly describes the related work for immersive training for an active shooter response, and disaster response training. Section 3 describes the implementation of an immersive VR active shooter response environment. Section 4, describes the evaluation of the immersive active shooter training environment. Section 5 discusses the drawn conclusions. Finally, Sect. 6 states acknowledgments.

2 Related Work

A Collaborative virtual reality environments (CVE) represent a powerful tool for active shooter response training. Their immersive and interactive nature enhances the realism of training scenarios and helps improve teamwork and communication among participants. As research continues to demonstrate the effectiveness of VR in training applications, the integration of CVEs into emergency preparedness programs is likely to become increasingly prevalent.

Active shooter response training in a VR environment can be impactful because of its ability to simulate real-life emergencies in a controlled setting. Studies have shown that VR can significantly enhance situational awareness and decision-making skills among participants [5, 6]. For instance, immersive VR environments can replicate the stress and urgency of an active shooter situation which enables the users to experience and react to simulated threats without the risks associated with them [7, 8]. The collaborative aspect of VR enables teams to practice communication and coordination, which are vital components of effective emergency response [9]. Immersive VR has been used as an education, training, and emergency response tool for an aircraft evacuation [10], a library evacuation [11], a subway evacuation [12], a megacity evacuation [13], a night club evacuation [14], a university campus evacuation [15].

VR environments can improve the psychological preparedness of individuals facing emergency scenarios. By engaging in realistic simulations, participants can develop a better understanding of their responses to stress and anxiety, which are common during such incidents [8]. The use of VR in training has been linked to increased motivation and engagement, as users often find the immersive experience more compelling than traditional training methods [16]. This heightened engagement can lead to better retention of training protocols, such as the run, hide, and fight protocols, which are critical for survival during active shooter events [17].

3 Implementation of Immersive Active Shooter Environment

The implementation of this project is divided into five main phases: Modeling, Unity Integration, GUI and User Interaction, Photon Integration, and VR Integration. Each phase builds upon the previous, culminating in a fully immersive, multi-user virtual environment.

3.1 Phase 1: Modeling

The first phase involved creating a detailed, to-scale replica of the campus building using 3D software's such as 3ds Max and Google Sketch UP. The 3D digital model of the physical building includes all its architectural details, dimensions, textures, and features and is represented in a three-dimensional virtual environment. As the 2D architectural model was available, it was easy to create 3D model of the building. The creation of a 3D model of the campus building involved:

- Extruding the 2D floor plan with precise dimensions to a 3D floor plan.
- Adding walls, windows, doors, and other structural elements.
- Incorporating architectural details like stairs, columns, and roofs.
- Including features like lighting fixtures, furniture, textures, and other signage that are part of the space.
- Textures were applied to give it a realistic appearance.
- Adding lights and environment setup.

Real-time images were captured for textures to be applied to carpet, walls, signage, etc. Textures were applied to give it a realistic appearance by adding finishes like paint, flooring, wall coverings, and other surface details. 3D modeling software allowed for the application of materials and textures that mimic real-world surfaces, adding depth and realism to the model. The incorporating lighting was a crucial step in recreating the building's atmosphere. By setting up virtual light sources for natural light and interior lights we were able to replicate how the building would appear at different times of day or under different conditions. This was important as the model was used for simulations or visualizations of emergency scenarios for active shooter response training.

Figure 2 shows the initial 2D models of the campus building. We exported the 2D model into Sketch-Up to create a 3D model of the building. As shown in Figs. 3, the building is large, and creating the 3D models along with adding textures, furniture, and other details required significant effort.

