Virtual Reality-Based CPR Training: Exploring its efficacy as a tool to raise awareness and an Alternative to Conventional Teaching Methods

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Abstract

There is a significant percentage of the general population in the UK who unfortunately do not possess the correct information and proper method of performing Cardiopulmonary Resuscitation (CPR). General awareness and knowledge about the said procedure can prove to be beneficial as it helps to save lives in an emergency.

With the use of Virtual Reality (VR) technologies, this project aims to find out if the application developed for the study can assist in improving the levels of awareness about CPR among participants, change their attitude towards taking action in an emergency for the better, and if the application can be used as a substitute or an alternative to other traditional forms of teaching and training.

The simulator for this study was developed using the Unity Game Engine and the HTC Vive Pro VR Headset. This application was then evaluated by several participants who were asked questions about CPR and VR in a “before” and “after” manner through a questionnaire and the results were collected and displayed using the Microsoft Forms website.

The results from the survey showed that the majority of participants preferred to use the VR-based application over traditional training tools such as Videos or Diagrams. The results also showed that the participants had an increased knowledge of CPR after testing the application alongside feeling confident to take charge in an emergency if regularly trained through similar applications in a gamified environment.

The conclusion derived based on the results of the study state that the use of VR applications such as the one used in this study can prove to be beneficial to raise awareness and potentially train medical trainees instead of training them through traditional methods.

Abbreviations, Symbols and Notation

AED	Automated External Defibrillator
CPR	Cardiopulmonary Resuscitation
DNA	Deoxyribonucleic Acid
HCI	Human-Computer Interaction
NHS	National Health Service
NPC	Non-Player Character
VR	Virtual Reality
WHO	World Health Organization
XR	Extended Reality

Chapter 1 Introduction

With the increasing number of technological advancements in almost every phase of life, it should not come as a surprise that the medical sector is also progressing tremendously daily. New inventions and discoveries are being presented in the medical sector that amazes the average person regularly. One such development in this sector is the utilisation of VR applications and techniques. This honours project aims to measure the effectiveness of these new and intriguing methods and see how they can be used as educational tools to raise awareness and advance the methods of training and teaching different life-saving medical procedures.

The idea for this project stemmed from the fact that basic awareness, knowledge, and a positive attitude about performing the correct procedure in an emergency are not widespread among the general population. This is an alarming fact, as emergencies which require people to resuscitate a casualty by the method of performing CPR can be prevented with regular training and timely testing. People can often ignore CPR's importance, not knowing that it can prove to be the difference between life and death.

The conventional method of training people about CPR methods can be a bit mundane as people might miss important factual information that might be given to them through a video or a diagram. A VR application was developed during this honours project to make the training methods engaging and alluring for the user. The following chapters explain and prove how VR techniques are being used to find an alternative to these traditional methods. The chapters go into detail about the design approach, the development process for the application and how the results were gathered for this study. The results are then extrapolated and discussed in the later sections. The last chapter in the study states the implications that can be derived from this study and the criticism and feedback from the participants. It also provides further ideas that can help develop the application further and how to implement them methodically.

The literature discussed in this dissertation provides several peer-reviewed pieces of literature that are evidence of the fact that people grasp concepts and retain

information better when taught through appealing means that are supported by audio and visual aids. The gamification of a procedure puts the user right in the centre of the scenario to deal with the situation at hand where they learn by performing the procedures instead of reading about it or watching a video for the same.

The methodology of this project aims to present the thought process of the researcher and the approach that was taken to develop an application and questionnaire for the same that can gauge the effectiveness of the simulator.

The methodology of this paper is divided into two parts. The first one goes into detail about the design approach used to build the application and the second part discusses how the questionnaire for the survey was framed to study the effectiveness of the application methodically.

The results section of this study is dedicated to present the data gathered from this research in an organised manner and intends to study whether a positive outcome was achieved from the developing and testing of the simulator built for the purposes discussed in Chapter 1. It employs the use of pie charts to represent the percentages and distribution of the answers given by the participants and also records the opinions of the participants about their attitudes towards training methods and CPR before and after testing the application.

Chapter 5 of the dissertation discusses the results and what the results mean. It evaluates the answers of the participants recorded during the duration of the study and how it relates to the existing literature presented in Chapter 2. The results gathered from the study reinforce and adds to the literature reviewed but also provide valuable insights on how to convey important technical information regarding life-saving procedures.

The final chapter of this paper concludes the study and evaluates the steps that went right and what other improvements can be made including further developing the existing work and improving results to deploy an application that brings a positive change in the medical sector. It also takes into account the suggestions provided by

the participants to make the application better and more engaging while being technically proficient.

The application and this study’s final purpose is to raise awareness about life-saving procedures, such as CPR, and introduce innovative and attractive teaching methods that can help transform the conventional teaching methods and create a more immersive environment for the trainees which can increase their knowledge retention ability.

Chapter 2 Literature Review

2.1 Attitudes toward CPR

2.1.1 Healthcare Professionals' Attitude Towards CPR.

Healthcare professionals, despite having a positive feeling towards performing CPR in case of a cardiac arrest, reportedly had feelings of stress and anxiety during real-life CPR scenarios. The need for a regular training method and procedure is important to maintain competence and reduce feelings of anxiety. The study conducted in this research article provides the results and statistics to understand that even well-trained healthcare professionals can feel nervous and anxious in the case of a real-life emergency. According to the article, 61% of healthcare professionals felt confident in their CPR knowledge. 86% of them knew what to do and almost 60% were reported to take command in a situation that demanded the proper CPR procedure (Silverplats *et al.*, 2022). However, almost 42% of them relayed feelings of nervousness and 26% of them were anxious. Since this honours project aims to spread awareness and make CPR training more accessible to the general population, it is important to be informed about the attitudes and perspectives of people not in the medical field. The study showed the statistics to be worse than the healthcare professionals' figures. The article states that the contrast in professions exhibited significant differences as other university-educated staff showed that only a few people from that group had confidence in their knowledge of the CPR procedure and more reported feelings of anxiety in the event of a cardiac arrest situation.

2.1.2 Importance of training to improve bystander response.

A well-structured and meticulous training program that teaches people the importance of CPR and provides them with essential knowledge on how to use a public access AED can be key in improving the belief and confidence of people witnessing a cardiac arrest emergency (Liaw *et al.*, 2020). To improve response timing, confidence, and the perception of people towards bystander CPR and using the AED, several factors are deemed to be important that should be instilled in the training program. These are as follows:

- Incorporating a positive attitude and enhancing the understanding of the public towards AED and CPR as well as alleviating any concerns or fears over the same.
- Encouraging positive societal expectations that prompt CPR and AED is called for if someone collapses.
- Reinforcing the idea that people can gain confidence in using an AED machine that is located within their reach and capability.

2.1.3 Value of acting quickly in an emergency

It is well known that promptness and quick thinking can prove to be the critical difference between a life and death situation. The objective of this honours project is to make CPR training readily accessible, so it can help the participants gain confidence and act instead of witnessing an emergency as a bystander. Training someone in the proper method of CPR can prepare them to act in a real-life emergency scenario. People may often overlook the need to train for basic first aid procedures, but this project is an attempt to employ VR technologies to spread the training methods to the general people in an attempt to make the proper procedure of CPR known to more and more people. The survey undertaken in this research article states that about 60% of the United Kingdom's public had undertaken some form of CPR education over the course of their lifetime (Hawkes *et al.*, 2019). However, only 17% - 27% of those trained within the past five years. An even unfortunate statistic states that less than 20% of people had trained in AED use. According to the article, CPR training yielded positive effects on participants' self-reported willingness to act if they met an out-of-hospital cardiac arrest. These articles and research papers prove that with proper training and correct procedures of CPR, lives can be saved by regular bystanders seeing a cardiac arrest in an emergency.

2.2 Games and Simulators as educational tools

While sounding similar, games and simulators have many key differences that make them distinct from one another (Sauvé *et al.*, 2007). While in a simulation, the activities done by the user are grounded in reality, simplified, and represented as close to reality as possible, a game generally consists of fictitious and artificial

elements. Games may be further away from the point of reality and may contain mechanics of competition and conflict within them with basically a scoring system where the objective is to win. However, a simulation by definition is an imitation of a procedure or a process in a real-life scenario that can never have the mechanics and elements of a video game. Despite their differences, games, and simulators can also have some similarities that cannot go unnoticed. For example, both applications are interactive forms of media that are controlled by a participant or a user. Both applications provide an engaging experience to the user that retains their attention. The line of difference between the two can get blurred quite easily to the general public but it is important to acknowledge the differences and similarities between both. The use of these applications as educational tools is in practice for decades.

2.2.1 Use of immersive applications

When the user of these applications is in a deep mental state of involvement with simulators or games, it is called immersion. It is reported that this can improve the learning process. Applications like these do a good job of facilitating factors that make them immersive. Such as: involving the user in a narrative, building a virtual application that resembles real life, or multisensory stimulants such as audio cues. Serious games and simulators that cannot be classified as “traditional games” are generally developed with a different objective in mind. These objectives are basically towards education, advertising, social, awareness, health, policies, etc. Numerous examples mentioned in this chapter of the book present a strong argument for using applications, such as simulators and games, to reach a learning objective (Carvalho, Coelho 2022).

- A treasure hunt game that was developed as an augmented reality application for primary school students. The evaluation by both students and teachers showed that the application has the potential to be used as a way to teach students about physics experiments as it allows them to manipulate virtual objects in a real-world space.
- League of emotions learners is a game app, designed for the development of the emotional intelligence of young people.

- The main focus of one of the VR applications was to increase knowledge and understanding of safety precautions. The application concentrated on the impact a seatbelt can have to save lives.

2.2.2 Advantages of Games as educational tools

Motivation acts as a key factor to learn anything. A motivated learner has a greater drive and a deeper desire to make a notable effort to gain knowledge about the subject matter (Llorens-Largo, Carmona, 2020). Some of the crucial elements that make a person feel motivated are:

- Learning by doing
- Interactivity
- Allowing and naturalizing errors
- Giving control to the learner

Simulators and games are being used in several ways to disseminate knowledge and information. These are namely:

- Games as teaching tools: A serious game with the objective of a mission to the moon was created with the use of VR technology. The game is designed as a serious VR game that immerses the player in activities of lunar exploration missions. To measure the levels of engagement, the players are provided with a game engagement questionnaire and an interview questionnaire. The participants were made to play both the normal and the VR version of the same game. The time taken by the user to finish the non-VR game was less but the longer it took for them to finish the VR version, the more it immersed them and motivated them to learn about lunar events.
- Games as learning objects: Games can be used as objects to study or research something. Games can be studied to notice aspects that are essential to them such as their interaction, usability, design, or the artificial intelligence of certain characters. Computer games can serve as good study material to study aspects of HCI.
- Games as a design philosophy: The design philosophy of games can be used to fit another disciple such as teaching methodologies. This process is called gamification, where the principles of video game design are applied

beyond the context of video games. The objective of gamification is to take advantage of the psychological tendency of people to participate in games and the quality of the game to motivate the participants.

2.2.3 The case for using games in education.

Simulations and games are changing the way the world learns rapidly. With the rise in recent technologies increasing day by day, the ways to learn and access information is becoming more and more convenient. Multiple reports from recognized healthcare institutes of the world such as WHO, the Organization for Economic Cooperation and Development, and the Commonwealth Fund have detailed gaps in healthcare quality and safety around the world. One of the 13 recommendations in their report was to change how medical education was delivered to the students (Yu So *et al.*, 2019). The use of VR technologies has helped to implement these significant changes. Information can be quickly dispersed through extended reality technologies with the help of web-based systems. These technologies can help bridge the gap between the trainer and the learner as they do not need to be physically present in the clinical areas to learn. The progress of the learner can be monitored, and feedback can be given virtually without the need for an in-person meeting.

2.3 Why VR is being used.

With the advancement of technology in all phases of life it should not come as a surprise that technological progress is quickly revolutionizing the field of education and training. Many research papers point to the fact that VR technologies provide several advantages to trainees and students. Providing students with an immersive virtual environment can increase their engagement with the subject matter. It increments knowledge retention and improves learning outcomes.

2.3.1 The Need for VR

To make the case for using VR techniques in place of traditional teaching methods, it has to be compared to the conventional teaching methods first. A VR application provides the user to be part of a virtual world which makes the experience for the

user more captivating than a normal video teaching them about a certain topic. The use of a VR device isolates the user from the real world which does not make them lose focus as all the other external factors of the environment around them and is blocked out in the virtual environment. Another advantage of using an application designed with the use of VR technology is that it can be utilized to train people for jobs that carry safety concerns and where the training can have irreversible real-life consequences (Hussein, Nätterdal 2015).

2.3.2 The Applications of VR in a medical environment

Research has shown that activities that require a good amount of visualization and imagination can benefit considerably if VR technologies are used. Especially in the medical field, trainees need to practice complex activities such as anatomical learning or manipulation and movement of strands of DNA (Hamilton *et al.*, 2020). The training for topics like this, if done through immersive means properly and procedurally can produce better learning outcomes if taught to people through conventional tests or traditional methods of training and testing. Other immersive experiences that are not particularly games or simulators, but VR videos also yielded better results than those who watched no immersive videos about the same topic. Even though immersive technologies, such as VR, are being used in scientific and cognitive fields; it is also reported that most popular sectors of work demonstrated improvements in learning outcomes if taught using immersive technologies instead of using conventional methods.

