

Interactive Emergency First Aid Response Training Simulation in Virtual Reality

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Abstract— Emergency preparedness remains a critical gap in public health education. Traditional first aid training methods often lack engagement, accessibility, and the ability to replicate real-world urgency in a safe environment. This paper presents an immersive Virtual Reality (VR) application that trains users in emergency first aid through scenario-based interaction set within a richly detailed historically inspired architectural compound. The application offers an engaging, gamified, and pedagogically grounded training experience suitable for students, workplace safety trainees, and general public users seeking consequence-free emergency preparedness practice.

Keywords— virtual reality, emergency first aid, VR training simulation, scenario-based learning, serious games

I. INTRODUCTION

The capacity to administer basic emergency first aid represents a critical competency for laypersons; however, access to formal training in such procedures remains unevenly distributed across populations due to economic constraints, scheduling limitations, and the lack of sufficiently engaging instructional modalities. Empirical evidence consistently demonstrates that experiential, scenario based learning approaches yield significantly improved outcomes in both knowledge retention and procedural skill transfer when compared to passive, lecture based instruction [1].

In response to these limitations, this project introduces an immersive Virtual Reality (VR) training simulation for emergency first aid response. The application situates participants within an expansive historically inspired heritage compound featuring a sakura blossom arboretum, traditional pavilions, a Japanese garden with ornamental water elements, stone-paved ceremonial pathways, and multi-tiered historical architecture. This environment functions not only as an aesthetically rich setting but also as the contextual stage for an unscripted medical emergency. The deliberate selection of a visually compelling, tourist attraction compatible environment is intended to enhance affective engagement by juxtaposing the tranquility of the surroundings with the abrupt onset and urgency of a clinical crisis.

The application is designed to address the needs of several primary user populations, including secondary and post-secondary students enrolled in health, biology, or life skills curricula; corporate employees required to complete occupational health and safety training; members of the general public seeking accessible emergency preparedness education; and healthcare or

first aid training organizations in need of supplementary, simulation-based instructional tools.

The project is guided by a set of clearly defined goals and objectives. First, it aims to educate participants on the recognition and management of three distinct categories of medical emergencies: minor lacerations, cardiac arrest, and dehydration. Second, it seeks to simulate realistic, evidence-based emergency response decision-making within an immersive, first-person virtual reality (VR) environment. Third, the application is intended to cultivate critical thinking skills through quiz-based situational assessments and guided task execution. Additionally, it endeavors to deliver an engaging and gamified learning experience through interactive user interface systems, audio-visual feedback mechanisms, and positive reinforcement upon task completion. Finally, the project aims to foster empathy and enhance users' readiness to respond effectively in real-world emergency situations by leveraging an immersive first-person perspective.

II. RELATED WORK

The application of virtual reality to medical education and emergency preparedness training has been the subject of sustained scholarly inquiry over the preceding two decades. Prior research shows VR as a critical medium capable of replicating high stakes clinical scenarios within environments that are safe, repeatable, and economically scalable. Pottle (2019) conducted a systematic review of VR-based interventions in medical education, concluding that immersive simulation modalities produced measurable improvements in clinical competency outcomes across multiple specialty domains, particularly where scenarios necessitated procedural skill acquisition and consequential decision-making under cognitive load [2]. Merchant et al. (2014), in a synthesis of simulation-based learning environments across educational contexts, confirmed that game-based and simulation-based training consistently demonstrated superior performance in knowledge retention and competency transfer relative to conventional instructional approaches [4]. These findings provide strong theoretical grounding for the gamified scenario based learning architecture adopted in the present system.

In the domain of emergency-specific simulation, Cheng et al. (2015) demonstrated that structured CPR training using mannequin-based simulation platforms significantly enhanced bystander confidence and willingness to intervene in genuine cardiac emergencies, a principle directly transferable to VR-mediated first aid

instruction [3]. This principle has been operationalized in VR-native training contexts through the development of virtual bystander cardiopulmonary resuscitation (CPR) scenarios, where participants completing VR-based instruction demonstrated procedural performance comparable to those trained using conventional mannequin based methods [5]. The clinical relevance of simulation based instruction has further been substantiated through evidence indicating that simulation-grounded training protocols yield statistically significant improvements in team coordination during simulated cardiac arrest events [6].

Prior work in pedagogical agent design, crowd simulation, and collaborative VR training demonstrates that both intelligent non-player characters (NPCs) and multi-user environments significantly enhance learner engagement, situational awareness, and procedural performance in emergency response contexts [7], [8], [9]. Accordingly, the present system adopts a hybrid approach that integrates ConvAI-driven NPC interaction with multiplayer networking to support both adaptive, context-aware instruction and coordinated, shared-scenario training.

Research on spatial audio in VR indicates that ecologically valid ambient soundscapes enhance presence and reduce cognitive load, supporting the use of layered audio feedback in immersive training systems [10]. Similarly, teleportation-based locomotion has been shown to be an effective and user-friendly navigation method for VR environments, particularly for novice users [11]. Accordingly, the present application integrates structured spatial audio cues alongside a simplified teleportation system adapted to a keyboard-driven interaction model.