3.2 Phase 2: Unity Integration

In the second phase, the Sketch Up model was imported in Unity 3D, which is a 3D gaming engine. Additional elements for interactivity such as opening the door and windows, proximity triggers, etc. were integrated in the VR environment. The building was

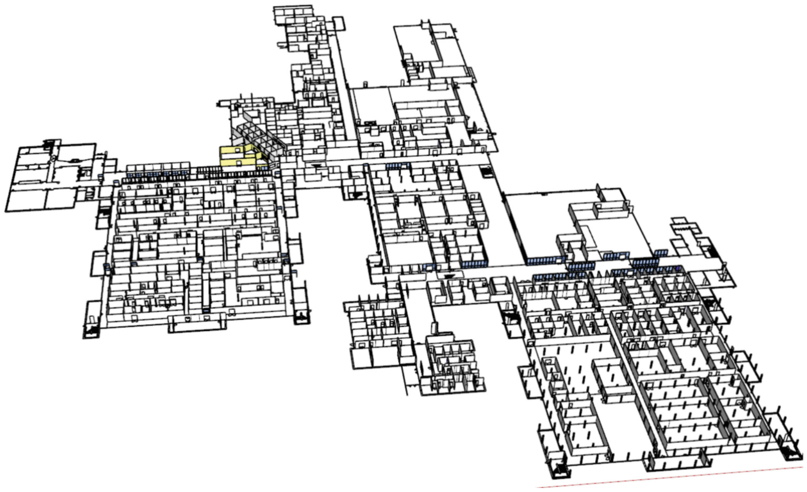

Fig. 2. 2D model of the UNTY building exported to sketch up (1st floor Plan).

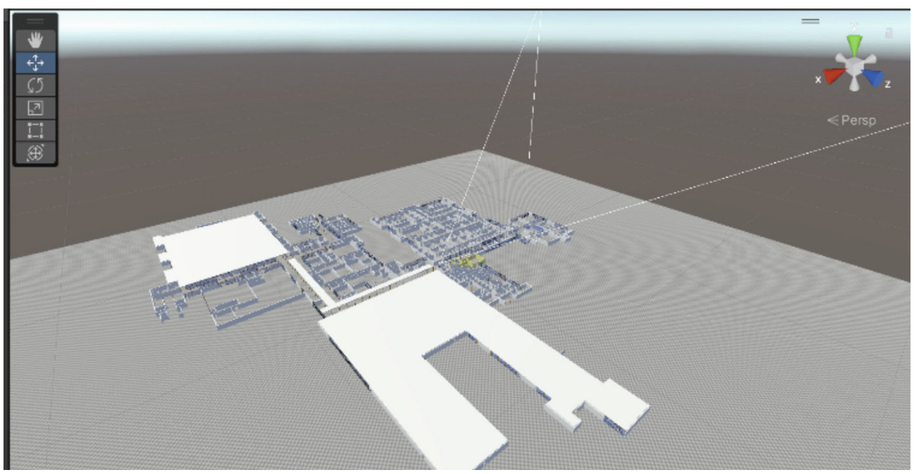

Fig. 3. Initial modeling: 2D model of the campus building exported to sketch up and extruded to create a 3D model (2nd floor plan).

modeled to scale. During this stage, we incorporated C# behavior scripts, looping, and key triggered animations. The use of smoke and fire as well as some consistent colored light flickering functionality was implemented through C# programming. The modeled virtual agents in the environment have a waypoint algorithm attached as a component to enable them to navigate toward their goal in the environment. The combined interactions of the agents and the environmental hazard created a more realistic experience for both immersive and non-immersive participants.

3.3 Phase 3: GUI and User Interaction Phase

Once the 3D model was fully integrated in Unity 3D, the focus shifted to designing user interfaces (UI) and enabling interactions within the virtual environment. Key UI elements, such as "Start," "Game," and "End" panels, were developed. A third-person player controller was introduced, allowing users to explore the environment and navigate seamlessly through mouse and keyboard in the non-immersive environment. Additional interactive elements, including functional doors and non-player characters (NPCs) or AI agents, were incorporated to create a dynamic, immersive, and lifelike virtual world.

Fig. 4. AI behavior for NPCs in the active shooter environment.