2.3.3 Positive Outcomes of VR Training

This honours project aims to find out if the training for performing CPR can be taught through a VR device and if so, can it prove to be better than the normal training methods? To test this a similar study was conducted to train prospective kindergarten teachers to gauge their learning outcomes, attitudes, and self-efficacy (Liu *et al.,* 2022). The candidates were randomly divided into 2 groups of an equal number. One group was given the training through an immersive VR application while the other group was taught through conventional video-based training. After the results of the study, it was concluded that the group which received immersive VR training demonstrated considerably more self-efficacy for performing CPR and more positive

attitudes towards CPR than the other group. Also, the group trained through the VR method showed significantly better knowledge of CPR than the other group.

Chapter 3 Methodology

The idea to pursue this honours project originated from a simple plan of using extended reality tools to aid in training people and for educational purposes. As the previous chapter highlighted, the use of these technologies has proven to be a helper in the educational sector rather than a hindrance. The perception of games as a mode of entertainment is changing with new technological advancements every day. Using these games as a medium of delivering crucial information helps the player to retain important information which can be used in real-life to contribute positively to society. To reach the objective of this honours project, a simulation application was developed in the Unity game engine with the help of the HTC Vive Pro to integrate the functionality of VR.

3.1 Design Methodology

The plan for this project was first conceived when the project proposal was turned in. There was a sense of ambiguity to choose between an Agile Incremental Development approach or the Waterfall Development approach. As mentioned before, there was a structure for the process already in place for building the application. Although the hardware tools were new to work with, the game engine and version control for keeping track of the features and bugs were familiar. This gave way to choosing the Waterfall development approach for building the application. The Waterfall methodology is a serial-building process that flows through all phases of a project, with each phase completely wrapping up before the next phase begins (Adobe Communications Team, 2022).

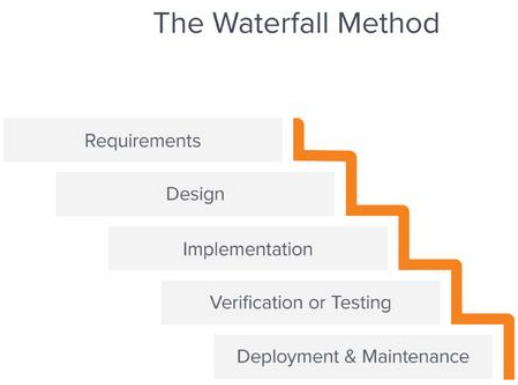

Figure 1: Waterfall Methodology Diagram

With this design pattern in mind, the first phase of developing the application was to recognise the requirements and demands of the simulator. The key requirement for building a working application is to specify what tools are to be used that will assist the developer in the development process. These were :

3.1.1 The Requirements

Unity Game Engine

The game engine used to build the application is the Unity game engine. This engine was chosen because it provides plenty of features and adaptability for technologies and plugins. The VR hardware used for the application is the HTC Vive. The game engine proved to be a good choice for the hardware as it comfortably provided at least two ways to interact with the controllers and the headset. The two avenues to start developing the application in harmony with the VR hardware and the game engine were the XR interaction Toolkit and the SteamVR plugin.

XR Interaction Toolkit

The XR Interaction Toolkit is a package developed by Unity Technologies specifically for developing extended reality applications (Unity Technologies, 2023). This package provided a lot of components that support interaction tasks. The fundamental of this package is a combination of a base interactor and an Interaction manager. The same package also contains elements that help in locomotion and drawing visuals. The package also provided several different scripts and physics-based interaction components that helped in simulating a real-world scene in a virtual world. To speed up the process of development even if the proper hardware is not available immediately, the package provided the developer with the feature of adding an XR Device Simulator to test the application in the editor’s play mode without the need for the headset and the corresponding controllers.

SteamVR plugin

The other option that could have been used in the development of this application is the SteamVR plugin developed by the Valve Corporation (Valve Corporation, 2023). The plugin is quite similar to the above-mentioned XR interaction Toolkit

package as it provided a lot of features and functionality that could have been utilised in the same way as the XR Interaction Toolkit.

The choice to pick one over the other was a tough one but finally, the XR Interaction toolkit was chosen. This was because of two main reasons:

- The Toolkit package provides cross-platform support when the final application is deployed. The Steam VR plugin can only publish applications that run through the Steam VR system. Since the aim of the application is to reach a wide audience to increase awareness about CPR, it was required to use a method that could provide access to every platform and not just platforms that use SteamVR.
- The XR Interaction Toolkit while providing a lot of their scripts does not limit the user to just using their libraries or code. This gives the developer the freedom to expand and build on the existing package whereas using the SteamVR plugin lets you work within the bounds of the libraries and scripts provided by them.

GitHub

The utilisation of GitHub was also important to monitor the bugs that occurred during the development of the application and if something went wrong, it provided the developer with the feature of reverting the changes that helps in increasing the efficiency of the development process.

HTC Vive

The VR Hardware to develop the application is the HTC Vive (Wikimedia Foundation, Inc., 2023). There were a lot of other headsets to choose from but some of the reasons why this particular equipment was chosen are as follows:

- Room-Scale VR: Several headsets support room-scale VR but the Vive was the first one to offer this functionality. The lighthouse base stations provided with the Vive provide the developer with precise and accurate tracking for both the headset and the controllers. It also provides the user to set up the play area as a small room or a big room and depending on the user's selection, it adjusts itself to provide the user with the best tracking possible.
- High-Resolution Display: A resolution of 2800 x 1600 pixels provides the user with a high-quality display screen with a refresh rate of 90 Hz which immerses

the user fully into the virtual environment. This helps in reducing motion blur and the screen-door effect.

Figure 2: Example of a screen-door effect where the lines separating the pixels become visible on closer inspection (Wikimedia Foundation, Inc, 2006)

- Wide Field of View: The Vive headset has a field of view of 110 degrees. This is wider than many other of its counterparts. This engages the user more by letting them see more of the virtual environment around them. This helps to reduce motion sickness and other discomforts that someone might encounter while or after using the application.
- Platform Compatibility: Unlike some VR devices, the HTC Vive is not bound by a specific ecosystem. This gives both the user and the developer more flexibility to choose when selecting the VR content.

3.1.2 Designing the Application

After assembling the required components for developing the application, the next step of the development approach used in building the application was the designing of the simulator. To design this application, it was first required to understand the task at a fundamental level. The aim was to create a simulator that taught people the correct ways of performing CPR in an emergency. To do this the steps of CPR were first recognised and then turned into a gamified version that utilised the head movement and controller inputs from the player. According to the NHS website, there are 5 steps that a person should follow to administer CPR to a casualty (National Health Service (NHS), 2022). Taking these steps into consideration, the simulation was designed around that. This method of completing tasks to reach the end of the simulation was similar to the game Among Us where players had to complete their

tasks to achieve victory. Each step in the correct procedure was made into a task that the player had to complete to start the next one. This helped to give structure to the application. To keep track of the completed tasks, a checklist was also designed which the player could refer to for the indication of the next tasks to perform. The flow of the simulator was designed to convey the important technical aspects of the procedure of CPR through auditory and visual cues as well as make them comfortable should they encounter a real-life emergency by training them in the correct procedure of CPR.

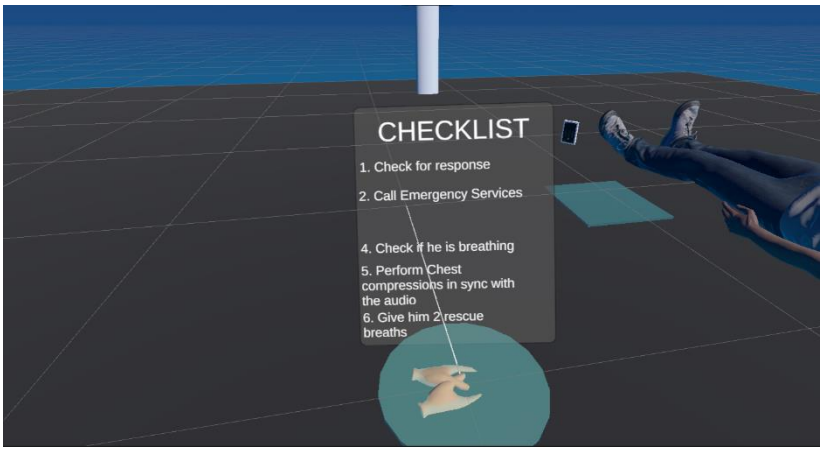

Figure 3: The checklist of tasks in development to control the flow of the steps

3.1.3 Implementing the Design

After the design of the simulator was outlined, the subsequent step was to start implementing the mechanics of each step to make the game loop. As discussed before in the requirements section, the XR Interaction Toolkit was utilised in the development of the project. The toolkit package provided important assets, scripts, and prefabs that were extremely useful for the player's basic movement and interactive actions in the virtual world. The most essential component provided by the toolkit for movement and tracking is the XR Origin.

XR Origin as the player character

The XR origin is a GameObject that represents the starting point for the player in the centre of the worldspace in a virtual scene. It transforms objects and other features to their intended position, orientation, and scale in the scene. The XR Origin is responsible for specifying a camera, a camera floor offset, and an origin for the player (Unity Technologies, 2022).

Figure 4: The arrows for the axes show the placement of the XROrigin in the scene.

Tracked Pose Driver

After adding an XROrigin GameObject to the scene, there needs to be a way to track the position and rotation data from the HTC Vive applied to the camera that is in the XR Origin GameObject. The Tracked Pose Driver script provides the necessary functionality to tackle this issue. It reads the position and rotation input of a tracked device which it communicates to the XROrigin GameObject.

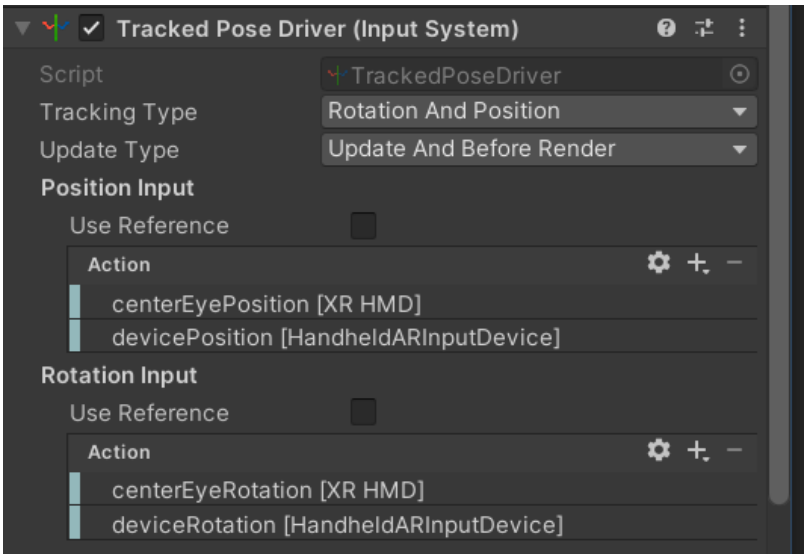

Figure 5: The tracked pose driver component on the XROrigin

Input Action Manager

The Input Action Manager is another component attached to the XROrigin that automatically enables or disables all inputs of type InputAction. The actions are

disabled at the start, which means that they do not react to the input. They only start doing this when the class in this script is used to mass enable actions so that they actively respond to the input by the user (Unity Technologies, 2022).

Locomotion System

This component is attached to the XROrigin GameObject which acts as the medium to provide access to locomotion for the XROrigin (Unity Technologies, 2021). After the locomotion system gets attached to the XROrigin, it has a variety of locomotion providers to choose from. These are Teleportation Provider, Snap turn provider, Continuous turn provider and Continuous move provider. For the aim of this project, the Teleportation Provider was utilised. The Teleportation Provider component lets the XROrigin GameObject transport through the world space by moving to a space on a plane at which the player points.

Character Controller Driver

The other important component essential to the application is the Character Controller Driver (Unity Technologies, 2022). This component is used to control the height of the XROrigin GameObject that acts as the player's character inside the virtual scene. This component is an important part of the development of the application as the user is required to crouch down and stand back up several times while playing the simulation.

Ray Interaction

For controlling where the character of the player is going to move, a teleportation ray is set up to assist the player in seeing where they are aiming. The script XR Ray Interactor (Unity Technologies, 2022) lets the user turn a game object into an interactor that can interact with objects that the user points at. The uses of the GameObject after attaching this component to it can range from being able to teleport, interact with objects at a distance and Interact with UI elements in the worldspace. The component of the interaction layer mask helps to distinguish between different GameObjects in the virtual world.

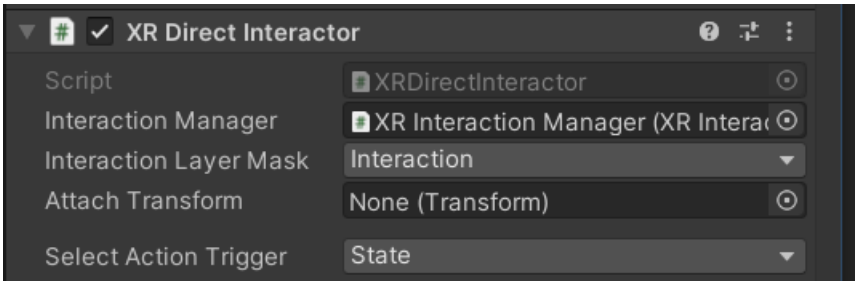

Figure 6: This figure shows the interaction layer is set to a custom interaction layer which means it can only interact with objects corresponding to the layer

If the layer of both the ray and the object is the same, then the ray can interact with the object, otherwise, it will not be visible coming out of the hand models of the player.

