University of Glasgow | School of Computing Science

Honours Individual Project Dissertation

Virtual Heritage App

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Abstract

The crossover between virtual reality (VR) and cultural heritage is still at its early stages in the field of research, and so there exists only a small number of this kind of VR applications. Therefore, the objective of this project is to develop a mobile VR application that showcases a specific region in Glasgow and its rich cultural heritage. The chosen attraction is the Tall Ship, Glenlee, that resides by the Riverside museum. The application's aim is to spread knowledge about its history and life under sail. Moreover, it also aims to positively change visitation intentions after their VR experience. This paper outlines the project lifecycle, rationalising the decisions made throughout that leads to the final product. Main technologies used are Unity, C# and Daydream View VR. Twenty participants have volunteered to experience the final application and the study investigated their opinions with regards to the application's user interface (UI) and user experience (UX). Overall results show a positive outcome with majority of the participants acquiring new knowledge about the ship's history and majority stated that they have become inspired to visit the museum ship.

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Contents

1 Introduction

1.1 Context

Virtual Reality in the tourism industry has had an impact in the most recent decade. From simple 360-degree video virtual tours, the innovation of VR has progressed onto having a higher level of accuracy accompanied by lifelike interactions in a way it has been possible to design some even more immersive applications that influences the industry. This was even predicted by Williams and Hobson (1995), which is evidently from two decades ago.

There are many areas that VR applications take part in tourism, one of which is aiding travel agencies in promoting destinations by providing their clients an "experience" of the real place in the business' hopes that it positively influences consumer decisions. It is also an opportunity for some individuals to experience popular tourist attractions that they otherwise would not be able to visit due to unfortunate circumstances such as fear of travelling or the lack of money to cover the expenses of a holiday.

A recent trend that VR has recently populated is its uses in education, particularly "edutainment"; a material that is intended to be both enjoyable and educational. In the tourism sector, VR is primarily integrated into science museums and contemporary art museums as edutainment. In science museums, the VR technology is installed in the physical museum that is accessible to the public, whilst in contemporary art museums, VR is merely taken advantage to communicate new forms of art.

1.2 Motivation

Cultural heritage is a field within tourism that VR is also becoming widespread; that is the conservation and restoration of historical environments and artefacts. However, the crossover between VR and cultural heritage is still at its early stages and so the field does not touch many research area. Moreover, the small number of existence of this kind of applications are, in most cases, available either in a niche educational organisation or installed in real traditional museums.

The research by Carrozzino and Bergamasco (2010) has concluded that such applications are not only expensive in terms of the device but it also requires an investment in money and time into the development of the application. It requires a team of experts, like software developer, historian, graphic designer, artist, and many more, in order to feasibly create an application that delivers an immersive cultural experience that takes users back in time.

The research by Economou and Tost (2008) has concluded that such applications' effects on the type learning it induces is still inconclusive. It infers that the users' background profile brings bias to the type of learning they were exposed. For example, the age of a person is correlated to the evolution of technology and so the learning process may not have been related to cognitive reasons.

The shared discussed conclusion of the above studies in the field of VR in cultural heritage is the limitation that VR generally brings in a social context. Majority of immersive VR applications to date only provide single-user experiences. Collaborative interactions with other individuals in a museum (or in a classroom) is an important aspect of the learning process.

1.3 Project Objectives

The main objective of this project is to develop a mobile VR application, showcasing a specific region in Glasgow and its rich cultural heritage. The chosen tourist attraction is the tall ship, Glenlee, that resides by the Riverside Museum. The goal is to spread knowledge about the historic ship and to change user attitude to show intentions of visiting the museum after their VR app experience.

A mobile VR will be used to create the application as this is the device that is most likely to be inexpensive and readily available for the public. With success, the application will be uploaded onto the Google Play Store under free license so that any user will be able to install the application free of charge. Also with success, the Scottish Tourism Industry will be contacted in the hope that they will be interested in extending the project so that it can be added to Glasgow's tourist experience. Therefore, with the overall success of the app, the application will overcome the issue of expensiveness for both users and the museum.

It is important to note that since the application will be created by a single developer, rather than by a team, the VR application is anticipated to only recreate some areas and rooms of the museum ship as it is too large to be created with a short time constraint. Therefore, a significant software principle that the implementation must follow is the open/closed principle (Meyer 1988). This means that software modules should be open for extensions but closed for modification. If other areas of the ship are added to the application, existing source code should not need to be changed.

Despite the possibility of the application being available globally, the main target audience will be individuals who are considering in visiting Glasgow (or the museum ship itself) and individuals who take particular interest in history. Users should use the application as a "sample" experience before making their decision whether or not it is worth investing their money and effort in visiting the ship. Another usage of the application is simply to experience new ways of gaining knowledge; learning historic information while exploring in the recreated virtual environment. In the latter usage, there is a risk that users would only experience the app once. In order to avoid users abandoning the app after a single experience, the deliverable must ensure that it conforms to the definition of "edutainment". The experience must be enjoyable, conveying a suitable high amount of interesting information that gets users hooked so that they would like to come back to the experience for more. Ideally, the experience should change user attitude positively that they would be inspired to visit the real museum ship.

Whilst there exists some multi-user VR experiences that this project can take motivation from, a great amount of time, which we lack, must be invested in order to create one that potentially improve the application in a way that meets the objectives. Moreover, research shows that there is still an unavoidable trade-off between lack of interaction and multi-user that keeps a VR immersive (Carrozzino and Bergamasco 2010). Rather, the project will focus on implementing a suitable interaction in order to meet the objectives.

1.4 SWOT(Risk) Analysis

Strengths	Weaknesses
• Google VR SDK supports Daydream, which allows to develop basic VR content. • Plenty of online resources available such as video tutorials for beginners. • Free 3D models from the Unity Asset Store and elsewhere.	• Most objects in the real ship require specific 3D models that cannot be found online. • No prior experience with Unity, C# and 3D modelling. • Repository will need to have a large storage space both remotely and locally.
Opportunities	**Threats**
• With success, The Scottish Tourism Industry can extend the project so that the app can be used to add to the tourist experience. • Spread knowledge about life at sea during the era of the ship.	• Conducting the user evaluation that is lacking diversity and with insufficient number of participants. • The ship is too large to recreate, which in turn adds extra time to the duration of user experience.

***Table** 1.1: SWOT(Risk) Analysis*

2 Literature Review

This chapter summarises the contribution of several research papers, discussing each of their conclusions and limitations. Reviewing papers that are project-specific and related to design is important to expand knowledge relevant to the field of this project. It would help anticipate issues that may arise and pay attention to what's been neglected. Additionally, it would help identify the gap that this research project could fill.

Next, this chapter lists the heuristics to design VR applications proposed by SutcliffeA and Kaur (2006) to determine a methodological focus when making decisions within this project. Finally, reviews of existing VR applications that adds to the tourism experience will identify how VR technology is currently being integrated in the industry.

2.1 Reviewing Project-Specific Papers

2.1.1 Virtual reality, presence, and attitude change: Empirical evidence from tourism (Tussyadiah et al. 2018)

This research analyses the effects of VR experience on post-VR attitude (increase or decrease in the level of attitude) and behavioural intention to visit a tourism destination. The measurement items were VR Presence, the main focus, and VR Enjoyment. VR presence is the subjects' mental states of being in and interacting with the virtual environment. VR Enjoyment is the participants' perceived enjoyment using VR to experience the tourism destination.

The first study was in Hong Kong with half of participants experiencing a street view of Tokyo while the other half experiencing an interactive 360-tour of Portugal. The second study included 724 festival goers in the Lake District as participants experiencing VR by looking at the park's natural landscape including its mountains, lakes, and forests that was captured by a drone.

Both studies confirm that there are positive consequences if there is a sense of presence in the VR experience. Overall, the immersion feeling while in the virtual environment increases enjoyment, which results in stronger liking and preference in the destination. This positive attitude change leads to a higher level of visitation intention towards the tourism destination.

One of the limitations of this study is that, in total, there was a small number of participants using Samsung Gear VR compared to Google Cardboard. This does not allow for testing a meaningful comparison to better understand how presence comes about.