This phase also involved implementing algorithms for NPCs or AI agent behavior in an active shooter events environment. We present two ways of modeling user behavior. First, by defining rules for AI agents or NPCs (Non-Player Characters). Second, by providing controls to the users-controlled agents or PCs (Player characters) to navigate in the VR environment as autonomous agents with a keyboard/ joystick or with an immersive VR headset. The user-controlled agents can enter the CVE and can respond to emergencies like active shooter events, bomb blasts, fire, and smoke. We have presented a multi-user virtual reality (VR) platform where experiments for active shooter response can be conducted using computer-controlled (AI) agents and user-controlled agents. As shown in Figs. 4 and 5 we have already implemented behavior for NPCs in the active shooter environment at the campus building. We have modeled the following behaviors for computer-controlled agents (AI agents) so that they can interact with user-controlled agents in a CVE.

- Hostile
- Non-hostile

- Selfish
- Leader-following

3.4 Phase 4: Photon Implementation Phase

This phase utilized Photon Unity Networking (PUN), a robust networking framework compatible with Unity, to enable multi-user functionality. PUN allows up to 20 users to interact simultaneously within the environment without incurring operational costs. Custom scripts were developed for room management, player synchronization, NPC behavior synchronization, and UI functionality, ensuring smooth and consistent interactions for all active users. This phase was critical for achieving the collaborative, multiplayer aspect of the virtual environment. C# scripts were incorporated for the implementation of a PUN system that allowed multiple users to collaborate and communicate with one another. The users were able to create a room on the server using a unique application ID. Other users as clients were also able to join the room to participate in the active shooter response environment for campus building. The photon network in Unity 3D allowed all users to view and interact with other user-controlled agents in real-time.

3.5 Phase 5: VR Integration Phase

The final phase involved integrating virtual reality (VR) support using the MetaXR SDK. This enabled VR devices, such as the Meta Quest 3, to interact with and navigate the virtual environment. Dedicated VR-compatible UI elements were designed and implemented to enable operation with these devices.

Fig. 5. Developed active shooter environment based on run. Hide, and fight.

The VR integration expanded the project's potential applications by providing an immersive and intuitive experience, allowing users to interact with the environment naturally through VR input systems. The collaborative immersive environment was implemented in Unity 3D and is based on run, hide, and fight approach for emergency response.

Figure 5 shows our developed CVE environment for active shooter events using Meta Quest 3 touch controllers for the course of action, visualization, and situational awareness for active shooter events.

4 Evaluation of Active Shooter Response Training Environment

A user study was conducted to evaluate the immersive VR training environment with a total of 195 participants at the university campus building (refer Figs. 3, 4, 5 and 6). Phase 1 of the user study included 80 participants whereas Phase 2 of the user study included 115 participants. Each session included 4 participants in the user study. Phase 1 user study included all participants in a multi-user VR environment using a monitor, mouse, and keyboard (non-immersive). On the other hand, phase 2 user study included 2 users on Meta Quest 3 (immersive environment) and 2 users on computer and keyboard (non-immersive) in the same multi-user environment. The experiment sought to examine how the proposed active shooter multi-user VR environment influenced participants' understanding of the safest actions to take during an active shooter situation. The post-evaluation includes questions on the Group Environment Questionnaire (GEQ) [18], Presence Questionnaire (PQ) [19], System Usability Scale (SUS) [20], and Technology Acceptance Model (TAM) Questionnaire [21]. Figure 6 shows the user study conducted for the evaluation of active shooter response training environment.