Prior research consistently demonstrates that virtual reality is an effective medium for medical and emergency response training, improving procedural performance, knowledge retention, and learner engagement compared to traditional instructional methods [2], [4]. Simulation-based training has further been shown to enhance confidence, decision-making, and team coordination in high-stakes clinical scenarios such as cardiopulmonary resuscitation [3], [5], [6]. Additionally, studies in VR interaction design highlight the importance of intelligent NPCs, collaborative multiplayer environments, spatial audio, and teleportation-based locomotion in improving presence, usability, and training effectiveness [7]–[11]. These findings collectively inform the design of the proposed system, which integrates scenario-based VR training with adaptive NPC interaction and optimized immersive interaction mechanisms.

III. SYSTEM DESIGN

A. Tools

The implementation proceeds through a structured multi-phase development pipeline encompassing three-dimensional environment construction, character and NPC configuration, procedural scripting, audio-visual systems integration, and multiplayer networking. The primary development platform is Unity 3D (version 2022 LTS) with C# scripting authored in Visual Studio. Multiplayer functionality is realized through Photon PUN (Photon Unity Networking), enabling concurrent multi-user presence within the compound environment. Participants are instantiated as networked first-person controllers, visible to peer users as third-person avatar representations. Room-level state synchronization ensures consistent emergency trigger timing across all connected clients. Each participant may progress through the diagnostic quiz and task execution sequences independently, thereby supporting both individual training and cooperative group training modalities. ConvAI has been used for NPC communication.

B. Modeling and Environment Design

The virtual environment constitutes a large-scale Japanese/Korean-style heritage compound, incorporating sakura blossom trees with dynamic particle systems, traditional wooden pavilion structures, a Japanese garden with grass field, flowers and ornamental stonework, ceremonially styled pathways, and multi-tiered historical architectural forms. Environmental assets were procured from the Unity Asset Store and integrated through custom placement, material adjustment, and scale calibration to achieve thematic coherence and visual fidelity.



Figure 1 : a) The main compound showing the ER, patient, and other marked spots such as information desk and well. b) Historical Pavilion. Similar buildings have been set up throughout the full compound.

Five navigational anchor points were established within the compound and designated as key interaction locations: (1) the Information Desk, (2) the First Aid Kit Station, (3) the Well (water procurement point), (4) the Japanese Garden, and (5) the Pavilion. Each location is accessible via keyboard shortcuts (keys 1 through 5), enabling immediate teleportation for participants who prefer expedited traversal over ambulatory navigation. To make the environment interactive, visual displays (monitors) were set up with video looping environmental footage with ambient sound were distributed throughout the compound to augment visual dynamism and reinforce the impression of a living, inhabited world. Appropriate UI panels, sound, alerts, congratulations messages and prompting were placed throughout the gaming workflow.



Figure 2 : Japanese Garden, one of the travel spots (third person view)

C. Character and NPC Configuration

Character assets and animation rigs were sourced from the Unity Asset Store. Multiple pedestrian NPC instances patrolled in designated paths throughout the compound via Unity's NavMesh Agent pathfinding system, simulating a populated tourist environment. Amelia, the ConVAI-powered AI tour guide, is stationed near the well and responds to participant queries with dynamically generated narration pertaining to the compound's architectural typologies, historical context, and cultural significance.



Figure 3 : NPC Amelia, working as a tour guide

The Emergency Responder NPC is positioned adjacent to the patient character, rendered in a prone distress pose with at the designated emergency site.

Upon emergency trigger, some of the bystander NPCs execute a behavioral state transition, switching from idle patrol animations to directional running animations oriented toward the emergency coordinates, generating a salient environmental cue that both heightens situational urgency and provides implicit wayfinding guidance for the participant.

D. Animation

The simulation incorporates a range of animated elements to enhance environmental realism and support narrative progression. Non-player characters (NPCs) navigate the compound by patrolling between predefined waypoints using continuous locomotion animations. In response to the onset of a medical emergency, bystander NPCs exhibit dynamic behavioral state transitions, shifting from idle or ambulatory states to directed running animations toward or away from the incident location. Additionally, the Emergency Responder character is animated during quiz-driven dialogue interactions, providing visual continuity during instructional sequences. Environmental animation is further reinforced through persistent sakura petal particle effects distributed throughout the compound, contributing to both aesthetic immersion and scene dynamism.

E. Interactivity

User-driven interactivity is facilitated through a series of discrete input-based actions integrated into the simulation workflow. These include: (1) personalized user identification via name entry on the startup interface; (2) activation of emergency acknowledgment and initiation of interaction with the Emergency Responder through the 'E' key; (3) engagement with diagnostic decision-making via multiple-choice selections within the quiz interface; (4) acquisition of the first aid kit using the 'F' key; (5) collection of water from the well through the 'T' key; (6) sequential input of digits on the 911 dial-pad user interface to simulate emergency calling procedures; and (7) rapid navigation across key locations within the compound through numeric key inputs (1-5), corresponding to predefined sites such as the Information Desk, First Aid Station, Well, Japanese Garden, and Pavilion.