This research is relevant in a way that the devices used are mobile VRs, just like the Daydream View, and it has measured participants' visitation intentions, just like what is going to be measured in this study. The success of this described research has inspired this study develop a VR that provides a high sense of presence and enjoyment while using the app.

2.1.2 Educational Tourism through a Virtual Reality Platform (Zarzuela et al. 2013)

This project has created a VR serious game that aims to increase players' knowledge about the city of Valladolid in Spain. Serious game is defined as a tool that is designed for other purposes other than entertainment. In this project, the serious game developed is utilised as a learning tool to acquire a set of knowledge and practical skills. The main technology used was a Microsoft Kinect with an output display and so it did not require a headset.

The main scene recreated was its Main Square and the historic building encompassing it. An avatar is in the virtual world that mimics that user's gestures captured by the kinect. There are questions at certain locations in the virtual world that must be answered by performing specific gestures that the application can register.

The contribution of the paper is that it is an intuitive system that promotes the city as a tourist attraction. It can be used by any ages of any level of prior knowledge. The complexity of the questions that can be played during a game session can be modified to suit the player's knowledge.

The mechanism of the developed app was for participants to answer a series of questions at different degree of difficulty depending on their prior knowledge. It was necessary for them to answer incorrectly in order to acquire new knowledge on a trial and error basis. The workflow is that when a question is failed, the correct answer is displayed twice, as soon as the incorrect answer is registered and when the game ends.

The limitation of this paper is that there were only 10 participants during testing. Each participant played the game once, finishing with their overall score. It was only claimed that participants acquired new knowledge from this single session. A second game should have been played so that the researcher could compare the first and second scores to confirm that the participants have indeed acquired new knowledge. This would have further confirmed the effectiveness of the serious game.

To avoid this fault from occurring in the proposed app, more than 10 participants will be attempted to recruit and a confirmation from them will be explicitly asked if they have learned something new after their VR experience.

2.1.3 When art meets tech: The role of augmented reality in enhancing museum experiences and purchase intentions (He et al. 2018)

This research analyses the effects of augmented reality's design elements on visitor's experiences and purchasing intentions. These elements are information type (dynamic verbal vs. dynamic visual cues) and augmenting immersive scenes (high vs. low virtual presence). There were 225 participants and they were asked to imagine being in an art museum as they were using an AR device, which displayed one of Vincent Van Gogh's paintings with their appointed virtual environment. Straight after, they were asked questions related to their experience, willingness to pay more, imagery vividness, demographics, etc.

The environment that caused an increase in the visitors' willingness to pay more was the combination of high virtual presence and dynamic verbal cues. In this environment, the painting was augmented with 2D dynamic visual cues portraying the imagery from Vincent van Gogh's perspective while the museum environment was augmented with a content-related virtual background. This environment was successful presumably because the contextual cue facilitates mental imagery, which in turn affects a vivid imagery processing that enhances the aesthetic experience.

The measure of willingness to pay more serves as the visitor's investment into the museum as they have taken more interest into the artefacts presented to them digitally. Therefore, the incorporation of this research's methodology into the VR app would be beneficial. If the VR app in this study presents a high virtual presence with verbal (textual) information, then users are more likely to invest into the effort of visiting the real tall ship museum.

2.2 Reviewing Papers Related To Design

2.2.1 Current and Future Virtual Reality Applications and the Application of User Experience Design Principles (Dylan Kreis 2018)

VR is discussed in this paper in terms of its place across different industries and its potential for future applications. It is comparing and contrasting previous literature that have already identified factors that constitutes usability so that features of a good UX (User Experience) design and their effects are inferred.

One of the research being reviewed in the museum industry is how individuals learn about environments that no longer exist while being in a museum (Roussou 2001). It provided an active and immersive engagement using a device called a "wand" to navigate in the reconstructed environment. A contrasting research examined was by Fischer (2017) who proposed that a virtual museum can be developed to showcase art designed through digital technology. The latter research encourages artists to exhibit their projects to a wider audience with the added advantage of no longer needing a physical space which in turn is less costly.

It was found that showcasing artefacts and art in a virtual museum, either recreated from real environment or created from scratch, is an effective method to spread knowledge. Additionally, Fischer (2017) envisioned a pure virtual museum providing opportunities for artists to use VR to test ideas of projects that they can potentially create depending on the instant feedback they receive from users. They would be able to iteratively improve their creations by simply changing the virtual environment before moving onto the physical prototypes.

Since the methodology used in this research is inferring from published scholarly research, the limitations depended on the literature review, which are large in scope. This research admittedly does not claim to have covered every potential current and future VR use and so there could be other relevant and significant form of sources that could affect the findings.

The study found that the ability to interact with information in similar ways as how visitors would in real museum simulate learning development. Visitors of the real tall ship normally inspect an artefact as well as read information about it. Therefore, the "wand" will be the daydream controller and virtual artefacts will be showcased along with some textual information in the proposed VR.

2.2.2 User Interface Design in Virtual Reality Research (Sanders (2018))

The motivation of this research is to develop and analyze different user interfaces that supports learning, as well as concluding the best design in the hope of future educational VR applications to implement the findings. The application being tested on is an Anatomy Builder VR that allows users to learn about the human or canine skeleton and the interface designs were developed in three iterations:

- The "bubble interface" provides hierarchical organisation allowing visuals to the main category and its subcategories together.
- The "tablet interface" is constantly attached to the user's hand controller to enable access to information and navigation tools at all times.
- The "spatial interface" is located on a corresponding location on the skeleton with a node that prompts users about its interactivity. This allows direct connections between the information on the interface and its whereabouts on the skeleton.

It was found that the combination of a hierarchical layout as seen in the bubble interface and structural layout as demonstrated by the spatial interface would be most effective when communicating anatomical information.

The main limitation of this study was the small sample size of only twelve people and the lack of diversity in terms of gender and course majors. This may have affected the close results that prohibited from discovering a definite front runner when comparing the three interface designs.

In the proposed VR, the successful interfaces will be implemented to enhance spreading knowledge. The bubble interface will be considered to group information by the different decks of the ship. The spatial interface will be considered to display information in the same area that information is referring to.

2.2.3 Designing an immersive tour experience system for cultural tour sites (Park et al. 2006)

This paper investigates new ways technology can be used in cultural sites. It uses a combination of Augmented Reality (AR) and audio to build a new system called "Immersive Tour Post" that can be placed in sites at a fixed position. The researchers designed a prototype in the hope that it helps visitors understand historical events by being immersed into the experience rather than just by reading textual information in the site. Therefore, this study has put great emphasis on the immersiveness that can be provided to the tourists.

The study was carried out in a real tourist attraction in Korea. The system was placed just outside a hut where prehistoric remains were found, that is meant to be setup within the New Stone age era. The prototype shows a 3D model animation of a caveman creating a stone axe, all the while producing a supposedly relevant sound.

The results of the prototype only showed a somewhat positive effect on the four categories: immersiveness, interest level, understandability and intention of use. Participants pointed out that there is a need to improve the virtual 3D model, but it was acknowledged that this type of technology has potential in contributing in the industry.

The use of virtual character is clearly significant for this study to meet the objectives of the AR. Therefore, incorporating virtual characters into the proposed VR application will be considered to add to the immersive design, however, it will not be a priority given the time constraint and the lack of experience.

2.3 List of heuristics to design VR applications

Sutcliffe and Gault (2004) proposed 12 heuristics for evaluating user interfaces in virtual environments. They based these on the research by SutcliffeA and Kaur (2006) which in turn was derived from the widely accepted usability heuristics by Nielsen and Molich (1990).

