BRIEF REPORT

Creating a Novel Disaster Medicine Virtual Reality Training Environment

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Abbreviations:
CBRN: chemical, biological, radiological, or nuclear
EMS: Emergency Medical Services
MCI: mass-casualty incident
VRE: Virtual Reality Environment

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Abstract

Introduction: Disasters are high-acuity, low-frequency events which require medical providers to respond in often chaotic settings. Due to this infrequency, skills can atrophy, so providers must train and drill to maintain them. Historically, drilling for disaster response has been costly, and thus infrequent. Virtual Reality Environments (VREs) have been demonstrated to be acceptable to trainees, and useful for training Disaster Medicine skills. The improved cost of virtual reality training can allow for increased frequency of simulation and training.

Problem: The problem addressed was to create a novel Disaster Medicine VRE for training and drilling.

Methods: A VRE was created using SecondLife (Linden Lab; San Francisco, California USA) and adapted for use in Disaster Medicine training and drilling. It is easily accessible for the end-users (trainees), and is adaptable for multiple scenario types due to the presence of varying architecture and objects. Victim models were created which can be role played by educators, or can be virtual dummies, and can be adapted for wide ranging scenarios. Finally, a unique physiologic simulator was created which allows for dummies to mimic disease processes, wounds, and treatment outcomes.

Results: The VRE was created and has been used extensively in an academic setting to train medical students, as well as to train and drill disaster responders.

Conclusions: This manuscript presents a new VRE for the training and drilling of Disaster Medicine scenarios in an immersive, interactive experience for trainees.

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Introduction

Disaster Simulation

In this manuscript is described a Virtual Reality Environment (VRE) to be used in the training and evaluation of hospital staff and first responders to mass-casualty incidents (MCIs). This VRE creates an immersive simulation for participants to allow for maximum engagement of the learners. This VRE also decreases the financial and logistical barriers to MCI teaching and drilling.

Most disasters are low-frequency, high-acuity events and because of this, responders must be knowledgeable and skillful in the rescue, treatment, and recovery phase, often performed in chaotic settings. Training responders for disasters allows them to move more quickly and to apply what resources are available to the important life-saving tasks.[1] This training can be in widely varying topics such as reduction of risk exposure (eg, removing an active shooter); triage; and damage control interventions (eg, tourniquet application).[1–5] While these topics vary based on responder type, it is necessary for anyone who plans to respond to disaster events to have the knowledge and skills which will allow them to make a positive impact on the situation.

Due to the infrequency of disasters, providers lack the ability to apply and update their skills regularly in real-world events. To ensure that the necessary knowledge and skills providers need to respond in an actual event do not fade, it is important to create drills which appropriately test them and aid in improvement. These have historically been done in many ways, including hands-on drills, didactic lectures, simulation, and tabletop drills.[1,6,7] Some research shows that mixed-methods of teaching and drilling for disasters can improve knowledge for participants.[6] Drilling of the medical response, which lies in the realm of

Disaster Medicine, is a time consuming and expensive undertaking, which often requires experts to travel to numerous sites to provide training.[5,8] However, using virtual reality, exercises can be undertaken with significantly less material expense compared to a real-world, full-scale simulation. Additionally, training programs can be performed in remote areas, which may not be easily reached by expert trainers.[9] Some studies have demonstrated these benefits using VREs such as: SecondLife (Linden Lab; San Francisco, California USA); OpenSimulator (OpenSimulator; online platform); and the Unity 4 games engine (Unity Technologies; San Francisco, California USA).[9,10] The improved cost of VRE drills can be leveraged to increase the frequency with which drills are performed by individual responders, and by responder organizations as a whole.

There has been a push over recent years to create more online Disaster Medicine training. Much of this online content is available free of charge, and is accessible to providers of all training levels. However, very little of this information is targeted towards physicians and other health care providers. Additionally, most of this material is lecture-based, and suffers from a lack of interactivity.[7] While there is value in having free, widely available training, there is a need to increase the rigor of this material, and to direct more of it toward more advanced providers who will be called upon to apply their skills in true scenarios.