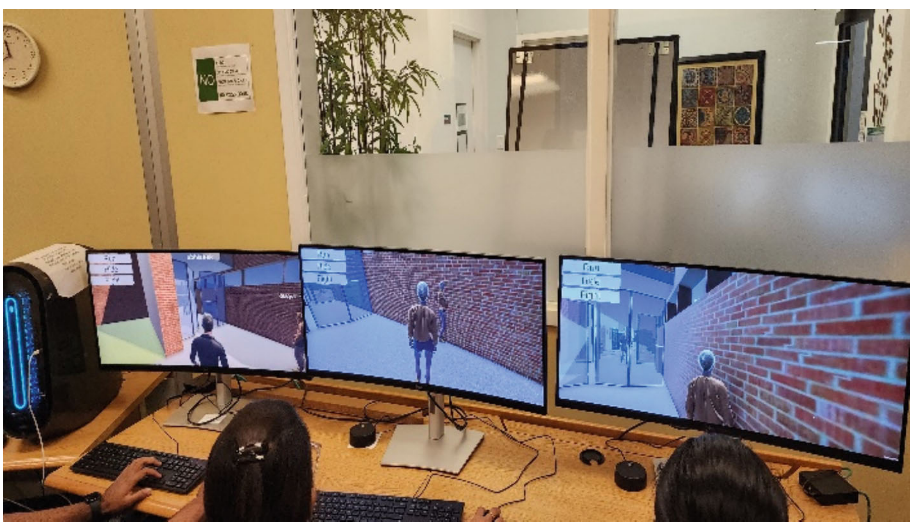

Fig. 6. User study in a multi-user VR environment or collaborative VR environment.

Figure 7 illustrates engagement in the environment by major and gender, with fields like Business Analytics, Data Science, Information Science, and Health Informatics showing the highest levels of engagement. Gender had little impact, though females in Health Informatics were slightly more engaged.

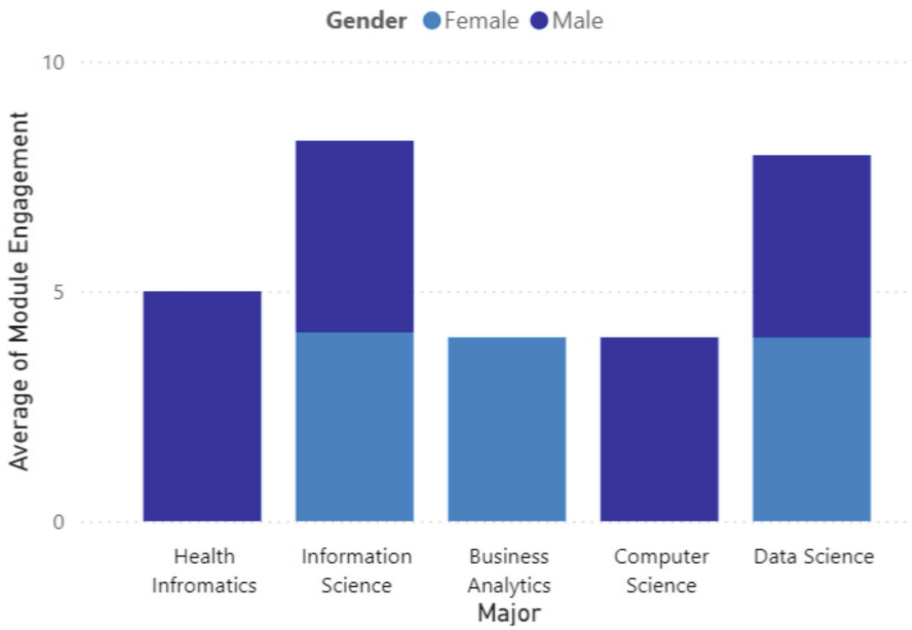

Fig. 7. Changes in Attitude Scores by Age Group.

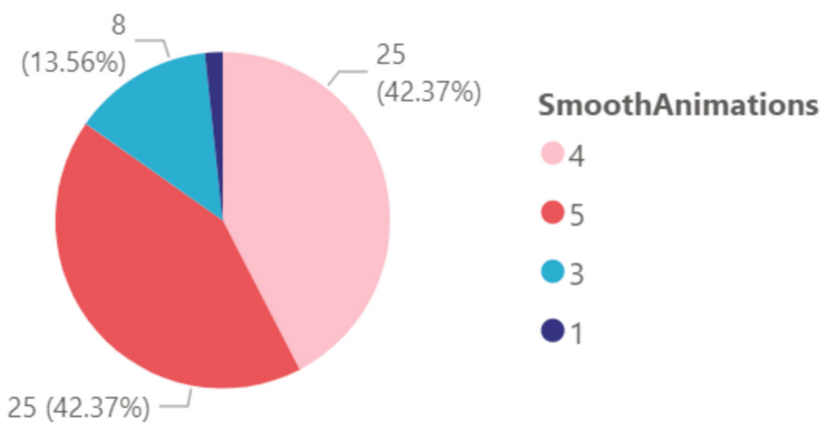

Fig. 8. Smooth Animations Needed.