ID	Heuristic	Description
H1	Natural engagement	Interactions in the virtual world should be expected by the users.
H2	Compatibility with the user's task and domain	The environment and behaviour of 3D objects in the virtual world should be very similar to that of the real world.
H3	Natural expression of action	The telepresence of users while in the virtual world should not restrict their normal physical actions.
H4	Close coordination of action and representation	Motion sickness during exploration should be addressed by giving the application an appropriate response time to user's intentions.
H5	Realistic feedback	User's actions to the virtual objects should conform to the laws of physics and user's visual expectation.
H6	Faithful viewpoints	User's visual perception should map to that representation in the virtual environment, even during movement.
H7	Navigation and orientation support	User should not be lost in the virtual environment and is able to return to the default positions at anytime.
H8	Clear entry and exit points	User should know how and when to enter and exit the virtual world.
H9	Consistent departures	When there is a trade-off between multi-designs, it should be consistent and clearly communicated.
H10	Support for learning	Contents in the virtual world should be explained to support learning.
H11	Clear turn-taking	System initiative should be clearly signaled during VR experience.
H12	Sense of presence	User's overall experience in the virtual world should be as natural as possible.

2.4 Reviewing Existing VR Applications

2.4.1 Viking VR (Schofield et al. 2018)

A team of experts from different background collaborated in order to develop the Viking VR application, which spreads knowledge about how the Vikings transformed life in Britain. The goal was to showcase this application in a museum exhibition, among many more deployments. The objective was to investigate how VR could be integrated into creational practices and how it can add to the storytelling technique at the curator's disposal.

The application provides an experience of being in a 9th Century Viking encampment, therefore, the team focused their designs based on the perspectives of human. They were interested in what kind of sound an individual would hear, what movements would they take in response to a stimuli and so on. An example scenario is recreating the feeling of standing at the edge of the camp on a snowing winter morning while looking at a view of uninhabited land.

Having a team that includes curatorial, 3D artist, sound designers and archaeologists benefited the developers to design an immersive application. The paper stated that there were positive comments during the exhibition regarding specific features based on some discussions. For example, visitors grew sympathy of the people in the past as they learned how they suffered in the camp especially during winter time.

The main disadvantage the application was the lack of interaction. It merely used a gaze based interaction instead of a remote controller. Due to the fact that designers were focused on exerting feelings out of users using a storytelling experience, the application did not allow walking around in the virtual world, which in turn did not allow examination of virtual objects up close.

2.4.2 Alt-Segeberger Burgerhaus museum (Kersten et al. 2017)

The museum "Alt-Segeberger Burgerhaus" is a historic town house that is also known as the oldest house in Germany. This was recreated in both in 3D to showcase in VR and in an interactive computer-based application. The purpose was to provide visitors a chance to explore the museum without travelling to the site. The interior and exterior was carefully modelled to deepen user's understanding about its history, especially the building's complex construction.

The focus of this application was to exhibit the construction of the building in high detail. Therefore, it was significant to create models that resemble the museum as close as possible. The idea was to develop 3D models that are compatible with computer-based and virtual reality so that they would only be created once. A specialised kind of technology and techniques were used to achieve this; intensive 3D CAD modelling in phases.

The project seemed to contribute positively to the historical house. It provides the public different ways in learning about it; a computer based and a VR application. Not only it focused on the design of the establishment, it also uses guide points that tell users where to go and info menus detailing facts, aiding user's understanding of its history.

Since the virtual museum is already available in multiple platforms, an enhancement developers could do is extending it to be compatible with augmented reality. The current applications are not available in the actual museum itself as it is targeted to be used by users who live remotely and so an AR application can be available to download from any device, even on visitors' mobile phones. This way, the application can be used when they visit.

2.4.3 Titanic: Honor and Glory

This VR application is an ongoing project that aims to deliver a re-creation of the famous ship, Titanic, in multiple platforms; PC, consoles and VR. The VR version has been developed using Unreal Engine 4, not Unity.

The aim of the project is to provide a storytelling experience delivered by virtual characters of supposedly legitimate people of the past who were on the ship. The application aims to convey some realistic viewpoints regarding how the titanic sank. The designs of the interior and exterior of the ship was also prioritised to allow future viewers to get a closer look, in extreme detail, of the ship's authenticity. Although there are still no deliverables up to this date, demos and models are available to the public of what has been developed so far.

The delivery of storytelling experiences from legitimate characters would be a useful feature that can be taken inspiration from, however, due to the fact that the project is not completed yet, other aspects of the project will be taken advantage from. Historical ships like the Glenlee and the Titanic would have a similar layout and design, therefore, available demos and assets from the Titanic VR application will be investigated further to see if they can be used in proposed VR application so that the development process quickens.

3 Field Study

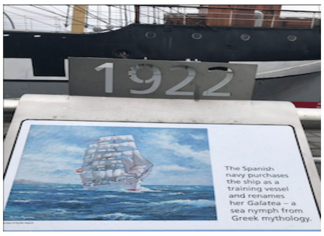
In order to create an application that resembles the chosen topic, a good understanding of its design and its history is significant. A field study was carried out to acquire this knowledge and so this chapter will provide a summary of what was observed about the topic of the proposed VR application, The tall ship. It will discuss how captured information can be incorporated into the VR application. Furthermore, it will propose how VR can be integrated into the museum itself to enhance visitors' experience.

3.1 Overview of the tall ship, Glenlee

The Glenlee ship, or better known as the Tall ship, is at the Riverside museum floating on the River Clyde in Glasgow. It is the remaining great Clyde-built sailing ship left in the world, which makes her a great prominence to the whole maritime trading history of the United Kingdom. What makes it a historic ship is that it has travelled around the world since 1896 for over a century experiencing traumatic events as a different kind of ship each time; a cargo ship, a training ship, and now a museum ship. Tackling countless storms were not easy, especially around the infamous Cape Horn, in which it managed to survive fifteen times despite having a well-deserved reputation as one of the most dangerous shipping lanes on Earth. Glenlee's longest recorded voyage was 1,269 days and maintaining endurance during this, and numerous more voyages, greatly depended on the men harnessing the wind for power. There is a remarkable story of life at sea under sail that is behind the hard work, frequent danger and constant challenge. The Clyde Maritime trust returned the tall ship to its berth at Riverside in 1992 and opened to the public as a museum ship in 1999 after its initial restoration. Based on the few remaining artefacts, such as a daily deck log, the ship today recaptures the era it was under sail. The Clyde Maritime trust, a registered Scottish Charity, aims to create an awareness of the maritime heritage of the River Clyde. They depend on support from the public and other donors to fund the upkeep and restoration of this historic sailing vessel. It ensures that it is continued to be a meaningful landmark and to further enable understanding of life at sea under sail.

3.2 Observations

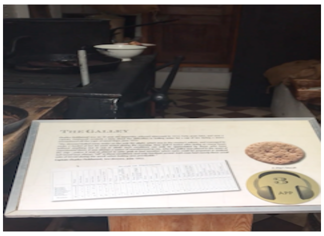
Museums generally showcase their artefacts and provide additional information through user interfaces. Examples of these interfaces in the real world tend to be pamphlets or audio so that visitors can read and listen while walking around the museum. During the field study in the Glenlee museum ship, information about the history of the ship were scattered throughout, even from yards away outside the ship. Furthermore, an audio guide and several books were also available at a price for visitors to use while exploring.