Virtual reality simulations have been proven to be effective in training participants for MCIs when studied alongside live simulations.[11] Additionally, they have been proven in multiple studies to be acceptable to trainees, who find these simulations to be valuable and realistic, and who wish to have further training with virtual environments.[6,9] With these facts in mind, it logically follows that a low-cost VRE, which is acceptable to students and has demonstrated the ability to improve skills, would be an invaluable addition to the arsenal of the medical education community.

There are several VRE platforms which have been used in the past by various groups and have been documented in the literature. Gale, et al demonstrated the use of a VRE to educate workers with exposure to highly infectious diseases on donning and doffing of personal protective equipment.[5] SecondLife and OpenSimulator have been used to create individual scenarios in which participants could respond to blast events.[9] The Unity 4 engine has also been used to create a disaster scenario for training.[10] This effort was notable in that it featured a modular design and was flexible for multiple possible scenarios. The advantages of all of these approaches were noted in the creation of the VRE described in this manuscript.

This VRE can be used to provide an immersive setting in which students and providers can practice their communication, cooperation, and coordination between varying response entities, as well as developing their own personal skills.

SecondLife

Platform—This simulation environment is built within the SecondLife platform, created by Philip Rosedale and his company, Linden Labs. SecondLife is a software, centrally hosted on Linden Labs' servers. This software-as-a-service solution (SaaS) offers a three-dimensional environment that can be modeled (known as "terra-forming") and tools to create and animate objects inside it. Mesh, textures, sounds, and gestures can also be created through other third-party's softwares and imported into SecondLife. Objects created by SecondLife users can be sold or given away through a SecondLife marketplace on the web, which can be used to populate a scenario environment. This marketplace is valuable in that it gives the ability to rapidly acquire a wide range of items and structures when a scenario must be constructed. There's a specific currency for this marketplace or in-world services called Linden Dollars; Linden Dollars can be bought or exchanged with real-world currency.

Power-Users—"Power-users" can rent virtual land in SecondLife and are free to create their own environment in order to achieve their own goals. Many experiences have been conducted around education purposes.[9,12] The basic unit of virtual land is called a "full region," which is effectively a powerful server, or in SecondLife terms, is a three-dimensional space of 65,000m2 on an isolated island. Multiple regions (servers) can be rented and connected to simulate a wider area. On a single server, multiple areas can be superimposed vertically, similar to a multi-story building, 65,000m2 on each level. Power-users can also simulate time of day, as well as varying weather conditions.

End-Users—This environment can be accessed and visualized by anyone through Linden Labs' viewer which can be downloaded for free from their website, or through third party's viewers. The viewer can be installed on Windows (Microsoft Corp.; Redmond, Washington USA), iOS (Apple Inc.; Cupertino, California USA), or Linux (Linux Foundation; San Francisco, California USA) personal computers, tablets, or mobile phone. Linden Labs' viewer is also compatible with Oculus Rift VR headsets (Oculus VR; Menlo Park, California USA). The end-user (student/responder) uses a free personal account, created on Linden Labs' website, to log in these viewers. Once logged in, the student can control a personal avatar and interact with objects and other avatars while visiting any of the tens of thousands of user-created environments. A specific region can be accessed by entering an address into the viewer, similar to a web URL. Each full region can allow as many as 100 avatars, allowing large-scale virtual drills.

Access

Access can be on an individual account basis (white-list or black-list), but SecondLife also gives the ability to create groups of avatars. These groups can be joined by end-users via invitation, self-enrollment, or pay-to-access. In every group, roles can be created, allowing different levels of access. These can include interaction with objects, ability to invite or ban others from the group, and so on. Additionally, the groups can be named to specify roles within a scenario, such as Emergency Medical Technician, Fire, or Group Captain. Those authorizations can apply to the whole region or a specified zone within a region. They can also apply to a single object (eg, drive a vehicle) or a specific ability (eg, send messages to the whole group). Written or oral communication between avatars can be either local (based on proximity), group-based, or one-to-one so they can easily mimic a conversation, a radio-communication, or a phone call.