Hand Animation Input

To animate the input given by the player on the controller, a script called "HandAnimationInput.cs" was made which defines an input action property. This component is a property type that can reference an action externally defined in an InputActionAsset (Unity Technologies, 2021).

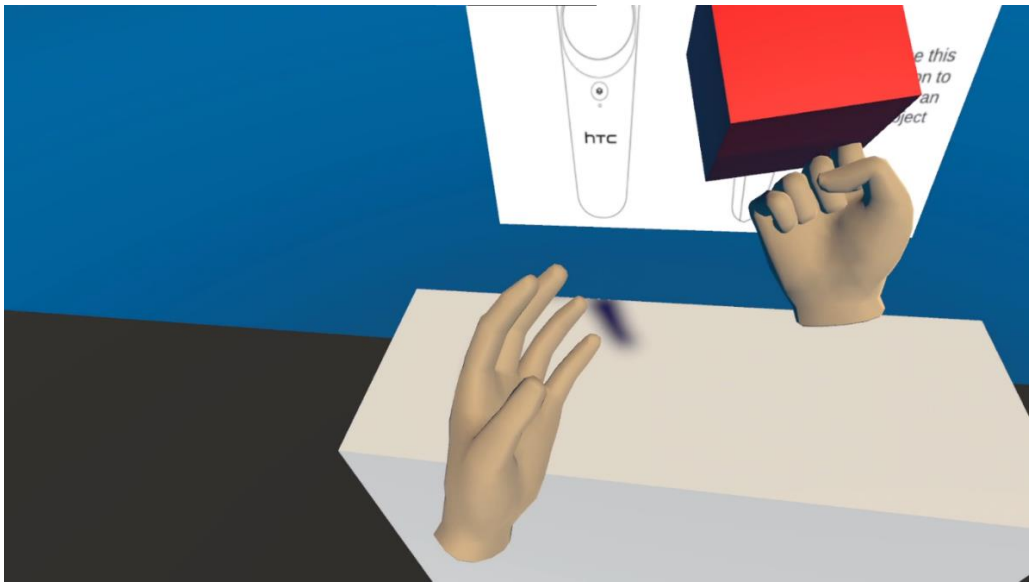

Figure 7: The Input from the controllers animates the hands when the user interacts with them

A reference can be used to the externally defined action asset provided by the XR Interaction Toolkit which can animate the hands of the player by reading the value of the button pressed on the controller. When the button is pressed, the float value becomes greater than 0 and the animation happens and stays there until the button is released. When the button is released, the hand goes back to its initial state at the beginning of the animation as the float value turns to 0.

Activate Teleportation Ray

Since the rays for both interacting with the UI and Teleportation are attached to the hands, it was essential for them to be only activated when an action was performed by the controller. To solve this problem, this script was written: “ActivateTeleportationRay.cs.” The script only ever lets the teleportation ray display for the user when the user squeezes the trigger on the right-hand controller. The way that the input is recognised is whenever the trigger is squeezed, the value of the InputActionProperty becomes greater than 1 (Unity Technologies, 2021). Whenever this happens, the ray appears and can be used by the user to teleport.

After the locomotion and interaction mechanic is set up, the next step is to implement the steps of CPR through a gamified way that employs the use of the headset, controllers and the positioning and movement of the player in the physical world. The different steps were implemented as follows:

Step 1: Checking for a response from the casualty

Long Button Click

The first step when you see a person unconscious in front of you is to call for them and see if they respond to you. The way to achieve this was to play an audio clip at the press of a button. However, just pressing a button would not feel correct as shouting or calling for someone does not happen in an instant like the press of a button. To make it feel more realistic, the mechanism of pressing down the button in world space and holding it till the button was filled up with a blue colour was implemented. This gave the feeling of time passing by like in the real world and not everything happening in an instant. To implement the long click for the button, the normal feature of a button was removed from the UI button that the Unity game engine provides. Instead, a new script was made called “LongClickButton.cs.” The script has a Boolean called “onPointerDown” that recognizes if the interactable ray has been pressed or not. The next step was to define two floats. One was called “pointerDownTimer” and the other one was called “requiredHoldtime.” As the names suggest, the former was used to store the time for how long the button was being held down and the latter was to be set by the developer which required the user to hold down the button as long as the developer pleases. After that, a Unity event was defined called “onLongClick.” This event was responsible for triggering an event after

the button was pressed. Then an image component was defined in the script which took an image and filled it according to the condition of the Boolean defined before in the script.

Figure 8: Button being filled with the blue image component after clicking and holding the trigger

Whenever the time between clicking the button and holding the pointer down was equal to the required hold time, the button would invoke the events in the variable of the unity event, otherwise, the button would reset by turning the Boolean false and letting the user start again until they got it right. After the interaction with the button a pre-recorded audio clip plays which tells the user that the action is complete.

UI Interaction with Buttons

To recognize inputs in a VR space, the canvas on which the buttons are put in the worldspace. But doing that was not enough. There needed to be a way so that the UI interactable ray could identify the buttons and whenever a player hovered their left controller in its direction, the ray would display itself and be able to click the button. This was done by changing the graphic raycaster on the canvas to the tracked device graphic raycaster (Unity technologies, 2020). The tracked device graphic raycaster is a custom implementation of the graphic raycaster by Unity specifically for the XR Interaction Toolkit. This behaviour is used to ray cast against a canvas. The Raycaster looks at all Graphics on the canvas and determines if any of them have been hit by a ray from a tracked device. This enabled UI interaction in a VR

environment with the help of rays. The above-mentioned two methods helped to create the response mechanic required for the first step of the CPR process.

XR Interaction Manager

The XR Interaction Manager component acts as a medium between the interactor and interactable objects in a VR scene. The methods defined in the components of both the interactable and interactors are scripted in such a way, that they are designed to be called by this interaction manager rather than being called directly to maintain consistency between both targets of an interaction event (Unity Technologies, 2022).

Step 2: Calling emergency services

The next step in the CPR procedure is to call for emergency services. To Implement this mechanism, a mobile phone model was made using cubes and a similar button with similar functionality was attached to the mobile phone's game object and positioned in a way that the user can pick it up with their right hand and interact with the button using the left hand. This brings up the topic of picking things up with the hand controllers. The mobile phone's game object had to have certain components attached to it for it to work as an object that could resemble a mobile phone in real life. The component that is attached to a GameObject to make it grabbable and make it resemble real life is the XR Grab Interactable. This component integrates with the XR Interaction Manager, and this allows the object to become an "interactable object." The object can then attach to a selecting interactor and follow it around while obeying physical laws (Unity Technologies, 2022). In the case of the application, the mobile phone acts as an interactable object and the character's hands are the interactors. After picking up the phone with any one of the virtual hands, the player can then press and hold the button which prompts them to call the emergency services.

Figure 9: The mobile phone being used with both types of interactions with the hands

The button then plays an audio clip that resembles the dialling tone of the number of the emergency services which is 999.

Step 3: Tilting the casualty's head to clear the airway

After calling the emergency services, the next step recommended by the NHS to perform is to tilt back the head of the unconscious person by placing a hand on their chin and pushing it back to clear the airway. This is done to check if they are breathing or not. To carry out this step in a virtual manner, the model being used in the scene had to be animated after an action was performed.

Figure 10: This figure shows that the participant can put their hand on the chin of the model to trigger an animation which tilts the head of the model

Initially, a script was made called “AnimateAirway.cs.” This script was responsible for changing the Boolean of the animator component to turn to true if the hand of the player collided with a box collider placed at the end of the chin. After the hand collided with the collider, the animation would play which tilted the head of the model back making it seem like the player had tilted back the head of the casualty in front of them.

Step 4: Checking if the casualty is breathing or not

After the airway of the victim is cleared, the responder (the player in this case) has to bring their ear near the victim’s face to hear for 10 seconds if the unconscious person is breathing or not. The way to implement this step was to start a countdown timer as soon as the head of the player (the main camera in the scene) got near the face of the model in the scene.

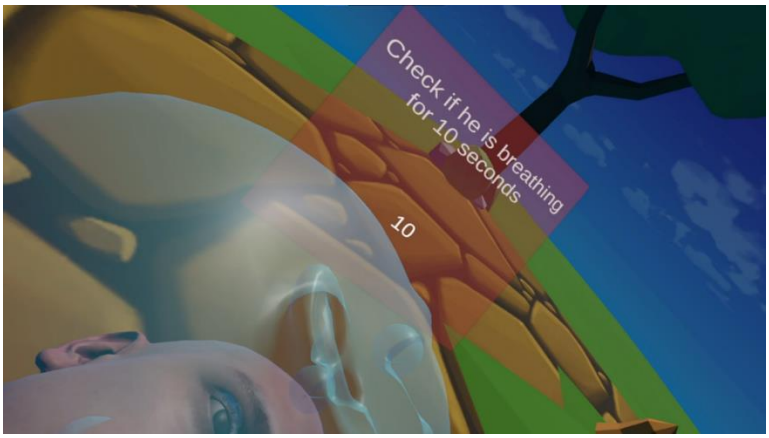

Figure 11: The participants put their heads on the hologram indicator to perform this step.

A box collider was placed near the face of the model that started the timer anytime the camera collided with the box collider. If at any point, the camera was moved out of contact with the collider, the timer would reset, and it would start again.

Step 5: Performing Chest Compressions

The subsequent step in the application after checking the breathing of the victim is to start chest compressions if no breathing sound is heard or felt.

Two separate components of this step are implemented in the application. These are the number of compressions and the speed by which the compressions are performed.

Number of valid compressions

Chest compression is valid if the depth of the compression is between 5 cm – 6 cm. To register the number of correct compressions, a box collider was placed in the centre of the chest of the model representing the victim at the correct depth inside the chest. A correct compression would only count if the hand exited the collider.

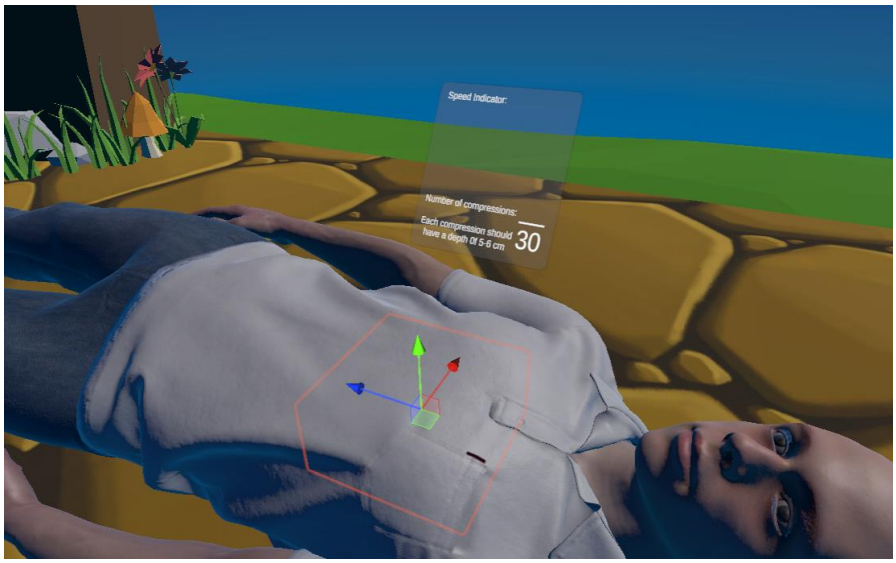

Figure 12: The placement of the Beats per Minute object that records the data for the number of compressions and the speed of compressions

Since the minimum number of compressions to be administered is 30, the count increased after each time the hand exited the collider.

Speed of compressions

The recommended speed of chest compressions to be performed on a victim according to the NHS website is 100-120 beats per minute. Since it is hard for someone to remember the correct speed, it was important for the application to indicate the correct tempo through an auditory cue. After the hands of the player collide with the box collider placed in the middle of the chest of the model, an audio clip with a speed of 100 beats per minute starts to play. This assists the player by letting them know the correct speed. To measure and display if the player is following the rhythm or not, a condition checking the time intervals between each compression was set up. Since the correct speed chosen is 100 beats per minute, the time interval between each compression is 0.6 seconds. If the player's compressions' time interval is close to that, then the application displayed the message that the speed is optimal. If the time interval went below the 0.6-second mark, the speed was too fast. If it was over, then it was too slow. Based on these conditions, the messages and colours

displayed on the canvas in front of the player would change and indicate the progress to the player.

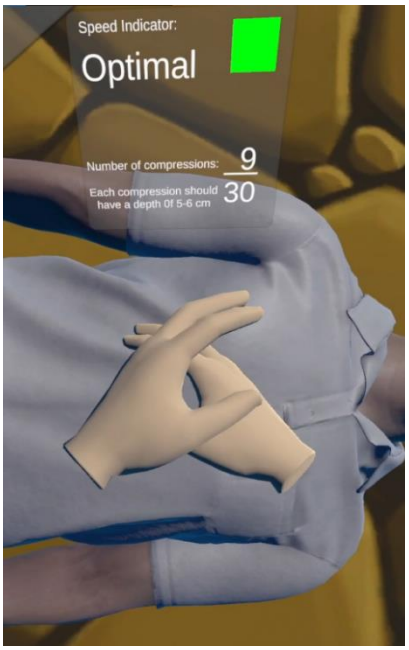

Figure 14: The canvas displays a green colour when the speed is correct

Figure 15: The canvas displays a red colour if the user is too slow

Figure 13: This canvas displays a yellow colour when the user needs to increase their speed

Step 6: Giving 2 rescue breaths

The step of giving 2 rescue breaths was implemented by making 2 buttons. The same principle of pressing and holding the button down was used here. This choice was made because a rescue breath needs to be 1 second long and since the button's press and hold time could be set through the inspector; it was set to 1 second which took the player to hold down the button for a second each two times to give exactly 2 rescue breaths after performing the compressions.