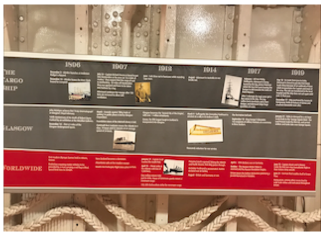
(a) *Short summary of what happened in 1922 is cemented into the ground outside the ship (Background is the Glenlee ship). Several of these, as different years, standstill yards away from the ship, lined up according to year.*

(b) *A section of the weather deck of the ship, showing information on a panel that is stuck on the main deckhouse.*

(c) *A section of the weather deck of the ship, showing the area around the poop cabin with a panel that lets visitors know that details about this area is available on the audio guide.*



(d) *A panel showing information about the Galley of the ship located inside the Galley itself.*

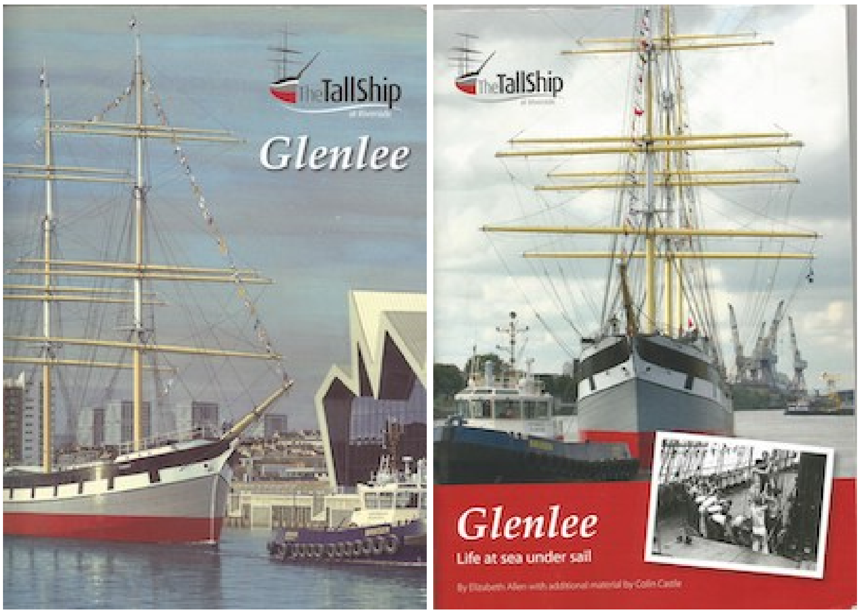


(e) *More information of what happened at certain years is available on the lower level of the ship.*

Figure 3.1: *A series of photos taken during the field study showing the different ways information is presented in the museum.*

3.3 Capturing Information

The museum also resides a shop within, selling souvenirs for visitors. Books were also popular displays in the shop and two particular books by Allen (2018) were found that serves as guidebooks to help visitors enjoy their visit and help them understand more about its history. Therefore, these books were purchased at the field to be used as reference so that information applied in the VR application align with these legitimate sources.



(a) (b)

Figure 3.2: Purchased books, by Allen (2018), at the field. Figure 3.2a entails information regarding the ship and Figure 3.2b entails information regarding the life under sail.

3.4 Possible VR Integration

Not only does the museum ship showcase its interior and exterior design, it can also be hired to host events such as parties. Another use of the ship that has been constant for years is offering a variety of teacher led learning workshops for primary school pupils. For example, pupils step back in time, investigating the lives of crewmen and officers during some of the ship's eventful voyage by unravelling contents of personal sea chests. Students get to discover the lives of characters through genuine sources like logbooks.

Children can often find it difficult to be engaged in cultural heritage type of museums but with the aid of virtual reality being integrated in the ship, demonstrators can take advantage of the immersive technique to intensify the pupils learning experience. A proposed use could be getting the pupils to experience travelling in treacherous waters, all the while hearing some captivating stories that shaped the World War One.

4 Requirements

This chapter will discuss the requirements gathering process, which derived a document detailing a list of user stories organised using the MoSCoW method. The document was established to present, in high-level form, the desired features of the application. It was used as a guideline throughout the development cycle to keep track of the implementation progress of each functionality.

4.1 Figure to capture requirements

The initial requirements gathered was the project proposal, which stated to develop a mobile VR application showcasing a specific region in Glasgow and its rich cultural heritage. This vague proposal was then elaborated during the initial meeting with the supervisory team. It was clarified that the choice of region is open, and so choosing an area within Glasgow was an assignment for the next meeting. Along this task, a number of research papers regarding VR and tourism were provided to review as the initial stages of the literature review (Chapter 2) for the project. Literature review is a significant phase to study existing work in the field that could supply insights in how to move forward with the project. Meetings with the supervisory team is the constant figure to capture requirements.

The aim for the second meeting with the supervisory team was to have a region chosen to showcase in the VR app. Therefore, the chosen historic tourist attraction is the tall ship, Glenlee, by the the Riverside museum, in which the field study was conducted (Chapter 3). From this stage, a requirements document was created and built upon throughout the requirements phase of the project while continuing to concurrently carry out the field study and review literature.

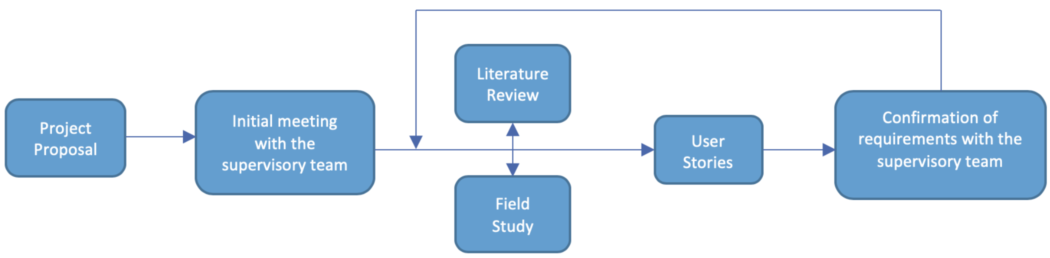


Figure 4.1: Iterative waterfall model of the requirements gathering lifecycle.

4.2 List Of Requirements

User stories are prioritised using the MoSCoW method. The order of user stories in each category are further prioritised, which can be seen by their assigned user story ID, 1 being the top-priority.

All user stories in the following tables are provided a description explaining the rationale behind the significance of the story with regards to the project. They also state which heuristic identified in Chapter 2 the feature will support.

4.2.1 Must Have

Essential requirements that must be implemented in the application to meet the objectives of the application.

ID	User Story	Description	Heuristic Support
M1	As a user, I want to see a map of the ship So I know where the different areas/rooms are on the ship	This is the most effective feature to aid spreading knowledge. The users are able to visualise the interior of the ship in 2D chart so that they have an idea in where to go when they are in the virtual ship.	H10, H7
M2	As a user I want to interactively navigate around the ship in the virtual world on my accord So that I only go to the areas I am curious to see	In a museum, visitors explore freely on their accord, therefore, users of the VR should not be forced into taking actions.	H3
M3	As a user I want to read a summary of the ship's history and life under sail So that I am informed while exploring the virtual contents of the ship	A summary should suffice in the proposed app to support for learning. Too in depth of information can be too overwhelming and so the app risks at not maintaining a sense of presence. There should also be a feature where users can learn more details if their curiosity deepens during their experience.	H10, H12
M4	As a user I want to walk around the virtual world without feeling unwell so that I can last longer in exploring the ship	This is a significant issue all VR apps should address, motion sickness.	H4

4.2.2 Should Have

Important requirements that should be implemented to further contribute to the success of the project.

ID	User Story	Description	Heuristic Support
S1	As a user I want to be able to choose which room/area to enter by interacting at a target location on the map So that I can quickly enter the desired location	Interaction is important to maintain a sense of presence.	H2, H12
S2	As a user I want to learn related information about random objects in the virtual world So that I learn more interesting facts about the past	Having information spatially near the object further support learning.	H10
S3	As a user I want an option stating the instructions in how to use the app So that I am not confused while using the app	Users should be able to know what to do during the experience, especially knowing when to leave the environment.	H8

4.2.3 Could Have

Features that enhance the usability of the application and provide a greater immersive VR experience. However, these will only be implemented if time permits.

ID	User Story	Description	Heuristic Support
C1	As a user I want to see a re-creation of the outdoor environment when I am on the deck of the ship in the virtual world So that I can visualise an old fashioned docking site or a typical weather while the ship is under sail	The tall ship's visitors see a docking site while on the ship. With a virtual environment that corresponds to the real one while on the ship exceeds user's expectation.	H2
C2	As a user I want a walk-through of the exterior of the model of the ship So that I learn what the ship looked like from the outside	This is another form of learning material of the app.	H10
C3	As a user I want to see the state of the ship when it was recovered after being forgotten So that I can see the improvements made to the ship for its restoration	Part of the history of the ship is how it was restored to become a museum ship, and so this is another form of learning material.	H10

4.2.4 Would Like To Have

Additional "bonus" features that don't affect the application's functionality and so success of the project do not rely on them. These will not be implemented as it won't be feasible by the delivery date.