Methods

After a period of various tests, a full region was rented to create the simulation zone.

Architecture

Prior to any simulation, the zone was filled with multiple structures. Some were bought on the SecondLife marketplace, and others were created new to simulate specific environments, such as a hospital and the Emergency Medical Services (EMS) headquarters, and to fulfill precise functions. Many of these core buildings are persistent and can be moved and re-grouped for specific scenarios. Other buildings exist for specific simulations, and can be used or stored depending on the desired scenario:

- Stadium (used for stampedes and active shooter scenarios);
- Collapsed building (used for earthquake, bombing, and search and rescue scenarios);
- Movie theater (used for chemical, biological, radiological, or nuclear [CBRN], explosion, and stampede scenarios);
- Warehouses (used for CBRN and fire scenarios);
- Burning house (used for fire suppression and rescue scenarios);
- Abandoned hotel (used for EMS field training);
- MASH tent (used for mass-casualty scenarios);
- Highway (used for vehicular pile up scenarios);
- Subway (used for transit crashes and terrorism scenarios); and
- Traffic tunnel (used for vehicular crash scenarios).

This region is capable of hosting up to 100 avatars simultaneously. To date, scenarios have been run with more than 50 participants. With multiple contiguous regions, each region can allow 100 avatars. There are also smaller regions that can allow up to 20 avatars.

Objects

Multiple objects were created to reflect the actual gear that first responders training in the scenarios would use, such as uniforms, backpacks, flashlights, stretchers, and oxygen tanks. Other objects have been bought on the marketplace, especially those that are more complex and would require more time, or skill, to create such as ambulances or medical helicopters. All of these objects, once created or purchased, are completely re-usable and can be pulled into, or excluded from, individual scenarios.

Victim Models

In a virtual drill, victims can be role-played by actors or observers who have their own avatars to create a totally interactive interface between the victim and the first responders. However, when a large-scale drill is desired, it may be necessary to have a larger cache of victims than would be reasonable to manage in this manner. For this purpose, pre-existing virtual dummies can be used, which are human-shaped objects with customizable positions, gestures, and information associated with each.

Three different levels of dummies were created. The simplest dummy, which can be easily used for mass casualties, offers three basic interactions. Each type of interaction takes slightly more time to evaluate, similar to real-life mass casualties:

- When the mouse hovers over the dummy, a brief description appears of what could be seen by a real-life responder without any interaction (eg, 20's male and bleeding);
- On a single click, answers to basic questions appear (eg, response to alertness and orientation questions);
- On double click, a text box appears with the results of a quick field clinical examination (eg, tachypneic or decreased breath sounds to right lung field).

A second type of dummy is used in smaller scale scenarios, such as a car crash with several victims. It offers the same three types of interactions, but with exam findings focused to each body part (eg, head, torso, abdomen, or each arm and leg). The third type of dummy has a real-time built-in physiological simulator.

Physiologic Simulator

Using Linden Script Language, objects were created and attached to dummies, hospital beds, and computers within the simulator. This code was linked to a back-end website were the simulation administrator can perform multiple actions:

- Create clinical cases, including a past medical history, results of clinical examination, labs, electrocardiograms, X-rays, computer topography scans, or other information which can be presented in plain-text or image formats;
- Create an array of variables that can reflect multiple parameters (eg, blood pressure, heart rate, and temperature), lab values (eg, hemoglobin and glucose), or any numeric value (eg, pain scale);
- Create factors that will influence these values in various ways (eg, diseases, wounds, or treatments), designating the speed of change and the range of effect.

During the scenario, the instructors can start the wound or disease process acting on the dummy, changing its physiologic parameters. The student must then act to start the treatment, reversing the changes in physiologic parameters.