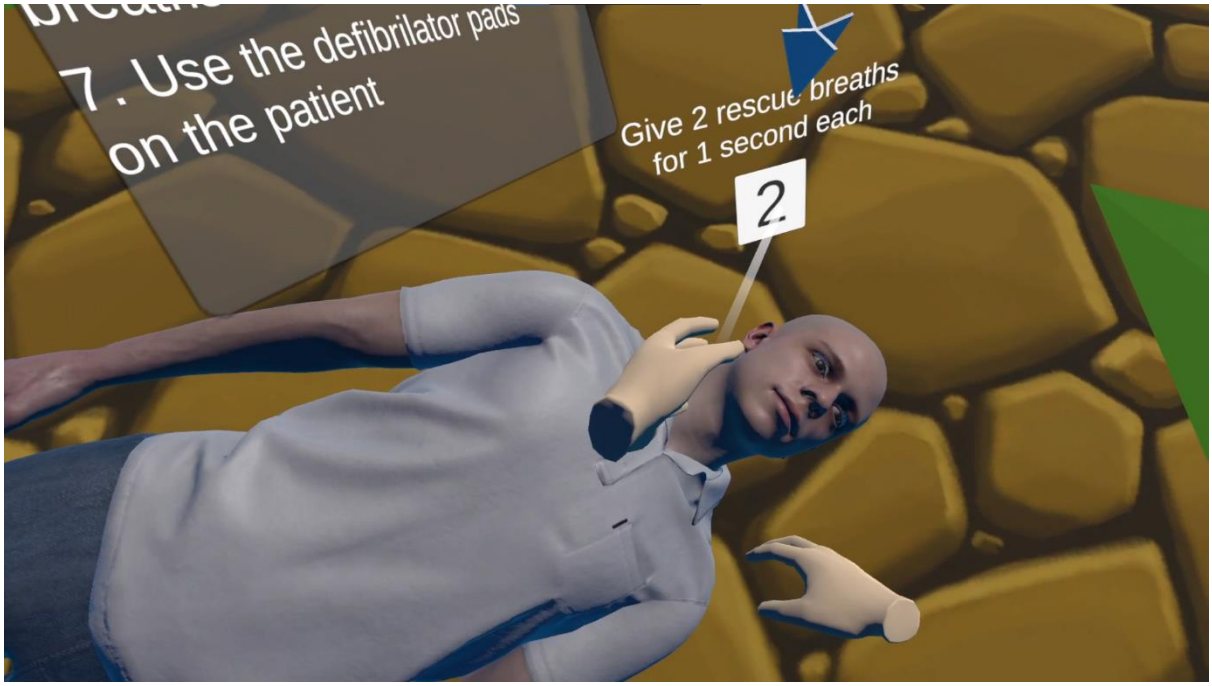

Figure 16: The users could interact with the buttons through the interacting ray on the left hand

After each button press a breath exhale audio clip was played to represent the completion of the step.

Step 7: Using Defibrillator pads

Using the defibrillator pads is an important step after giving the rescue breaths. This step is used if the victim is not revived after the performance of the previous steps. Even though this step is important it should be noted that sometimes this step might not be needed to be performed by the average bystander. This is because when the emergency services are called; they usually arrive at the scene of the emergency in the meantime and use the defibrillator pads by themselves. However, a step was added in the application which makes use of the XR Socket Interactor (Unity Technologies, 2022). This component can be attached to a GameObject to make it an interactor that can be used to hold an interactable object. It also provides the user with an option to make events happen once the desired object is placed in the socket. This feature was used to display the contents of an AED when placed in a socket interactor.

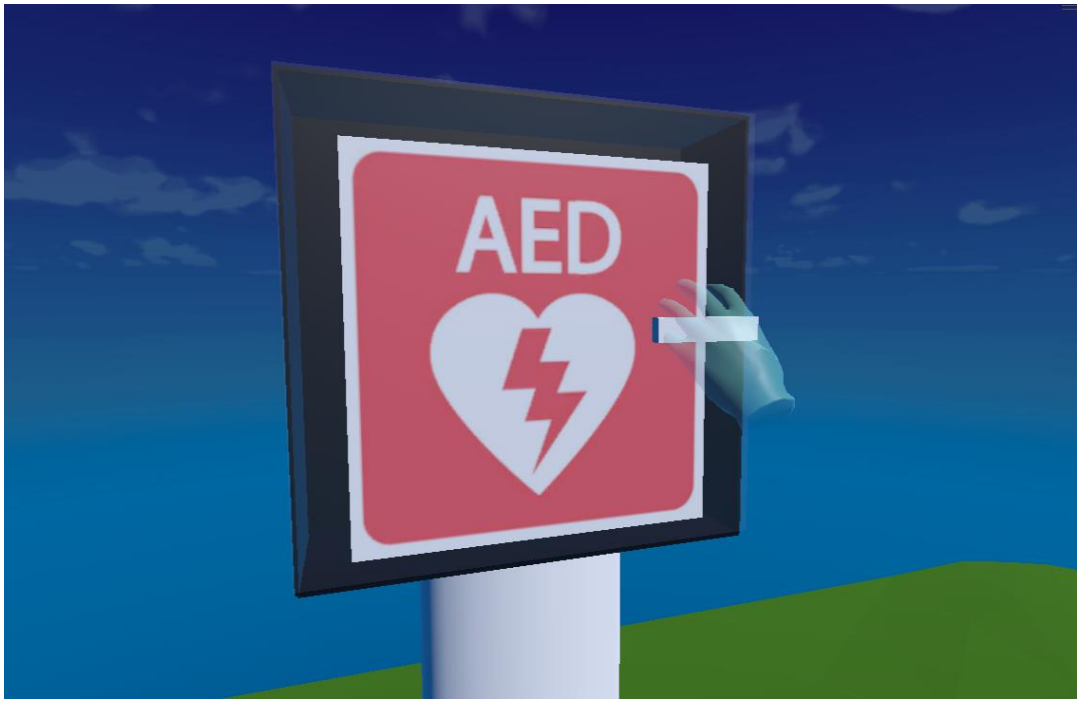

Figure 17: The AED machine that the player has to take out of the cabinet to place in the socket interactor

Once placed in the socket, the contents of the AED are displayed which are the defib pads represented by a green and yellow colour.

Figure 18: The defibrillator pads represented by green and yellow colours can get attached to the model's body using the XR Socket Interactors

Since the placement of these defibrillator pads on the body of the model is important, the same principle of attaching things to sockets is used to attach the now visible defibrillator pads onto the model's body. This concludes the steps of the application and after that, the player can exit the simulation completing the game loop.

Arrow Pointers for indicating the next steps

To make navigating through the steps easy, arrow pointers were also implemented in the application to let the players know their next step or destination in the simulator. Instead of just static arrows pointing at something, they were animated by rotating them and moving them up and down on their Y-axis. The rotation was done by using the Rotate function which can rotate the GameObject it is applied on depending on the axis wanted by the developer.

Figure 19: This is the model of the arrow used as a pointer to the next step in the procedure

The up-and-down movement was done by letting the GameObject follow the pattern of a sin wave but only in the Y-axis which makes it seem like the object is moving up and down instead of oscillating in a waveform.

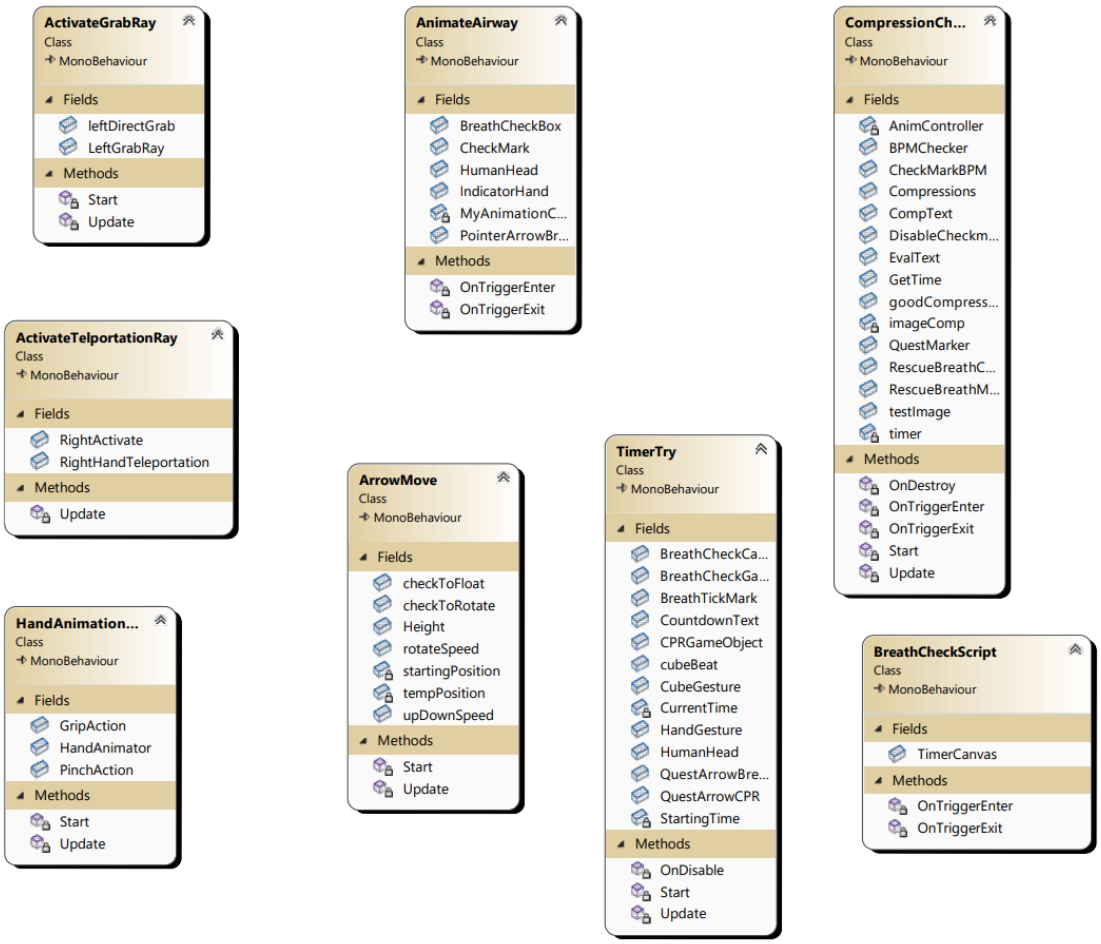

Figure 20: Class Diagram for the application representing all the major scripts as classes in a diagram

3.2 Designing the Questionnaire for the Survey

To gather the results of the study, a survey was made using the Microsoft Forms website. The survey was divided into two parts. This method was employed to study the effects of the application on the participants in an organised manner. The survey was split between a “before” and “after” section. Since studying relevant literature provided an idea about the knowledge and awareness levels of CPR training among the general population, it was essential to gauge the same about the participants.

Chapter 4 Results

The next part of the waterfall development methodology as discussed in Chapter 3, was the testing of the application. The whole testing process required the participants to play the simulator and answer a questionnaire which was part of a survey. The results gathered from the survey were recorded automatically by the Microsoft Forms website. The data recorded from it was converted into pie charts to convey the information about the application easily and in a methodical process.

The first question asked to the participants was what they will do in an emergency if someone collapses in front of them and 59% of them answered that they would know what to do but hesitate to act. 33% of them would be confident and take charge in a situation like that.

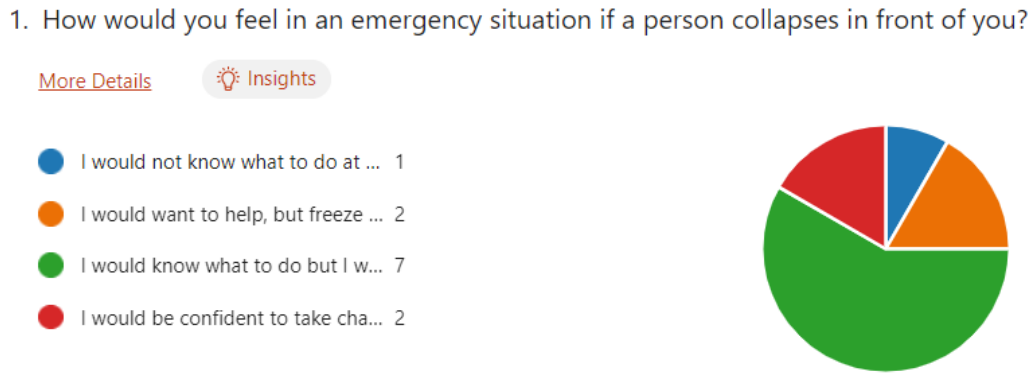

Figure 21: Information about the attitudes of the people in an emergency before testing the application represented in a pie chart

The next question asked them was if they had ever been in an emergency before where they had to act quickly or perform CPR. The figure shows that 92% of them never encountered an emergency before whereas 1 person had been in a situation like that.