ID	User Story	Description	Heuristic Support
W1	As a user I want to listen to information regarding what I see during a walk-through So that I can learn about the ship while exploring the ship	The real museum support audio for explaining what the visitors are seeing on the ship.	H2, H10
W2	As a user I want to see virtual historic people carrying out their daily tasks while on board so that I am fully immersed in the experience	Visualising what the people did on the ship while on board aids spreading knowledge about the past.	H10

5 Design And Implementation

This chapter will detail the iterative waterfall model of the development life cycle. It will list the technologies used and will rationalise why these were chosen instead of an alternative approach. Key screenshots of the virtual environment designs are presented with explanations, while the rest of the screenshots are in the Appendix A. Furthermore, it will also list some key summary of challenges encountered during the development.

5.1 Development Approach

Once the requirements have been gathered, the development commences. As a novice in VR development, the initial approach was to follow basic online tutorials that provide the foundations in how to operate the Unity platform and create 3D models. The main source of tutorials followed were the free online courses on the educational website, Udacity, along other resources such as YouTube, (Unity Learn) page and many more.

During the actual development of the project, an iterative model is followed based on the fixed requirements. This process includes the implementation, which in turn consists of the 3d modelling and programming, and approval by the supervisory team. This is repeated until the team is confident for the final prototype to move forward to the evaluation phase.

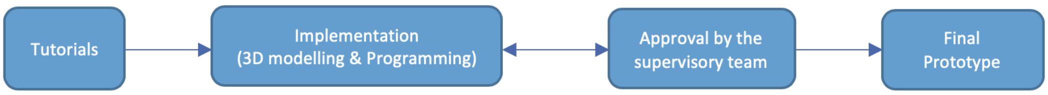


Figure 5.1: *Iterative waterfall model of the development lifecycle.*

5.2 Technology Used

5.2.1 Unity

(considered alternative - Unreal Engine 4)

When it comes to VR development, Unity and Unreal Engine 4 are the most popular and capable game engine tools. Unity seemed to be the obvious choice as it has an active, supported community with vast resources to aid a novice learner.

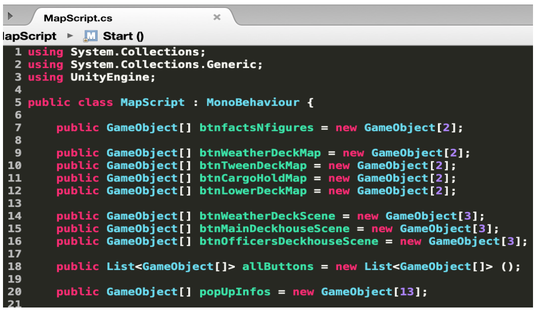
One shared advantage of both VR engine tools is that there are tons of pre-built software packages that external developers has uploaded onto the asset store. These are either under free license or with a charge. This greatly helps other developers to use assets such as scripts, 3d models, animations and many more for rapid development of their own applications.

5.2.2 C#

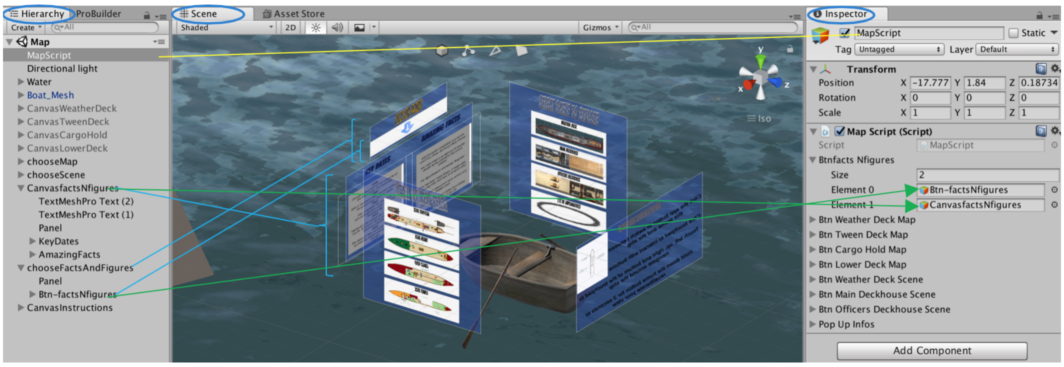
(considered alternative – JavaScript)

This language seemed to be the most obvious choice as a developer who already possessed an advanced skill-set in the very similar programming language, Java. Additionally, it was also the most common language in many tutorials and discussion on online forums at the time of development.

Programming in a high-level fashion is possible with the object-oriented language being integrated into unity since C# is supported in a component-based architecture. This means that when a public variable of a particular type class is declared in a C# script, they can easily be instantiated by a drag and drop method in the scene editor. A good example within the project is the C# MapScript.cs that is attached in a MapScript GameObject within the Map scene (Figure 5.2).



(a) A section of the C# script called MapScript.cs showing the variable fields. These are declared public so that they will show in the inspector window on Unity editor in Figure 5.2b below.



(b) A screenshot of Unity editor showing the map scene.
-The scene is composed of multiple GameObjects, which are listed in the hierarchy window. Examples of this is shown by the blue lines.
-When an object in the hierarchy window is selected, details of that object is shown in the inspector window. An example of this is shown by the yellow line; a MapScript object was created to attach the MapScript.cs script to it.
-The green arrows represent examples of how the drag and drop method is used. Fields in the MapScript.cs in Figure 5.2a were declared public so that they will appear in the inspector window. Those fields are then instantiated by dragging the GameObjects from the hierarchy into the corresponding boxes in the inspector.
-With this intuitive approach, sub-components of those GameObjects can be referenced in the C# script allowing simple tweaking of the objects appearance or behaviour.

Figure 5.2: *Screenshots showing how C# scripts are tied with the objects in scenes.*

5.2.3 Google Daydream View

(considered alternative - Google Cardboard or Samsung Gear VR)

A mobile VR headset is chosen over a standalone headset (such as the Oculus Rift, HTC Vive, etc) as they are simpler to set-up and requires lower commitment in terms of cost. For these reasons, mobile VR devices are more accessible to the public, which benefits this project presuming that the application will be uploaded on the Google Play Store.

The choice of the Google Daydream View stemmed from a purely subjective point of view. Firstly, Daydream and Gear allow more feature-rich experiences than Cardboard for obvious reasons. Lastly, having experienced both Google Daydream and Samsung Gear, it was found that the overall design of the chosen device wins. Daydream is lighter in weight with less straps attached and its sleek, fabric design is more comfortable as opposed to the bulky, plastic design of the Samsung Gear VR.

5.2.4 Samsung Galaxy Note8

(considered alternative - any Daydream-ready smartphones)

Among the long list of Daydream-ready phone apps, Samsung Galaxy Note is one of the top recommended smartphones that is best experienced with the Daydream headset. At the time of development, the Note8 was the device the school of Computing Science department already had accessed. Therefore it was highly likely to be the most compatible with the recent versions of any tools used within the project.

5.2.5 Beats Solo Headphones

(considered alternative - any high-quality headphones)

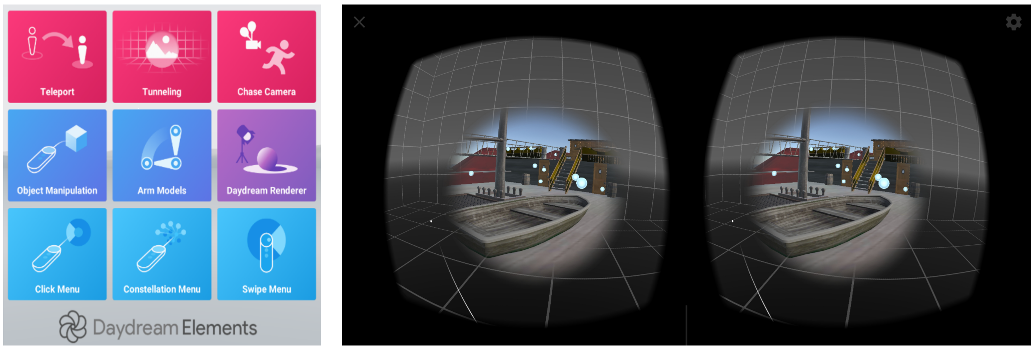
A pair of high quality headphones are needed for an immersive experience in virtual reality and this type of headphones happened to be the device already possessed during the development of the project.