Cost to Create

The goal of this project is to decrease the barriers to Disaster Medicine training and drilling. Thus, the financial cost of the VRE is an integral part of its usefulness. The private region in this VRE was purchased for US$349, with a current maintenance fee of US$249/month. Varying architectural structures and vehicles were purchased ranging from US$0.01 to US$10.00. The total amount spent in the marketplace over the past five years was roughly US$50. These figures represent a fraction of the cost which many institutions devote to individual Disaster Medicine drills. In addition to items from the marketplace, a significant amount of time was devoted to creating several unique structures and objects. For institutions which do not wish to re-create this environment, the creators plan to make it available to institutions for specific, individual drills.

Discussion

This VRE has now been used as a training tool for multiple years. It has been used to place Disaster Medicine learners as well as active first responders into life-like scenarios to practice skills and improve their group coordination. It has been used as a complementary solution to real-life drills. Due to the expense and complexity of real-life drills, it is difficult to perform enough to train active first responders, as well as students. This has led to many students graduating having only been observers in real-life drills. Supplementing this experience with interactive experience in the VRE allows for more multi-modality training and a greater range of experiences for learners.

One of the main benefits of this VRE is that it allows disaster management training. The lessons learned from emergency response to varying disasters highlight the need for a holistic approach to disaster management. This can be achieved through the core competencies of disaster management, broadly categorized as disaster preparedness (including early warning and response systems), patient care, and resource management (both human and material).[13] Most competencies can be obtained through traditional education and training programs. However, education for personnel operating in disaster situations should be based on the acquisition of task-related, profession-specific, and cross-disciplinary competencies that cannot be easily acquired through didactic programs.

This VRE allows for the standardization of competency-based education in disaster and humanitarian management. This serves as the foundation for training and validation of a common competency – a framework for all health professionals involved in crisis response.

The VRE has also allowed both students and first responders to assume responsibility in a crisis scenario. Experience in leadership positions, and confronting the issues resulting from that chaos, is likely helpful for learners when they are eventually confronted with these responsibilities in real-life scenarios.[14,15] These virtual drills can be paused at any time by instructors, allowing them to comment or correct the actions of learners, and it can be repeated as many times as needed.

One feature which has been particularly beneficial is the capability to be a remote participant from anywhere in the world. This allows learners from disparate geographic locations to participate in training simultaneously on the same scenario. Briefings and de-briefings can also be held remotely, in addition to in real-life. Students have also commented on the benefits of the free role-play simulation aspect of this VRE. They feel that they benefit from an experience where anything can happen, as a result of many individual choices as opposed to standardized multiple-choice testing.

Limitations

Limitations of the simulation environment are most obvious in the need for infrastructure. The SecondLife software requires active internet connections to run for all participants in the VRE. In some low-resource settings, this may be difficult to overcome. Additionally, while participants can access the software for free, obtaining the land for use in disaster simulations is not. It requires a financial commitment from the trainers or institution which will run the simulations. Although it is possible to design and build most of the architecture and items used within the VRE, this can be time consuming and require significant technical expertise. Alternatively, many items/structures are available for purchase, though this requires further financial outlay. Additional limitations include the limit of 100 participants in the VRE at any one time.

As in all simulations, there is a limit to the realism of this VRE. Participants interact with the VRE through a mouse, keyboard, and microphone rather than their hands. While teaching can be undertaken on how to perform critical actions, participants lack the muscle memory of having done so themselves. They also may not get the adrenaline elevation which comes from responding in a true disaster. However, these limitations are present to some degree in many disaster simulations.

Conclusion

This manuscript presents a new VRE for the training and drilling of Disaster Medicine scenarios. It allows for an immersive, interactive experience without the extreme cost often associated with most large-scale drills. It has been employed for both active first responders and trainees, and offers a number of features which allow for customization of scenarios, including architecture, objects, and dummies.

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