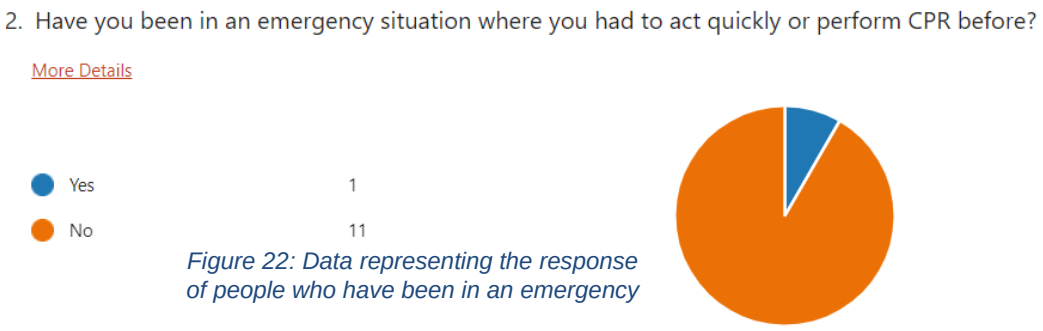

Figure 22: Data representing the response of people who have been in an emergency

The person that had been in an emergency stated that they are a nurse by profession and while they have not performed CPR by themselves, they have been in several cardiac arrest situations.

The following two questions asked the participants about their CPR training:

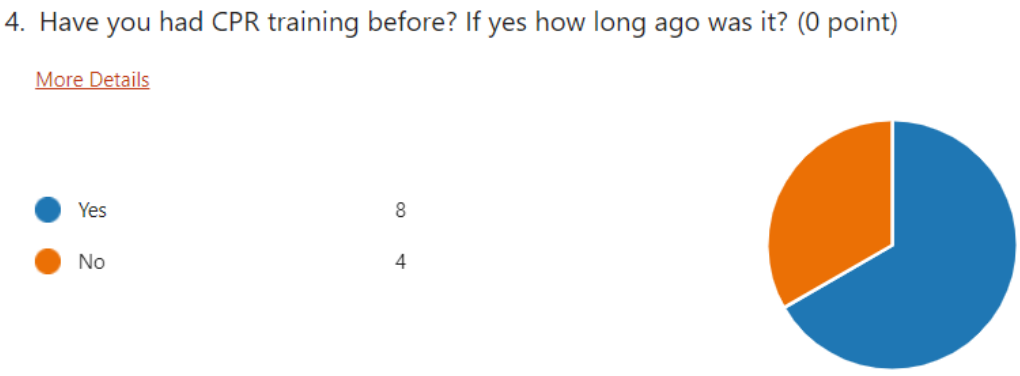

Figure 23: Representation of participants who have had CPR training before

As the data shows, 67% of the participants have had CPR training. 88% of the people who answered yes had CPR training over a year ago and the other 12% had training 4 – 6 months ago.

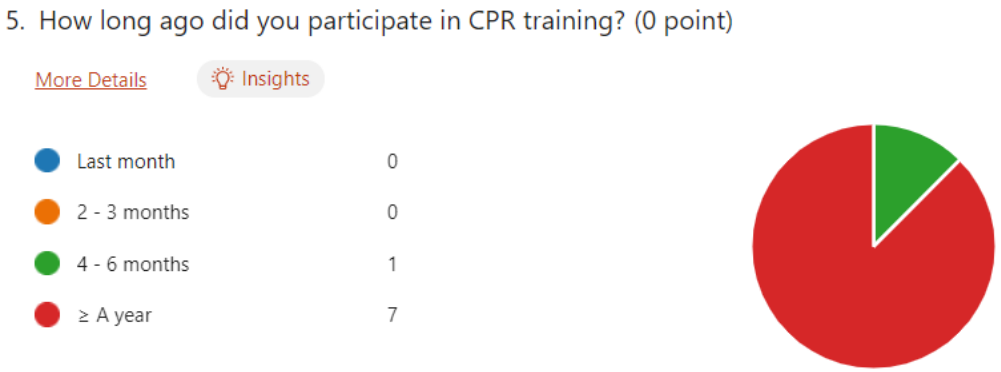

Figure 24: Pie chart stating the time period of the last time the participants took part in CPR training

The previously presented data belonged to the “before” section of the survey to understand the general awareness and attitudes toward performing CPR and CPR training. The following questions were asked by the participants after they tested the application. This section contained questions about CPR procedures, VR, and their attitudes in emergencies. The answers regarding the CPR methods were as follows:

Everyone answered the question regarding the number of chest compressions correctly.

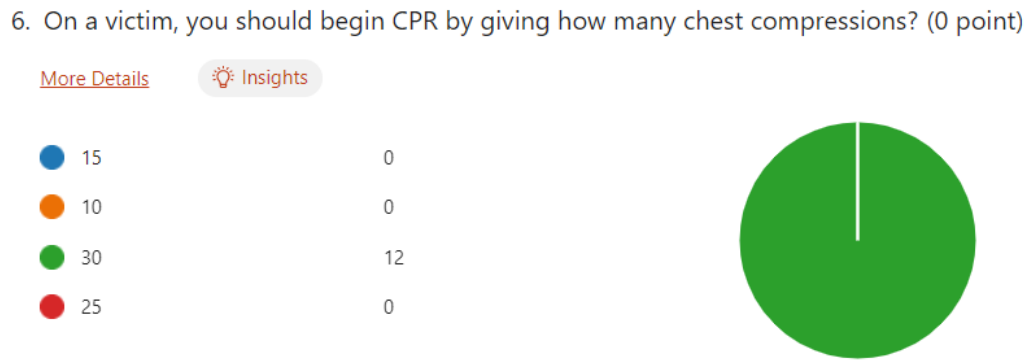

Figure 25: This figure shows the response rate for question number 6

The result was the same for the next question which asked them about the number of rescue breaths to be given after the chest compressions.

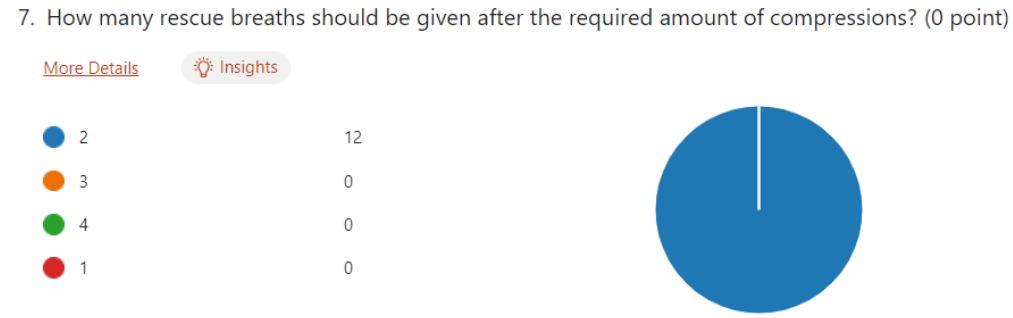

Figure 26: Response rate for the question about the number of rescue breaths

The next question asked them about the duration of each rescue breath which was answered correctly by the majority of the participants.

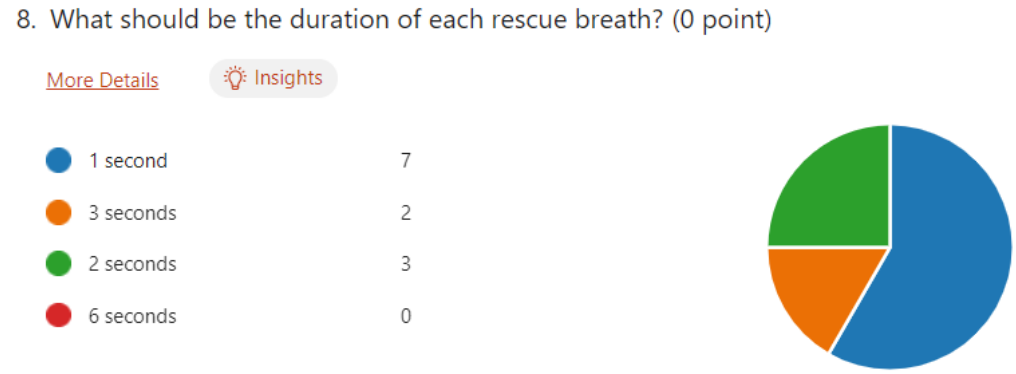

Figure 27: Response distribution for question number 8

The subsequent question asked them about the maximum time someone should spend to check if the victim is breathing or not. It was answered correctly by 75% of the participants.

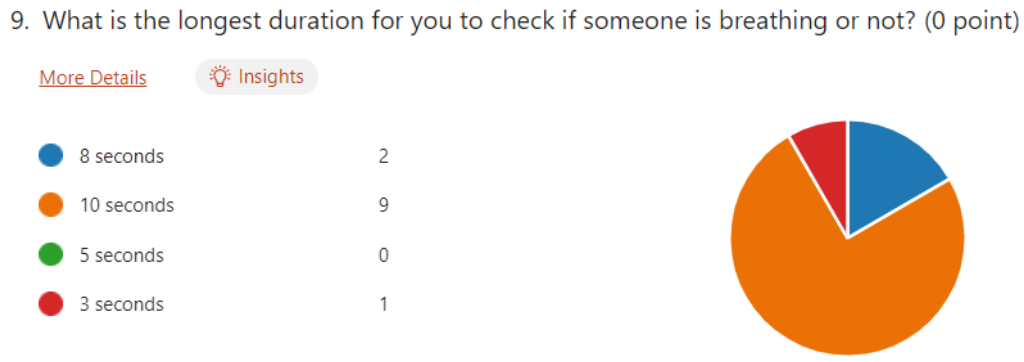

Figure 28: Pie chart depicting the responses for question number 9

83% of the participants answered correctly when asked about how to open the airway of a victim.

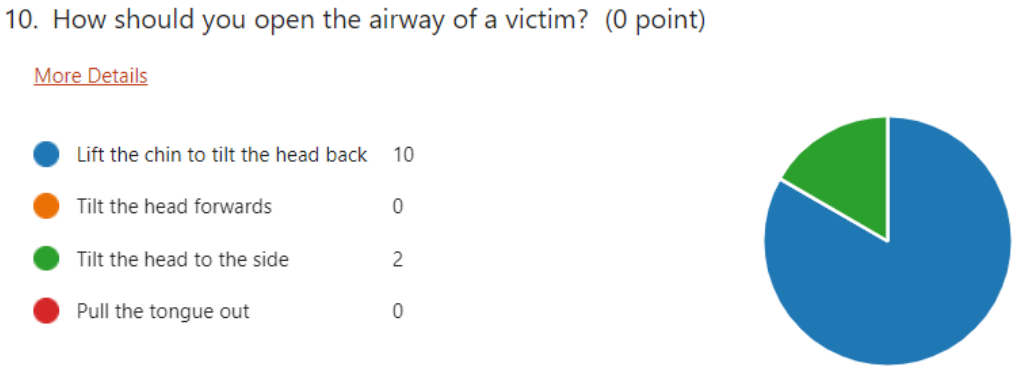

Figure 29: Response distribution for question number 10

The response to the question regarding the type of heart problem in which CPR should be performed was answered correctly by 100% of the participants.

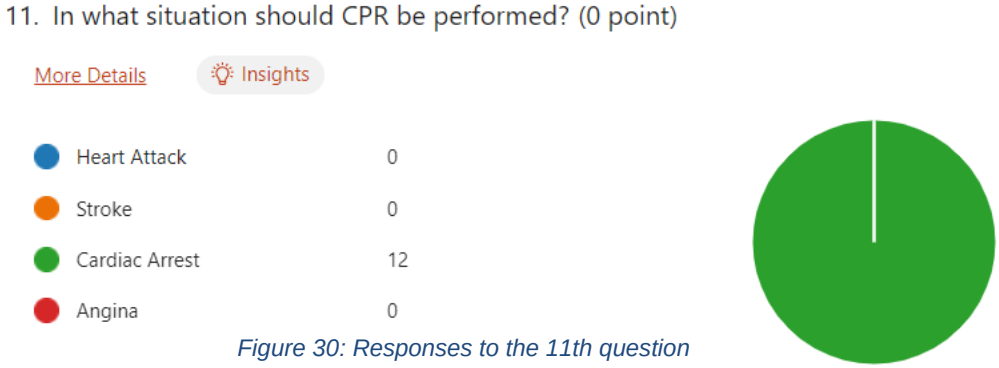

Figure 30: Responses to the 11th question

It was a similar case to the previous one when asked about how to check for a response from a victim.

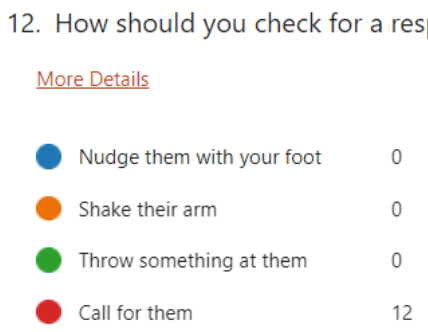

Figure 31: Pie chart format of the responses to the 12th question

75% of participants answered the question about the speed of the chest compressions correctly.

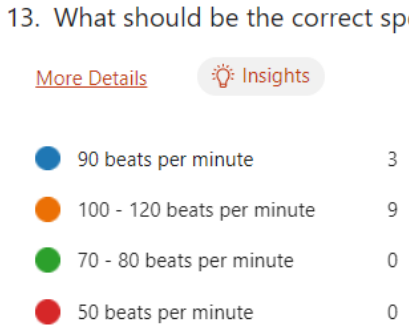

Figure 32: Answers regarding the speed of compressions

The correct answer percentage to the question about the correct depth of compressions was not favourable.