5.2.6 Google VR SDK For Unity version 1.180.0

(considered alternative - any other SDK version that is compatible with Daydream Elements)

The software development kit is required when creating a VR application for Android. It provides developers simple, ready-to-use API's that can be referenced to add interactive elements into their application. For example, some of these APIs are needed to access functions of the daydream controller. The package also includes, as extras, some demo scenes to provide developers an overview of the fundamentals of VR development in Android.

More recently, Google introduced an open source project, **Daydream Elements** shown in Figure 5.3a, that uses the Google VR SDK to present solutions to some physiological, ergonomic, and technical challenges. It includes more complex demos showcasing principles and best practices for developing high-quality VR experiences. The idea is for them to be easily configurable and reusable for any applications and so, the capability of the tunnelling element is used in this project to attempt to rectify any possibility of motion sickness issue while walking in the virtual environment. It is a technique where, during movement, the camera is cropped and a high-contrast stable grid is displayed in the user's peripheral vision.



(a) Daydream Elements. *(b) Tunnelling element in action.*

Figure 5.3: *Figure 5.3a shows icons of the Daydream Elements available with the Google VR SDK. The tunnelling element is used in the VR application to combat motion sickness and Figure 5.3b shows this element in action within the developed VR application.*

5.2.7 Tools used to build 3D models

(Unity Asset Store, TurboSquid and ProBuilder)

Throughout the project, one of the biggest challenge was finding 3D models resembling the artefacts in the actual museum ship. The main resource used to obtain these 3D models was the Unity Asset Store and even despite it being the most useful source of the project's many assets, it was still not enough. Eventually, it was necessary to resort to external resources like the website TurboSquid.

Due to the project's demand of a recreation of an existing real-world ship, it was inevitable to resort to other tools that allow creation of new models. The wise choice of tool was ProBuilder, an official Unity extension tool that is used for creating different types of custom assets for enhanced realistic VR scenes. ProBuilder required little knowledge with 3D modelling and so it aligned with the lack of experience in the area.

5.2.8 GitHub

(considered alternative - GitLab)

This is the version control system used to manage the source code throughout the duration of the project. The repository of the project is private that is free of charge, taken advantage from the GitHub Student Developer Pack. It is also an additional resource to log details relevant to the project such as meeting minutes with the supervisory team, time log summarising the tasks achieved on the days worked on the project, and a few other miscellaneous information.

Another tricky challenge tackled during the stages of the project progressing was the limited storage space, both locally and remotely. GitHub only allows push up to 100 megabytes, which is generally not ideal when dealing with any major VR project due to their large file size from assets. In order to solve this problem, an open source Git extension called Git Large File Storage (LFS) (Git LFS) was used. The repository's large asset files are replaced with text pointers inside Git, while storing the file contents on a remote server, in this case GitHub.com (GitHub).

5.3 Design

The VR application consists of five scenes in total:

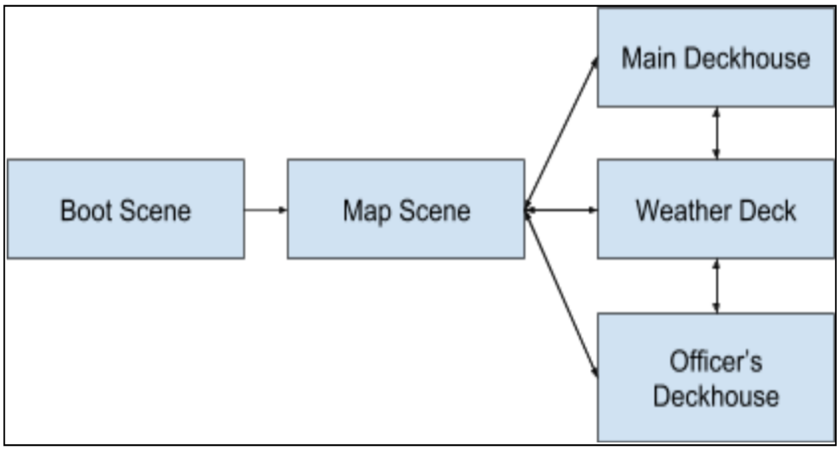


Figure 5.4: *Boxes represent the different scenes in the app and the arrows represent which scenes can be accessed from other scenes.*

- The **boot scene** used to load the GameObjects that are constantly used throughout the VR app. These include the player, audio and used prefabs provided by the Google VR SDK. These are loaded once and they are not destroyed between scene transitions.
- The **map scene** containing 2D maps of the different level of the ship aided with lots of information about its history. It also serves as the "main menu" as it contains an instruction and selections of what information to view and which scene to explore.
- **Three explorable scenes**, each of which are a recreation of an area/room of the actual ship.

5.3.1 Scene Screenshots

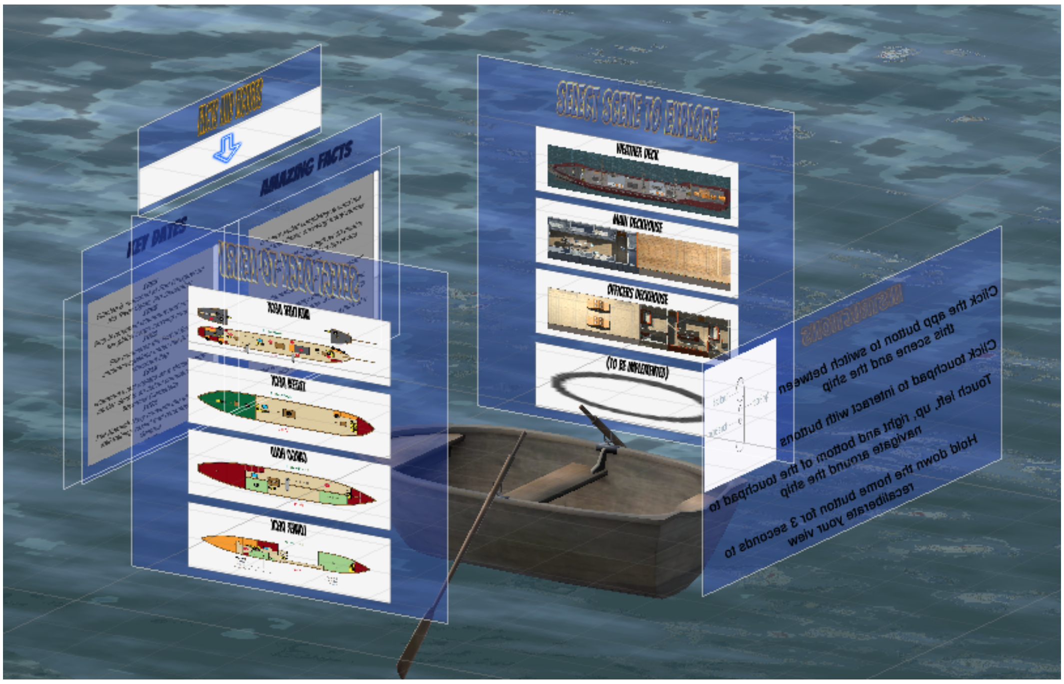


Figure 5.5: Map Scene on editor mode in Unity.

Figure 5.6: A bird's eye view screenshot of the weather deck scene taken on editor mode in Unity.

Figure 5.7: A bird's eye view of the officer's deckhouse scene taken on editor mode in Unity. The ceiling was temporarily moved to the left side so that this screenshot can be taken.

Figure 5.8: A bird's eye view of the main deckhouse scene taken on editor mode in Unity. The ceiling was temporarily moved to the right side so that this screenshot can be taken.

5.3.2 The Map/Main Scene

On the first time opening the app with a new user, they will begin their journey in the map scene, facing the instructions (Figure 5.3.2) in how to use the daydream controller in order to navigate around the virtual world. In the same scene, they will be able to look around where they will find themselves sitting on a small wooden boat with paddles hanging on either side. They are in the middle of the sea listening to the soothing sound of a sailing ship, a sound effect that is constant throughout their VR journey. Looking around, they will find several options to move forward with their experience, whether to read about the ship in this scene or to switch into a new scene to explore the virtual recreation of the ship. If the latter is chosen, they have the power to return to the map scene at anytime.