Figure 8 shows that 43% of respondents believe smooth animations are necessary. This means a little less than half of the survey participants found smooth animations to be an important feature.

As shown in Fig. 9, respondents rated the VR environment highest for its ability to help them achieve safe evacuation (around 6.5 on a 7-point scale). Finding an evacuation route quickly using the active shooter response training environment also received a high

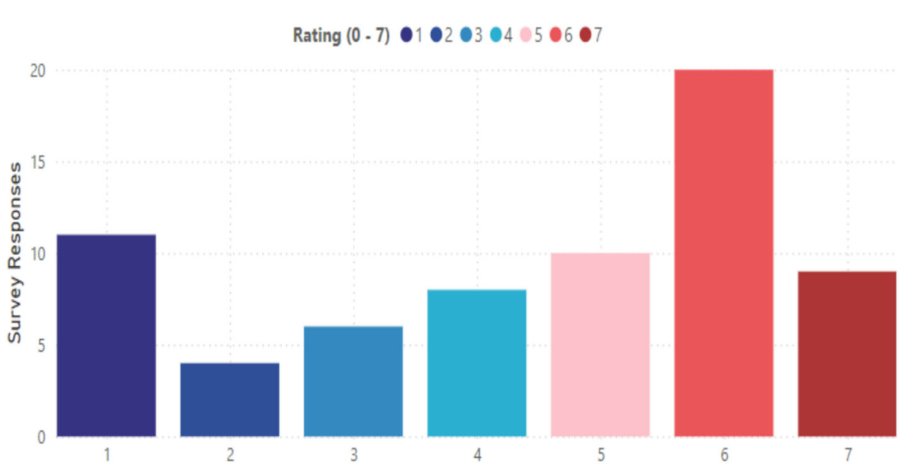

Fig. 9. Usefulness of VR environment to accomplish evacuation safety.

average rating (around 6). These findings suggest the active shooter response training environment effectively addresses core user needs in emergency situations.

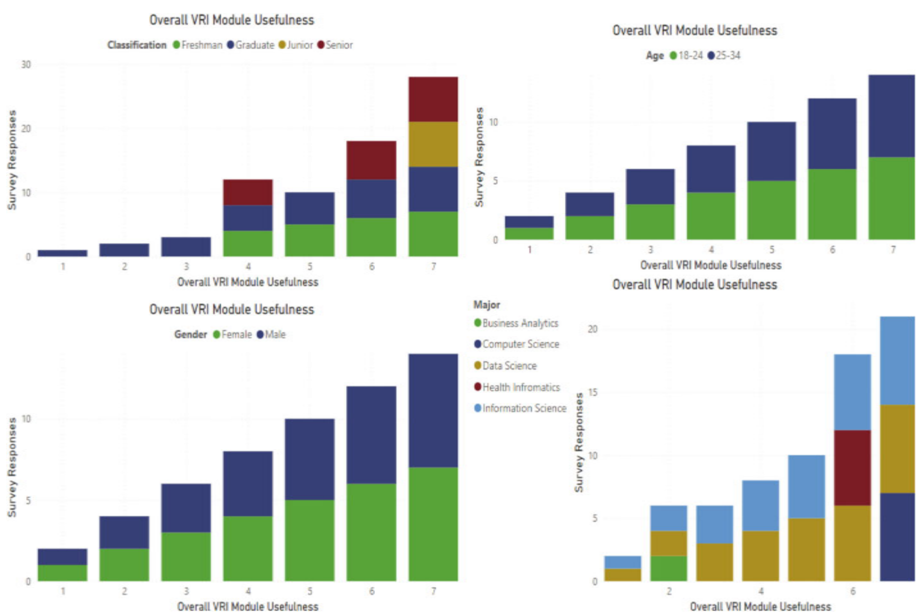

Fig. 10. Overall usefulness in multi-user VR environment or collaborative VR environment.