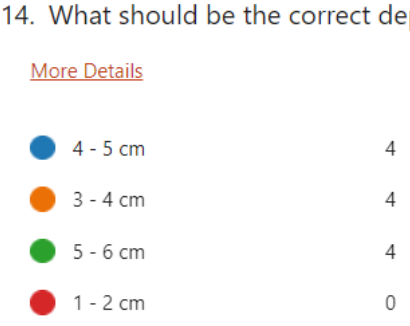

Figure 33: Results of the 14th question

After responding to the questions regarding the CPR methods, the participants were asked about their attitudes towards emergencies and CPR. The data is as follows: When participants were asked about their ability to act after using the application in an emergency if faced with one, 58% of them responded positively 25% of them strongly agreed that they will be able to take charge.

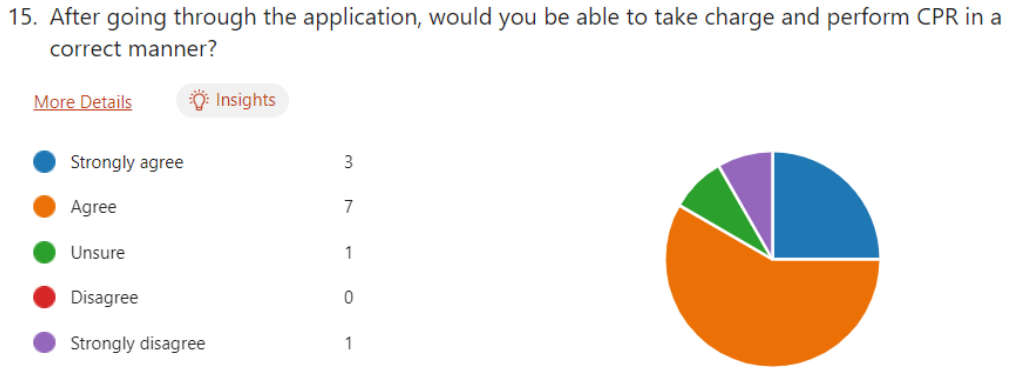

Figure 34:Responses recorded for the 15th question

83% of the participants preferred the use of VR tools over traditional training methods.

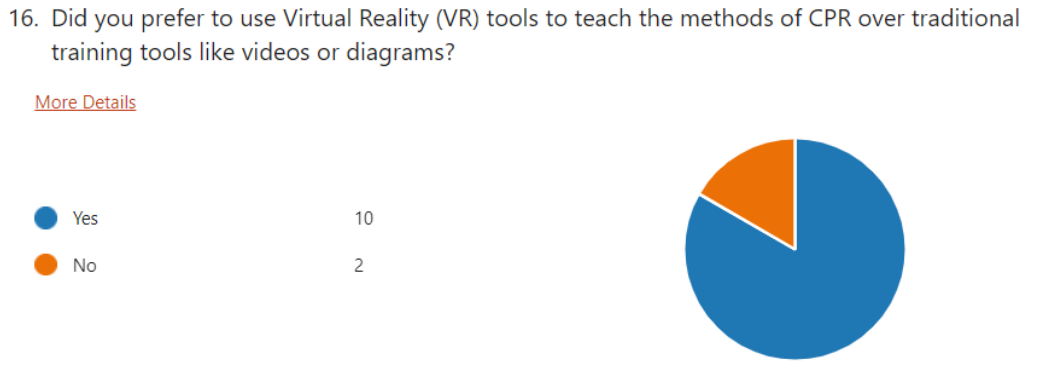

Figure 35: Responses for the question asking the participants about their opinion on Virtual Reality teaching methods

100% of people who took part in the study agreed that their knowledge about the CPR procedure had increased.

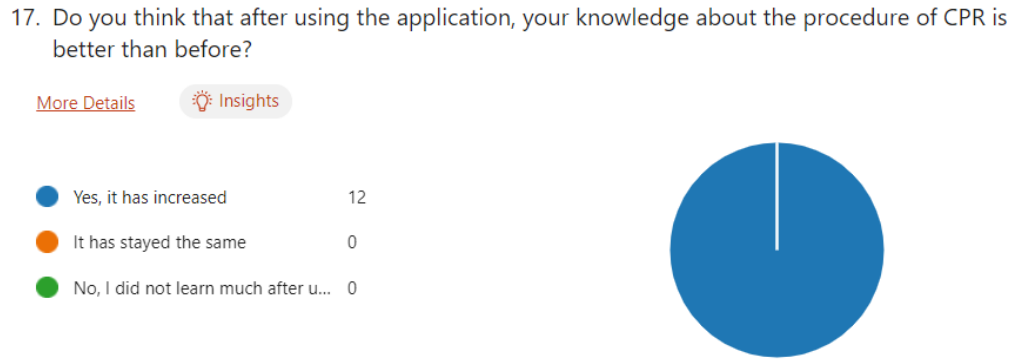

Figure 36: Responses regarding the participants' knowledge of CPR after testing the application

The majority of participants agreed that they would feel much more confident in emergencies if they went through similar types of training simulators regularly. 75% of them agreed while 17% of them strongly agreed.

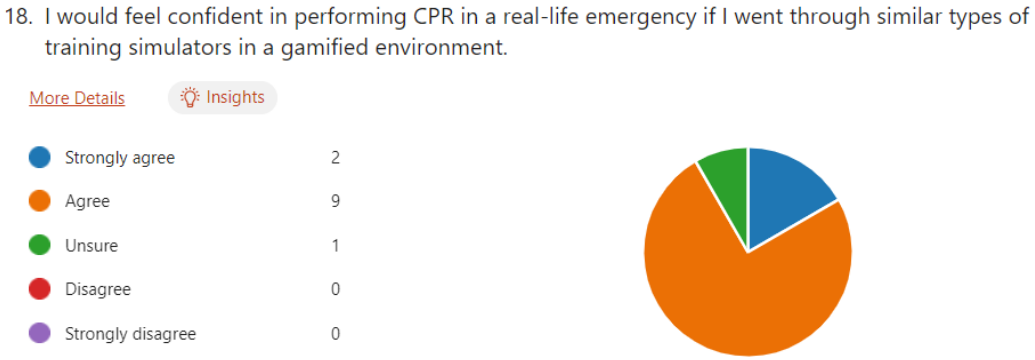

Figure 37: Recorded responses about the question which asked the participants about their confidence if they used other similar virtual reality applications

ID	Responses
1	Audio (voice) instructions, maybe examples. Better emphasis on the CPR actions taken, with more precision.
2	Have a more open area and wireless headset
3	A Bit more clarity with instructions,
4	indication if I saved the character
5	Improvement of the collision bug with the defibrillator. Maybe during the tutorial, start a little bit closer to the first information panel. I'm a little bit blind so I had a hard time seeing that I should go there first. Also, maybe the UI for the breathing part could be from multiple angles around the head so it's easier to see for how long to hold.
6	Make it more intuitive by adding more visual and auditory cues.
7	More animations for the casualty, more scenarios.

Table 1: Table Displaying the responses of the participants when asked for improvements/suggestions to the application

Chapter 5 Discussion

5.1 Discussion of Results

This chapter engages in an in-depth conversation about the results gathered from the questionnaire answered by the participants during the survey. The results culminated from a study of 12 participants. The questions were both subjective and objective, which helped to understand the participants' attitudes toward CPR while analysing their technical knowledge about the same. To study if the application had a hypothesised effect on the participants, the questionnaire was divided into "before" and "after" sections.

5.1.1 Before Questions

The questions in this section were asked to the participants to scope out their attitudes and awareness towards CPR and CPR training. **Q1 – Q3** of the questionnaire asked the participants the following questions:

- **Q1:** "How would you feel in an emergency if a person collapses in front of you?" This question had options ranging from not knowing what to do in a situation like that at all to be confident enough to act correctly in a methodical manner. Out of the 12 participants, the majority replied that they would know what to do but, they would hesitate to act. As discussed previously in the 2nd chapter, it is evident that promptness and quick thinking can save lives. Feelings of anxiety and being ill-prepared can cause valuable time to be lost and result in a casualty. This question aimed to measure the attitude of the participants and the results showed that just knowing what to do cannot prove to be enough if not acted upon. A bystander can become a lifesaver if their ability to make decisions is not hindered by solvable problems such as ill-preparedness or not being confident enough.
- **Q2:** "Have you been in an emergency where you had to act quickly or perform CPR before?" This question was asked to evaluate the participants' past experiences in emergencies. The results showed that only 8% of participants (1 out of 12) had been in an emergency. This statistic seems like a positive one as no one wants to be part of a situation where the level of stress is high and the chance of making an error is almost 0 but that is what an emergency is. A

thing that can happen to anyone, anywhere out of the blue. The following two questions portrayed the general awareness of CPR among the participants.

- **Q3:** “Have you had CPR training before? If yes how long ago was it?” 8 out of the 12 participants had CPR training before in their lifetime. Out of those 8 people, only 1 had trained in the method of CPR 4 – 6 months ago. The other 7 participants had participated in CPR training over a year ago. This showed the lack of regular training among the majority of the participants. According to the literature discussed in Chapter 2, regular training and tutoring about life-saving methods help reduce feelings of anxiety and increase confidence among people. This is essential as properly trained people can then go on to save a victim in real-life.

5.1.2 After Questions

After answering questions from the previous section, the participants were asked to test the application by using the VR headset. The “after” section of the study started with technical questions regarding the CPR procedure. The discussions about the responses for Q6 – Q18 are as follows:

- **Q6:** “On a victim, you should begin CPR by giving how many chest compressions?” The correct response rate to this question was 100%. The response efficiency to this question displayed that the application was successful in disseminating the knowledge about the correct number of chest compressions in a CPR procedure. The method of transferring this information to the participants proved to be successful as well due to the efficiency of the response rate.
- **Q7:** “How many rescue breaths should be given after the required number of compressions?” The success rate of answering this question was also 100%. The way this step of the procedure was designed was to introduce some interactive events. The participants had to press and hold down 2 buttons for a second each. After each button press, an auditory cue was played that resembled an exhaling breath to notify the participant that their action has been successful. The results of this question show that interactive methods of teaching people yield positive results.
- **Q8:** “What should be the duration of each rescue breath?” The answers to this question were majorly right. 58% of people gave the correct answer to this

question. The reason behind the average success rate of this question can be attributed to the fact that the information about this question was displayed in the application in text form rather than giving the user a visual image or auditory cue. In a gamified environment, the participants might have overlooked the written information and were more interested in moving to the next step which seemed more interactive. This supports the findings of the article discussed in Chapter 2, which suggests that people get motivated to learn if they are doing the said activity instead of reading about it. Interactivity plays a key role in getting someone to be motivated to learn something.

- **Q9:** “What is the longest duration for you to check if someone is breathing or not?” The answer to this question was answered correctly by 9 out of 12 people. This step in the procedure was designed so that the player can interact with the casualty in front of them by moving their head in the real world. Since this step was an interactive one, the correct response rate supports the use of interactive methods of teaching over traditional ones. The addition of a countdown timer in the application also provided them with crucial information which was correctly remembered by them during the answering of these questions.
- **Q10:** “How should you open the airway of the victim?” 10 out of 12 people answered this question correctly. This step required the participants to put their hands on the victim’s chin. Even without being outright told by the application about what to do, the participants who answered the question correctly were able to figure out that the question asked from them was indirect and wanted to gather information about the result of the activity performed but not the activity itself (the activity being, putting their hand on the chin of the victim to tilt their head backwards).
- **Q11:** “In what situation should CPR be performed?” Every participant answered this question correctly. This information was given to the participants on the start screen of the application. The information was quickly absorbed by the participants, as it was the first panel of information they saw and read.
- **Q12:** “How should you check for a response from the victim?” This question was also answered correctly by every participant. This was a standard

question, and the mechanic of this step in the application was just a simple button click that gave an auditory output.

- **Q13:** “What should be the correct speed of chest compressions?” This question was answered correctly by 75% of the participants but the rest of the participants’ answers were not far from the correct answer. This portrays that the information displayed on the canvas in front of them, the checklist task and the auditory cues that told them to compress the victim’s chest in sync with the beat were successful in conveying this useful information to the participants. The success rate of the answers to this question is an important statistic as this is one of the most vital steps in the whole CPR procedure.
- **Q14:** “What should be the correct depth of compressions?” The answers to this question were evenly divided among three options. The correct answer only shared 33% of the total weightage of all the answers recorded for this question. The main reason behind this was giving out the information about the question just through words on a canvas and no specific interactive visual or auditory cues.

The above-mentioned questions were technical questions about CPR methods. The questions to be discussed now measure the attitudes of the participants towards CPR methods and their general feelings after testing the application procedurally.

- **Q15:** “After going through the application, would you be able to take charge and correctly perform CPR?” This question was asked to identify if the application had a positive or a negative impact on the attitudes of the participants in the case of an emergency. 10 out of the 12 participants agreed that the application helped increase their confidence and 3 out of those 10 strongly agreed for the same. This solidifies the fact that training and simulation scenarios can help people feel more confident in their abilities, reduce anxiousness, and prepare them to act in case of an emergency.
- **Q16:** “Did you prefer to use VR tools to teach the methods of CPR over traditional training tools like videos or diagrams?” This question was asked to validate the use of VR technologies in the development of this application. The ultimate aim of this honours project was to find out if VR technologies can contribute positively to different areas of life such as the medical sector. 10 out

of the 12 participants in the study answered yes to this question. This statistic shows that people are inclined to absorb more information and learn important life-saving procedures if taught using an engaging and innovative way. The use of immersive technologies, where the participant had to perform the steps instead of learning about them through conventional training tools, can help accelerate the learning process and can even be used to train people professionally if implemented in a correct and organised manner.