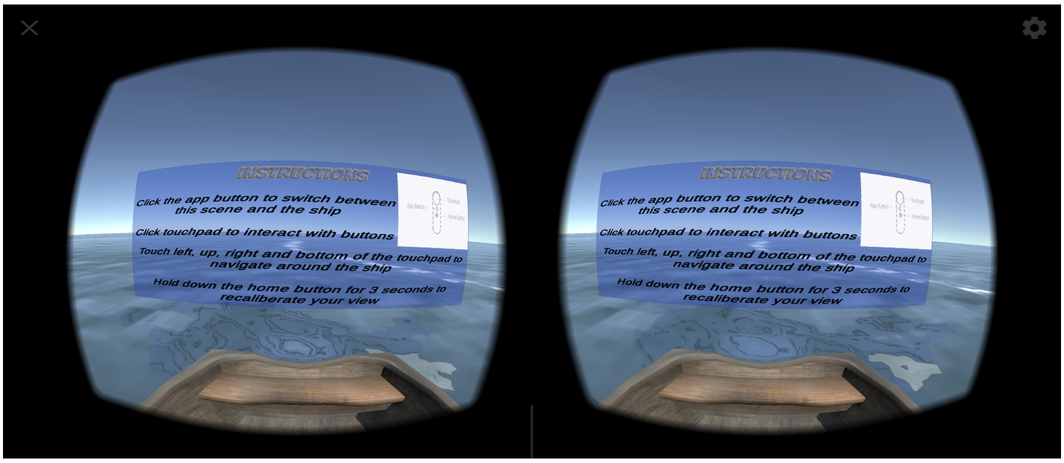
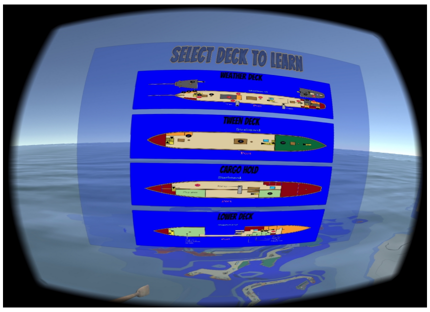
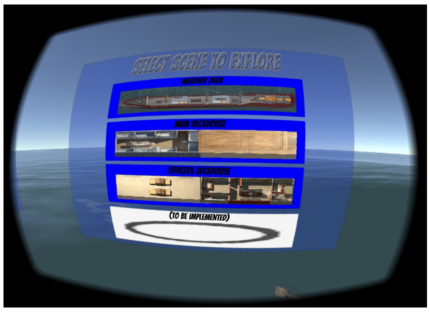


Figure 5.9: *Instructions on a canvas in the map scene, which the user faces when opening the app for the first time*

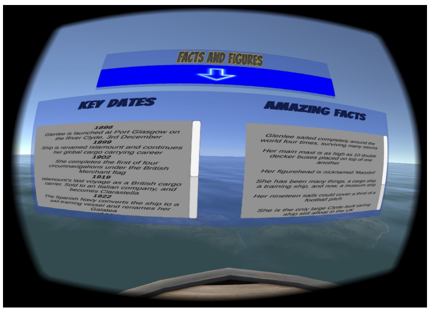
The map scene displays the timeline of the ship's lifetime, interesting facts and a map with information of each deck level. Around the user who is sitting on a boat, there are several UI canvases on each side (5.10), one of which contains instructions (Figure 5.3.2) as previously mentioned.



(a) Map canvas containing buttons, each showing a map of the corresponding deck level of the ship.



(b) Scene canvas containing buttons, each showing an overview image of the corresponding scene.

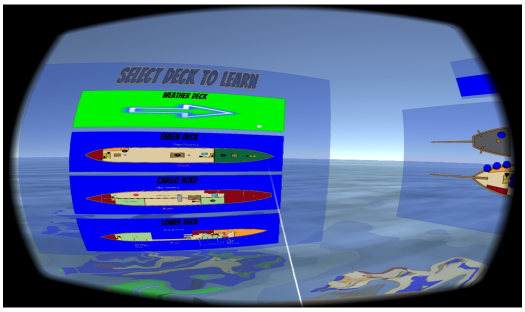


(c) The main canvas showing highlights of interesting information about the ship.

Figure 5.10: *These are the other canvases in the map scene, along with the instructions canvas in Figure 5.3.2. The information on the main canvas is the default view, however, each button in (a) and (b) replaces contents in that main canvas in (c)*

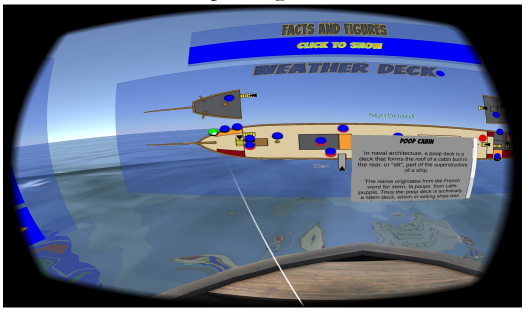
The main canvas (Figure 5.10c) changes appearance depending on the selection the user makes from the other canvases. Above this main canvas is a button that is when clicked reveals the timeline and facts, the default view of the main canvas.

Another canvas (Figure 5.10a) contains several buttons representing each deck of the ship and when clicked, shows the map on the main canvas. Each map contains buttons that is when clicked, shows/hide a UI canvas containing information of the room/area specific to their location on the map. On some of these canvases on the map, there is another button that allows users to go into a scene that is a recreation of a room/area on the ship presented by that information. An example of this kind of interaction is shown in Figures 5.11.

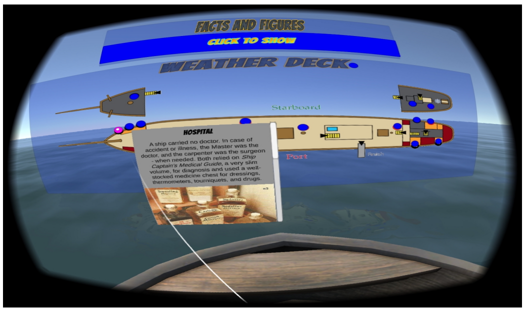


(a) A canvas containing buttons of the maps where the weather deck was clicked. The arrow hints to the user to look at the canvas it is pointing, shown in 5.11b.

(b) Actions from 5.11a replaces main canvas with the weather deck map. The blue circular shapes are buttons representing a room/area on the corresponding position.



(c) The weather deck map showing pop up information after the "poop cabin" button was clicked, which is indicated by its button being red. The raycast is pointing at another button, triggering a colour change.



(d) Clicking the button being targeted in Figure 5.11c triggers a closure of an opened pop up and opens another pop up.

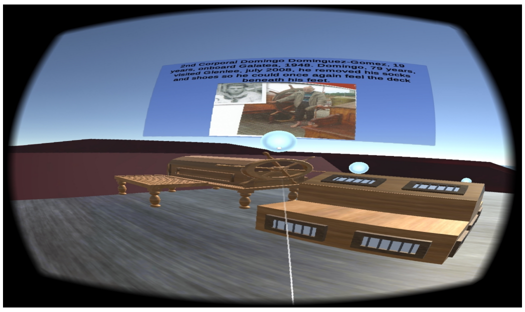
Figure 5.11: *An example of interaction in the map scene that aids spreading knowledge.*

Lastly, another canvas (Figure 5.10b) contains buttons representing the implemented scenes with one exception; one button is not clickable as this can be used for when the app is extended to implement more scenes in the future. When a button is selected on this canvas, the main canvas jumps to show the corresponding deck map with the information of the selected scene, as if a button on the map has already been selected. An example of this kind of interaction is shown in Figures 5.14.