Figure 10, shows the active shooter response training environment's usefulness varied based on gender, age, major, and academic classification. Both male and female respondents found it useful, with males rating it slightly higher. Older respondents found it more useful, while the Computer Science and Health Informatics majors rated it most favorably. Juniors and seniors rated it more positively.

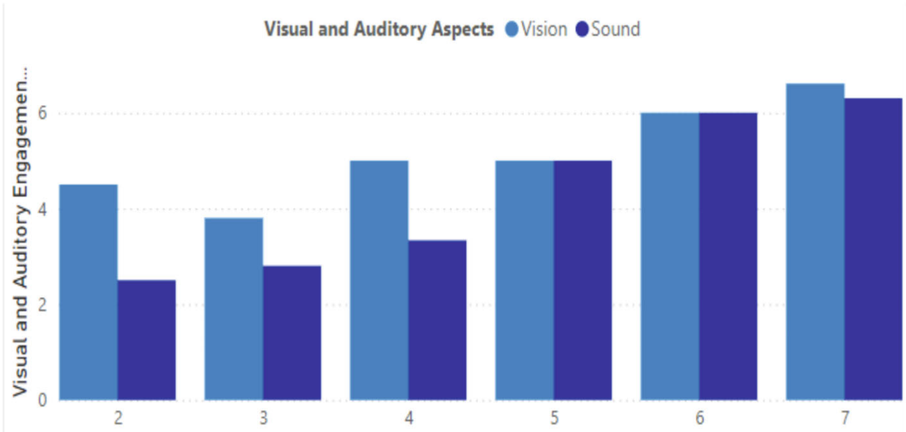

Fig. 11. Visual and auditory engagement aspects

Figure 11, shows that respondents found auditory aspects much more engaging than visual ones. The virtual environment appears to be particularly effective in delivering immersive auditory experiences, while visual engagement falls behind. It was suggested that designers and developers should focus on achieving a balance between both sensory elements to improve the overall user experience. This means ensuring that visuals are as captivating and enriching as the auditory components to create a more immersive and enjoyable virtual environment for users.

5 Conclusions

This paper has presented a multi-user virtual reality (VR) platform where experiments for active shooter response can be conducted using computer-controlled (AI) agents and user-controlled agents. This multi-user VR platform is fully immersive with the use of Meta Quest 3 and touch controllers. It can also be used as non-immersive desktop version through the use of a monitor, mouse and keyboard. The multi-user VR environment is set up using photon unity networking on the cloud and users can participate in the active shooter training drill which leads to considerable cost advantages over large-scale real-life exercises. Studying human behavior during emergencies is often challenging due to the complexity of the scenarios that need to be simulated. Immersive virtual reality provides the opportunity to conduct such human behavior experiments without putting participants at risk. User computer-controlled agents or AI agent's behavior was implemented using behavior trees within the Unity game engine.

A user study was conducted to evaluate the immersive VR active shooter training environment with 195 participants. The evaluation of the immersive VR active shooter training environment included post survey questions from Group Environment Questionnaire (GEQ), Presence Questionnaire (PQ), System Usability Scale (SUS), and Technology Acceptance Model (TAM) Questionnaire. The findings suggest that participants' knowledge, intrinsic motivation, and self-efficacy showed a significant increase immediately following the training. The results indicate that most users felt a stronger sense of presence when engaging with the immersive emergency response training environment designed for an active shooter evacuation scenario. By utilizing the immersive VR platform, trainees enhance their spatial awareness and gain a better understanding of how to navigate the building during high-stress situations, ultimately improving their chances of survival and successful evacuation. The results from the user studies indicate that participants experienced a notable increase in their knowledge, intrinsic motivation, and self-efficacy right after the training. The results show that most users felt that the sense of presence increased when using the immersive emergency response training active shooter environment.

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