- **Q17:** ” Do you think that after using the application, your knowledge about the procedure of CPR is better than before?” 100% of the participants answered yes when asked if their knowledge about CPR increased after testing the application. This information points to the successful implementation of the procedures of CPR in a virtual environment. The information learnt virtually with the use of extended reality hardware helped the participants to increase their knowledge, which helps to increase their promptness and make them more prepared to deal with these situations should they encounter them in real life.
- **Q18:** ”I would feel confident in performing CPR in a real-life emergency if I went through similar types of training simulators in a gamified environment.” 11 out of 12 people responded positively to this statement and 2 out of the 11 strongly agreed that learning through a gamified environment can prove to be a better way of learning over traditional tools. The interactivity, elements of immersion, and other factors can help in increasing information retention within the player. In doing an activity, the player feels motivated and gains the required confidence to learn about a topic which leaves a lasting effect on the user’s mind.

5.2 Evaluation of Development

There were some obstacles in the development of the application during the study that made it necessary to make changes in the development schedule. The original approach of getting the application to the testing phase was delayed due to not getting the university-provided HTC Vive VR headset a month and a half after the schedule to develop the application was set in motion. This situation presented a compulsion to use the time to study more relevant literature and find alternative methods to implement the design drawn up for the application. This resulted in overlooking some components that would have impacted the application in a positive

way. The elements that were not implemented due to time constraints would have made the application more engaging, given them better knowledge retention, provided them with a heightened sense of urgency and make it feel more like real-life. These elements were as follows:

- Adding Gesture recognition: The application could have been closer to technical accuracy by adding gesture recognition that tracked the movement of the fingers of the participants. While compressing the chest of the casualty, the participant would have made a specific gesture which is a vital step while performing this procedure. The XR Hands package (Unity Technologies, 2023) recently released by Unity Technologies would have allowed the development process to deploy an application that recognised gesture control which would have made the simulation closer to reality.
- Asking questions about the application in the application itself would have put the participant in a situation of answering the questions right there and not through a survey which would have provided the surveyor with more correct answers as the memory of the information would still be fresh in their minds. This would have been implemented in the application by adding UI elements with images and buttons that would check the answer for the user as they answered each question.
- Making the environment livelier: The virtual environment around the player could have been improved upon by adding more models and reactive NPCs in the scene. These additions would have proved to engage the player more by presenting the scene as close to real life as possible.

5.3 Significance of the Study

The objective of this project was to develop an application that can help raise awareness and possibly act as a training/teaching tool that can be more engaging than traditional teaching methods. The culmination of the results from the study point to the fact that alternative methods of teaching that employ the use of VR technologies were preferred by the majority of participants involved in the study. This study adds to the previous similar research and journal articles as reviewed in Chapter 2. The teaching methodologies that employ the use of VR technologies have proven that people learn more efficiently and their quality of information retention seems to be better. The results from the survey however also show that

tasks which required the user to take part physically and engage with the mechanics of the hardware yielded better-quality of answers to questions specific to those tasks. Whereas questions related to tasks that required less interactivity and engagement did not have the same success rate as the other type of questions. This strengthens the fact that if a participant is given control of the steps to be performed instead of being told what to do in that situation, then the information makes a better impact on the user.

Chapter 6 Conclusion and Future Work

The application and the results gathered from the participants who tested it worked in alignment with the idea of using VR devices to teach and train people about essential and life-saving procedures. The data from the survey shows that the effects of the application were mostly positive. This solidifies the fact that applications like these, where the user learns in a gamified environment, can prove to be a beneficial improvement in the medical and education sector. The visualization and interactive nature of the application were essential part of the simulator's positive feedback. The different components of the application designed and drawn up with a specific result in mind provided favourable outcomes.

6.1 Implications after the study:

Several implications can be drawn after conducting this study to its end. Some of them are:

- Extended reality technologies, such as VR applications and augmented reality applications, are not limited to functioning as sources of entertainment, games, and leisure. There are several methods where technologies like these can be used as a force for good, raise awareness and help provide training about concepts that might seem mundane in theory but can prove to be engaging and interesting if implemented practically.
- The confidence of people can be increased through regular practice. If people keep practising the required fundamental skills about a certain procedure, they can get more confident and less anxious about the procedure they are learning. This increases their will to act instead of just witnessing the emergency. The time taken to act reduces and the ability to take the right decision at the right time becomes significantly better.
- Since this is a fairly new method of teaching and training, many participants tested an application like this for the first time. The statistics collected from the questionnaires showed that a gamified version can prove to be the next step forward in the sectors that contain a teaching factor. The majority of participants in the study also agreed that learning in a gamified environment was more appealing and similar environments can prove to be a substitute for traditional methods of learning such as diagrams and videos.

6.2 Future Improvements and Implementations:

After the questions were answered by the participants, they were asked for any suggestions to improve the application. The responses are categorised as follows:

- Auditory cues: the majority of suggestions were to add more auditory cues in the simulator. Some of the technical data such as the depth of compressions and the speed of compressions would have been conveyed better if they had been told to the participant through a voice acting as a guide. Similarly, the auditory cues could also instruct them in the direction of the next task that they have to perform after completing the previous one. To implement this, audio could be recorded either by a person or an AI-generated voice which can be then implemented in the scene using Unity's audio system. This can help add another method of imparting knowledge about the procedures to the participants and direct them to do the next steps instead of the participants reading the instructions.
- Animations: another improvement suggested was to add more animations to the victim and to the environment around it to make the simulation feel livelier. After completing the last step an animation playing that indicated if the character was saved or not would have made the application even more immersive. To create a sense of more urgency, the casualty could have had a collapsing animation in front of the player and while giving the casualty CPR, the chest would animate. The application could have also been improved by adding reactive NPCs in the environment which could react to the person collapsing around them.
- UI elements: Some of the positioning of the UI elements was not the best and it made interacting with the objects a bit uncomfortable. The UI could have been made more intuitive by making it a heads-up display which would make the scene a bit more practical. The placement of certain UI elements such as the button used to call the emergency services could have been changed. Similarly, the placement of the timer canvas that shows the time left to check for breathing from the casualty could be changed to move with the placement of the head of the participant as well.
- Adding different scenarios: The implementation of different emergency scenarios such as a person getting stabbed or someone slipping and falling

and accidentally hurting themselves could be chalked down as future work scenarios that can also be made following similar design and development methodologies and prove to be a success.

In conclusion, the application designed for the honours project gave satisfactory results. The viability of the application was further reinforced by one of the participants who is a nurse by profession and provided the feedback that the application was technically sound and the same steps were taught to them during their academic career while in training. A few more cosmetic improvements and polishing of the UI can make the application better and such applications can contribute positively to the medical sector. Overall, it can be said that VR applications if used and implemented in an educational capacity, can prove to be good teaching tools, and potentially replace traditional training methods.

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Appendices

Appendix A Flow Diagram of the Application

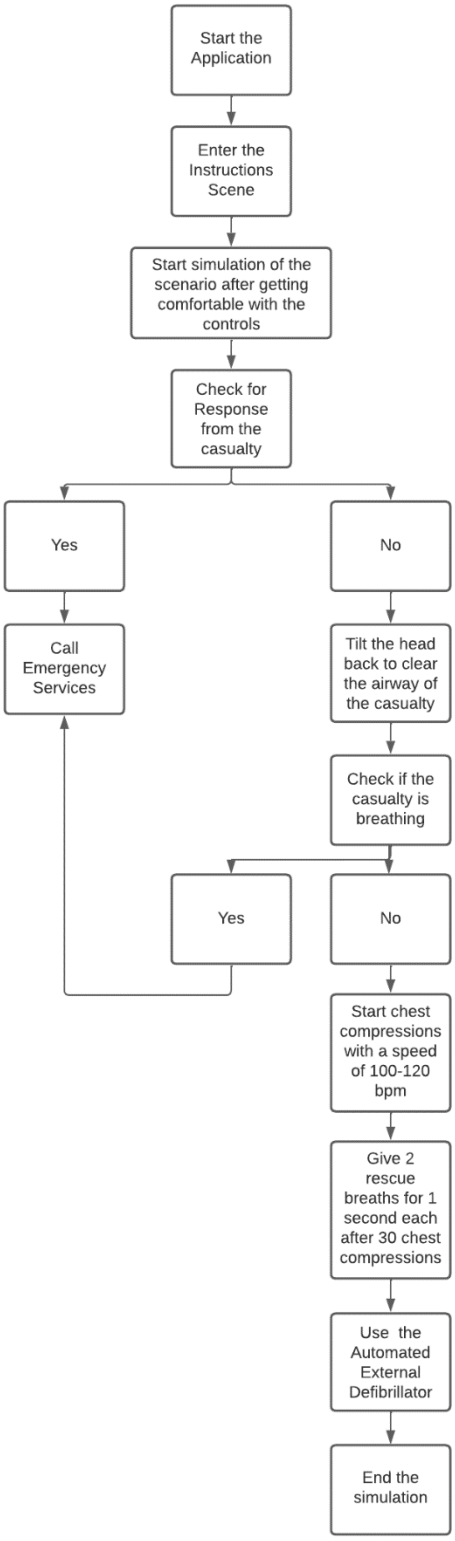


Figure 38: Flow diagram for the simulator application

Appendix B Code Snippets

AnimateAirway.cs

Assembly-CSharp | AnimateAirway

```
4
5   public class AnimateAirway : MonoBehaviour
6   {
7
8       [SerializeField] private Animator MyAnimationController;
9       public GameObject CheckMark;
10      public GameObject BreathCheckBox;
11      public GameObject PointerArrowBreathCheck;
12      public GameObject IndicatorHand;
13      public GameObject HumanHead;
14
15
16      private void OnTriggerEnter(Collider other)
17      {
18          if (other.gameObject.tag=="Left Hand")
19          {
20              MyAnimationController.SetBool("playHeadTilt", true);
21              CheckMark.SetActive(true);
22              Debug.Log("Collision true");
23          }
24      }
25
26      private void OnTriggerExit(Collider other)
27      {
28          if (other.gameObject.tag == "Left Hand")
29          {
30              IndicatorHand.SetActive(false);
31              PointerArrowBreathCheck.SetActive(true);
32              BreathCheckBox.SetActive(true);
33              HumanHead.SetActive(true);
34              Debug.Log("Collision false");
35          }
36      }
37  }
38
```

Figure 39: Code Snippet for AnimateAirway.cs Script

TimerTry.cs

Assembly-CSharp | TimerTry

```
28
29      public GameObject CubeGesture;
30
31      float CurrentTime = 0f;
32      float StartingTime = 10f;
33
34      private void Start()
35      {
36
37          CurrentTime = StartingTime;
38
39      }
40
41
42      private void OnDisable()
43      {
44          CurrentTime = StartingTime;
45      }
46
47
48
49      private void Update()
50      {
51          CurrentTime -= 1 * Time.deltaTime;
52          CountdownText.text = CurrentTime.ToString("0");
53
54          if(CurrentTime<=0)
55          {
56              CurrentTime = 0;
57              Object.Destroy(BreathCheckGameObject, 0);
58
59              CubeGesture.SetActive(true);
60
61              cubeBeat.SetActive(true);
62
63              QuestArrowCPR.SetActive(true);
64
65              BreathTickMark.SetActive(true);
66
67              QuestArrowBreath.SetActive(false);
68
69              CPRGameObject.SetActive(true);
70
71              HumanHead.SetActive(false);
72
73              HandGesture.SetActive(true);
```

Figure 40: Code Snippet for TimerTry.cs Script

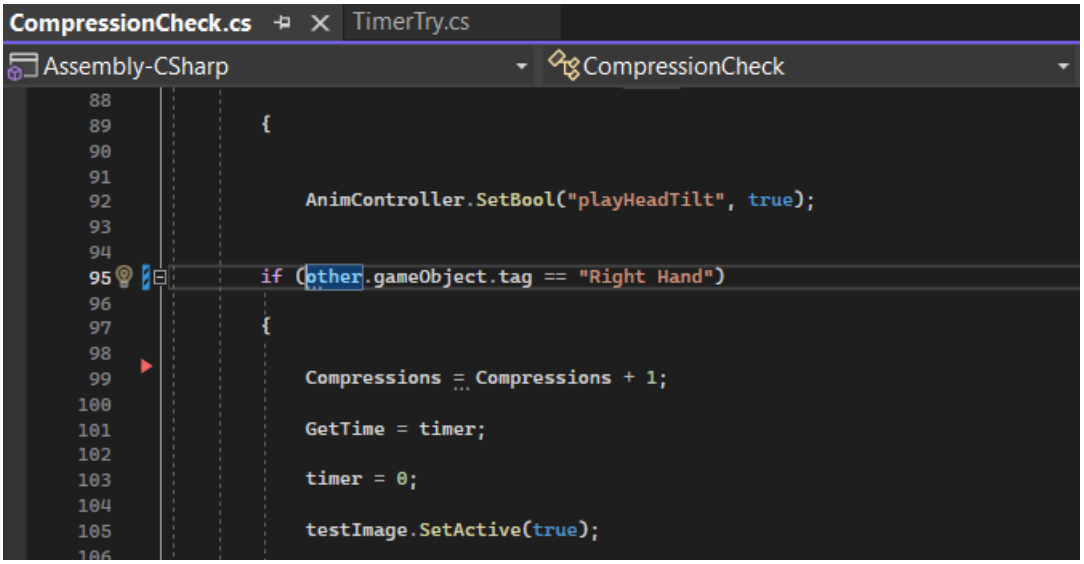


Figure 41: Code Snippet to increase the number of Compressions

```
if (GetTime<=0.2f) //Red too quick
{

    imageComp.color = new Color32(255, 0, 0, 255);
    EvalText.GetComponent<TextMeshProUGUI>().text = "Too quick";

    //Debug.Log("Very fast");
}

if(GetTime >= 0.3 && GetTime <= 0.4) // Yellow Decrease
{
  imageComp.color = new Color32(255,186,0,255);
  EvalText.GetComponent<TextMeshProUGUI>().text = "Decrease Speed";
  //Debug.Log("Decrease speed");

}

if (GetTime >= 0.5f && GetTime <= 0.6f) // Green Optimal
{

   imageComp.color = new Color32(0, 255, 15, 255);
    EvalText.GetComponent<TextMeshProUGUI>().text = "Optimal";
    goodCompressions++;
    Debug.Log(goodCompressions);
   // Debug.Log("Optimal");
}

if(GetTime>=0.7 && GetTime<=0.8) // Yellow Increase
{

  imageComp.color = new Color32(255,186,0,255);
  EvalText.GetComponent<TextMeshProUGUI>().text = "Increase Speed";
 // Debug.Log("Increase speed");

}

if (GetTime>=0.9) // Red Too slow
{

    imageComp.color = new Color32(255, 0, 0, 255);
    EvalText.GetComponent<TextMeshProUGUI>().text = "Too slow";
   // Debug.Log("Too slow");
}
```