F. Sensors and Teleportation

The system integrates both system-driven triggers and user-driven input mechanisms to support interactive scenario progression. Temporal control is implemented via a coroutine-based trigger (WaitForSeconds), which activates the emergency alert interface five seconds after scene initialization. Spatial interaction is facilitated through collider-based proximity detection, enabling automatic activation of contextual UI elements and interaction affordances when the user enters designated regions.

User input is managed through discrete keyboard interactions mapped via Unity's Input system. Specifically, the 'E' key initiates emergency acknowledgment and interaction with the Emergency Responder; the 'F' and 'T'

keys enable first aid kit acquisition and water collection, respectively; and numeric keys (1–5) allow rapid teleportation between predefined locations. Together, these mechanisms establish a cohesive interaction framework that combines automated system responsiveness with explicit user control.

G. Gameplay via Scenario Based Learning

The simulation is structured as a state-driven interactive training system implemented through a finite state machine comprising five core states: Exploring, EmergencyAlert, QuizActive, PerformingTask, and TaskComplete. The experience begins in the Exploring state, where the participant navigates the environment freely until a time-delayed event is triggered via a coroutine-based mechanism. After a customizable delay of pre-defined time in seconds from scene initialization, the system transitions into the EmergencyAlert state, during which NPC bystanders are programmatically directed to move toward the emergency location using scripted locomotion behaviors, and an emergency alert UI is displayed alongside auditory alarm feedback. The game starts from a welcome screen where the user can specify their name and room name (for multiplayer setting). When the trigger is initiated, user is prompted to move to the emergency location by pressing 1 or walking.



Figure 4 : Welcome screen and emergency alert.

Following alert activation, the participant may initiate the diagnostic phase, transitioning the system into the QuizActive state. In this phase, the Emergency Responder presents a multiple-choice diagnostic assessment with three response options corresponding to predefined emergency

categories: Small Cut, Heart Attack, and Dehydration. Selection of an option triggers a scenario specific instructional pathway and transitions the system into a contextual decision interface. The player has to be situated near the ER and press E to initiate conversation.



Figure 5 : The quiz screen where user can explore each scenario by clicking the options.

Upon each answer selection, a scenario description panel is presented, providing clinically grounded procedural guidance and prompting user confirmation through a binary decision interface (Yes/No). A positive confirmation advances the system to a scenario acknowledgment stage, whereas a negative response returns the user to the EmergencyAlert state and resets scenario progression. If the participant confirms continuation, the system transitions into the PerformingTask state, activating one of three scenario-specific interaction flows.

In the **Small Cut** scenario, users are instructed to navigate to the Information Desk using either free exploration or the teleportation system and retrieve a first aid kit. Upon reaching the designated interaction zone, the user engages with the object through the 'F' key, simulating the acquisition and application of basic first aid equipment within a controlled training context. In the **Dehydration** scenario, participants are directed toward the well location, where they are required to collect water resources. Interaction is similarly executed through the 'T' key once the user is within the appropriate proximity range, reinforcing location-based task execution and procedural responsiveness. In the **Heart Attack** scenario, users are prompted to initiate an emergency response procedure by placing a simulated call using a dedicated 911 dial-pad interface presented through a contextual UI panel. This interaction is designed to replicate critical decision-making under time-sensitive conditions. Upon successful completion of the required actions in each scenario, the system transitions to the TaskComplete state. In this final state, the Emergency Responder NPC provides verbal acknowledgment of task completion, a congratulatory UI overlay is displayed featuring the participant's input name, and positive auditory feedback is triggered.



Figure 6 : Small cut scenario step by step game-play. The dehydration scenario works similarly.

cycle and reinforces correct procedural decision-making through multimodal feedback. The demographic of our user base is expected to be young students, so we have made the gameplay function with step by step acknowledgement of the emergency and consent of the user to proceed to the next step.



Figure 7 : Dial Panel for the heart attack scenario

In the heart attack scenario instead of picking up item, we simulate a phone screen to show the user calling 911, along with error handling if the user puts the wrong number in. After each of the scenario completion the user receives a congratulatory message to wrap the scenario.

IV. CONCLUSION

This project presented the design and implementation of an immersive Virtual Reality (VR) emergency first aid training simulation developed in Unity 3D and situated

within a Japanese/Korean-style heritage environment. The system operationalized three clinically relevant emergency scenarios, minor laceration management, cardiac arrest response, and dehydration treatment, through a quiz-driven interaction framework aligned with established first aid protocols and evidence-based instructional design principles. The application demonstrates the potential of VR as an effective medium for scalable and accessible emergency preparedness training. By leveraging first-person immersion, interactive scenario engagement, and gamified feedback mechanisms, the system facilitates active learning, reinforces correct response behaviors, and enables repeatable, consequence-free practice without reliance on physical infrastructure or certified instructors. The proposed approach is particularly relevant for students in health related disciplines, corporate trainees, and the general public, offering a practical pathway toward improved emergency response confidence, enhanced decision making under simulated pressure, and broader access to standardized first aid education.

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