Figure 42: Code Snippet to check the speed of compressions

Appendix C Consent Form Template

Abertay University

Appendix C(i): Participant Information Sheet and Research Consent Form

Project title: Using extended reality technologies to aid in the training of administering Cardiopulmonary Resuscitation (CPR)

Researcher name(s): Arjun Bhatnagar,
Naman Merchant (Supervisor)

What is the research about?

We invite you to participate in a research project about Cardiopulmonary resuscitation (CPR) training for the general population through a virtual reality application to study the effects of virtual reality teaching methods and to increase awareness about administering CPR.

Do I have to take part?

This form has been written to help you decide if you would like to take part. It is up to you and you alone whether you wish to take part. If you do decide to take part, you will be free to withdraw at any time without providing a reason and without penalty. Since the study only takes age into account, it will be impossible to withdraw data if the participant decides to take part in the study as it is going to be anonymous, and nobody will be explicitly named.

What will I be required to do?

The participant will be required to play a training simulation application which will guide them through the proper steps of CPR and train them on how to act in an emergency. After they have gone through the application, the participants will be required to fill out a questionnaire to assess the feasibility of teaching methods through virtual reality.

How will you handle my data?

Your data will be stored in an anonymized form and will only be accessible to [Arjun Bhatnagar, Naman Merchant (Supervisor)] Your data will be stored in [Secure university servers], with data fully anonymized. Your responses are treated in the strictest confidence - it will be impossible to identify individuals within a dataset when any of the research is disseminated (e.g., in publications/presentations). Abertay University acts as Data Controller (DataProtectionOfficer@abertay.ac.uk).

Retention of research data

Researchers are obliged to retain research data for up to 10 years post-publication, however, your anonymized research data may be retained indefinitely (e.g., so that researchers engage in open practice and other researchers can access their data to confirm the conclusions of published work). Consistent with our data retention policy, researchers retain consent forms for as long as we continue to hold information about a data subject andfor 10 years for published research (including a Research Degree thesis).

Consent statement:

Abertay University attaches high priority to the ethical conduct of research. Please consider the following before indicating your consent on this form. Indicating your consent confirms that you are willing to participate in the research, however, indicating consent does not commit you to anything you do not wish to do and you are free to withdraw your participation at any time. You are indicating consent under the following assumptions:

- I understand the contents of the participant information sheet and consent form.
- I have been given the opportunity to ask questions about the research and have had them answered satisfactorily.
- I understand that my participation is entirely voluntary and that I can withdraw from the research (parts ofthe project or the entire project) at any time without penalty and without having to provide an explanation.
- I understand who has access to my data and how it will be handled at all stages of the research project.

PLEASE INITIAL BOX:	Yes, I do consent	No, I do not consent
I consent to take part in this study conducted by [Arjun Bhatnagar, Naman Merchant (Supervisor)] who intends to use my data for further research examining.		
I consent for [Arjun Bhatnagar, Naman Merchant (Supervisor)] to collect and process my sensitive data [(1) Age, (2) Sex]		

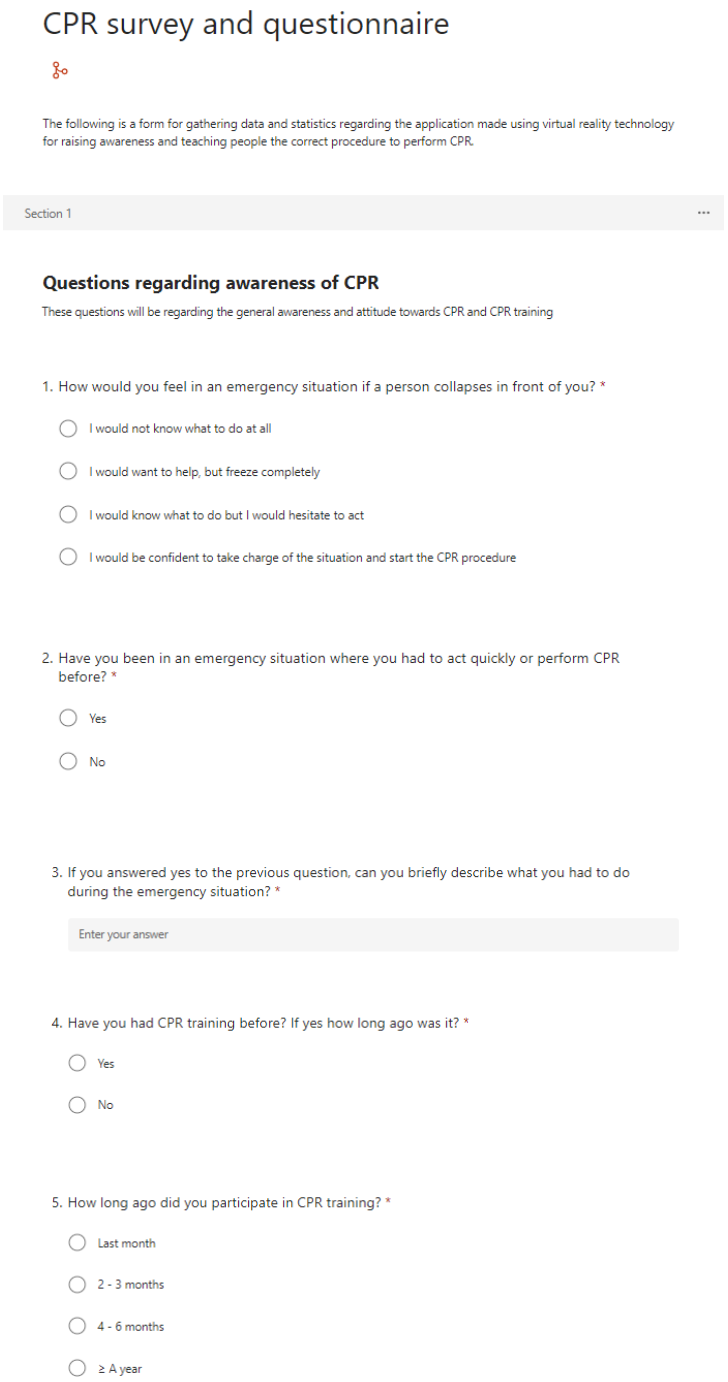
I confirm that I am willing to take part in this research:
NAME:
SIGNATURE:
DATE:
You can find our procedure for complaints (regarding research projects) and our privacy notice and legal basis for processing research data at: https://www.abertay.ac.uk/legal/privacy-notice-for-research-participants/

Figure 43: Consent Form Template

Appendix D Survey Questions

The link to the questionnaire and survey can be found here:

https://forms.office.com/e/hnaap2uVYi



CPR survey and questionnaire

The following is a form for gathering data and statistics regarding the application made using virtual reality technology for raising awareness and teaching people the correct procedure to perform CPR.

Section 1

Questions regarding awareness of CPR

These questions will be regarding the general awareness and attitude towards CPR and CPR training

1. How would you feel in an emergency situation if a person collapses in front of you? *
   - I would not know what to do at all
   - I would want to help, but freeze completely
   - I would know what to do but I would hesitate to act
   - I would be confident to take charge of the situation and start the CPR procedure

2. Have you been in an emergency situation where you had to act quickly or perform CPR before? *
   - Yes
   - No

3. If you answered yes to the previous question, can you briefly describe what you had to do during the emergency situation? *

   Enter your answer

4. Have you had CPR training before? If yes how long ago was it? *
   - Yes
   - No

5. How long ago did you participate in CPR training? *
   - Last month
   - 2 - 3 months
   - 4 - 6 months
   - ≥ A year

Questions regarding the procedure of performing CPR

These questions are regarding the proper methods of CPR. *(The following questions are to be answered only after you have tested the VR application)*

6. On a victim, you should begin CPR by giving how many chest compressions? *

- ◯ 15
- ◯ 10
- ◯ 30
- ◯ 25

7. How many rescue breaths should be given after the required amount of compressions? *

- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 1

8. What should be the duration of each rescue breath? *

- ◯ 1 second
- ◯ 3 seconds
- ◯ 2 seconds
- ◯ 6 seconds

9. What is the longest duration for you to check if someone is breathing or not? *

- ◯ 8 seconds
- ◯ 10 seconds
- ◯ 5 seconds
- ◯ 3 seconds

10. How should you open the airway of a victim? *

- ◯ Lift the chin to tilt the head back
- ◯ Tilt the head forwards
- ◯ Tilt the head to the side
- ◯ Pull the tongue out

11. In what situation should CPR be performed? *

- ◯ Heart Attack
- ◯ Stroke
- ◯ Cardiac Arrest
- ◯ Angina

12. How should you check for a response from the victim? *

- ◯ Nudge them with your foot
- ◯ Shake their arm
- ◯ Throw something at them
- ◯ Call for them

13. What should be the correct speed of chest compressions? *

- ◯ 90 beats per minute
- ◯ 100 - 120 beats per minute
- ◯ 70 - 80 beats per minute
- ◯ 50 beats per minute

14. What should be the correct depth of compressions? *

- ◯ 4 - 5 cm
- ◯ 3 - 4 cm
- ◯ 5 - 6 cm
- ◯ 1 - 2 cm

Questions regarding CPR training after using the application

These questions are regarding the attitudes and awareness related to CPR and CPR training after using the application

15. After going through the application, would you be able to take charge and perform CPR in a correct manner? *

- ◯ Strongly agree
- ◯ Agree
- ◯ Unsure
- ◯ Disagree
- ◯ Strongly disagree

16. Did you prefer to use Virtual Reality (VR) tools to teach the methods of CPR over traditional training tools like videos or diagrams? *

- ◯ Yes
- ◯ No

17. Do you think that after using the application, your knowledge about the procedure of CPR is better than before? *

- ◯ Yes, it has increased
- ◯ It has stayed the same
- ◯ No, I did not learn much after using the application

18. I would feel confident in performing CPR in a real-life emergency if I went through similar types of training simulators in a gamified environment. *

- ◯ Strongly agree
- ◯ Agree
- ◯ Unsure
- ◯ Disagree
- ◯ Strongly disagree

19. Would you like to recommend any improvements to the application? *

- ◯ Yes
- ◯ No

20. Suggestions for any improvements to the application *

Enter your answer

Figure 44: Survey Questions' Screenshots

Appendix E GDPR Data Management Sign Off Form

Abertay University

GDPR Research Data Management
Data Sign Off Form

For undergraduate or postgraduate student projects supervised by an Abertay staff member.

This form MUST be included in the student's thesis/dissertation. Note that failure to do this will mean that the student's project cannot be assessed/examined.

Part 1: Supervisors to Complete

By signing this form, you are confirming that you have checked and verified your student's data according to the criteria stated below (e.g., raw data, completed questionnaires, superlab/Eprime output, transcriptions etc.)

Student Name:	Arjun Bhatnagar		
Student Number:	1904516		
Lead Supervisor Name:	Naman Merchant		
Lead Supervisor Signature	*Naman Merchant*		
Project title:	Using extended reality technologies to aid in the training of administering Cardiopulmonary Resuscitation (CPR)		
Study route:	PhD ☐	MbR ☐	MPhil ☐
	Undergraduate ☑	PhD by Publication ☐	

Part 2: Student to Complete

	Initial here to confirm 'Yes'
I confirm that I have handed over all manual records from my research project (e.g., consent forms, transcripts) to my supervisor for archiving/storage	Yes
I confirm that I have handed over all digital records from my research project (e.g., recordings, data files) to my supervisor for archiving/storage	Yes
I confirm that I no longer hold any digital records from my research project on any device other than the university network and the only data that I may retain is a copy of an anonymised data file(s) from my research	Yes
I understand that, for undergraduate projects, my supervisor may delete manual/digital records of data if there is no foreseeable use for that data (with the exception of consent forms, which should be retained for 10 years)	Yes

Student signature : Arjun

Date: 09/05/2023

Figure 45: GDPR Data Management Sign Off Form