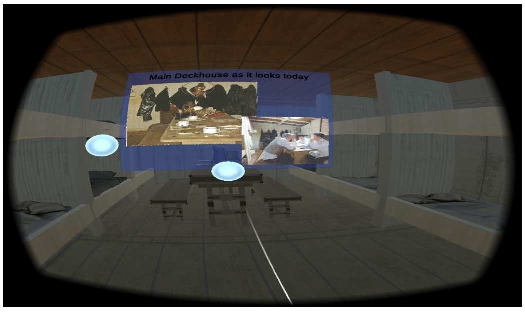
5.3.3 The Virtual Museum (Explorable) Scenes

In the virtual museum ship, users will be able to explore by communicating with the daydream controller. Touching the forward edge and the backward edge of the touchpad allows the user to walk forward and backwards in the virtual world respectively, while touching the left edge and the right edge of the touchpad allows the user to rotate their view left and right respectively. While on the ship, they will find many "orbs" and each reveals a UI canvas when the raycast from the controller is hovered over them. Each UI canvas presents information and/or image that is specific to its spatial location on the ship. This allows users to make direct connections between the area on the ship and the fact presented. Additionally, the orientation of the canvases is fixed so that when viewing an image, the part of the virtual ship visible to the user is shown as background and this is also what is shown on the image.

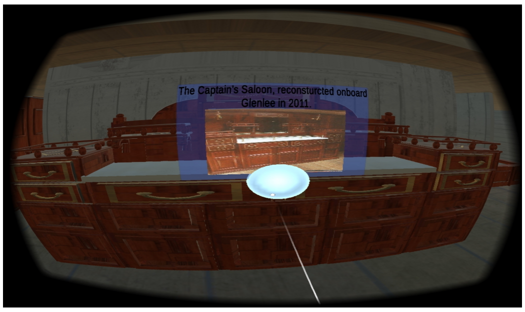
(a) From the weather deck scene.



(b) From the weather deck scene.



(c) From the main deckhouse scene.



(d) From the officers deckhouse scene.

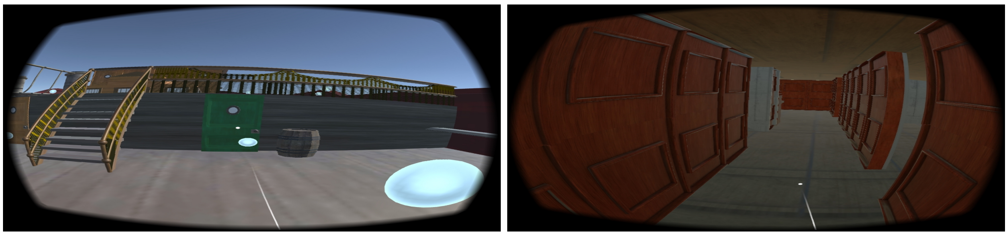
Figure 5.12: *Examples of "orbs" in the virtual environments being hovered over by the raycast (white line) from the daydream controller, revealing information and images relevant to the spatial positioning of the canvas.*

5.3.4 Switching Between Scenes

There are three ways to switch between scenes:

- **Clicking the app button on the daydream controller**
  This is the only way to switch between the map scene and the virtual ship. This method remembers the state of the map and the position of the user in the virtual world. When the app button is clicked for the first time, which the user will most likely be in the map scene, they will be redirected to the weather deck of the ship at default position. An example of this kind of navigation is when the user is reading about certain contents on a specific UI canvas, let's say about the "Chart Room", in the map scene and they switch into the virtual ship by clicking the app button on the daydream controller. The user is then free to walk around the ship on their accord. If the user returns to the map scene by clicking the app button again, they will return into the scene with the Chart Room canvas already opened. Likewise, the user can leave the map scene by clicking the app button and they will begin in the position of where they left off in the virtual world.

- **Through doors in the virtual world**
  Certain doors are highlighted when the raycast (a white line from the daydream controller used to target) is pointed at them. This lets users make the obvious assumption that the highlighted door leads to another area of the ship, which can be then be entered by clicking the touchpad. If the user decides to explore what's on the other side of the door, they begin their journey in the next scene at a suitable position, a few inches and facing away from that door.

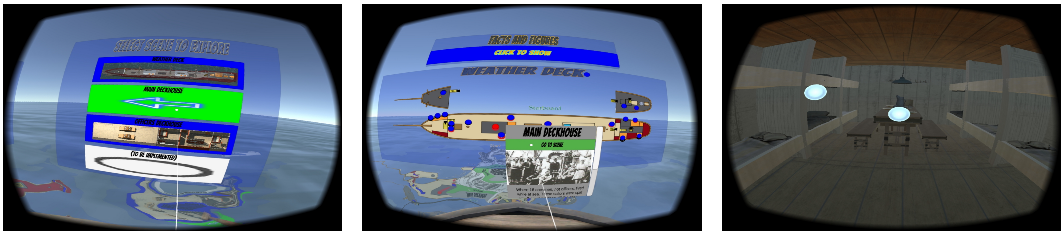


(a) A door on the weather deck scene is highlighted while the raycast from the controller targets it. When touchpad is clicked, the scene changes. See 5.13b.

(b) The action in 5.13a triggers a change to the officers deckhouse scene, spawned at a specific position. Behind this view is the other side of the door that was highlighted.

Figure 5.13: *An example of scene transition through doors in the virtual environment from the weather deck to the officers deckhouse.*

- **Clicking buttons on UI canvases in the map scene**
  As previously explained, one canvas contains a selection of implemented areas/rooms in the virtual world. When a selection is made, the main canvas shows the map of the deck where the room resides, information of the room and an option to go into the virtual room. If the user decides to explore the room, they begin their journey in the next scene at a default position.



(a) A canvas containing buttons of the scenes where the main deckhouse was clicked. The arrow indicates to look at what is pointing, which is shown in 5.14b.

(b) Actions from 5.14a triggers a pop up information of the main deckhouse. It also contains a button "Go To Scene" that teleports the user to the corresponding scene.

(c) Actions from 5.14b spawns user at this default position in the main deckhouse. The blue "orbs" can be hovered over to reveal more information about the history of this room.

Figure 5.14: *An example of scene transition through clicking buttons on UI canvases in the map scene; from the map scene to the main deckhouse.*

5.3.5 Design Summary

The app essentially consists of different kinds of interactivity in order to learn about the history of the ship. The virtual environment in the map scene only consists of UI elements, which the user communicates based on their past knowledge on using any computer device. For example; clicking the touchpad on the daydream controller to interact with buttons on the UI, swiping the touchpad to scroll a UI to reveal more information, etc. The other type of interactivity, assumed as the more immersive experience, is the one where the participant walks around the virtual environment of a re-created ship, exploring the virtual model and learning the history on UIs located on some locations on the ship.

The organisation of the user interfaces in this app is inspired by the research of Sanders (2018), reviewed in Chapter 2, who found that spatial interface is most effective when communicating knowledge. Information and images are only located at the area in the virtual world that relates to the information. This allows for users to make direct connections between the area and information.

5.4 Summary Of Challenges

- The real ship is too large to recreate that includes all of the areas and rooms, especially with the short time constraint. This resulted into implementation of only three areas.
- Finding assets online that resembles the real physical objects is difficult. These include 3D objects, material, audio.
- Above challenge resulted in the need to create 3D models from scratch, which in turn is time consuming especially without any prior experience in 3D modelling.
- VR projects naturally require large storage due to the high quality models and GitHub only allows push up to 100 megabytes, which was not enough. This was solved using Git Large File Storage (LFS).

6 Evaluation Of The Application

This chapter will discuss the objectives and structure of the evaluation. It will include details of the participants and how they were recruited. Finally, it will describe the structure of how data was gathered and the findings based on the perspectives of the participants.

6.1 Objective

The primary objective of this evaluation is to identify an effective method to spread knowledge, in VR, about a tourist attraction, in this case the museum tall ship. Additionally, it should be possible to compare user's visitation intentions before and after their VR experience.

In order to make a good comparison, examination of the participants background is significant and so the factors that must be determined are:

- user's knowledge of the tall ship
- user's experience with any VR technology
- user's perspective on tourism

The usability evaluation methodology that will be used specifically for this project will be split into evaluating the application's user interface (UI) and user experience (UX). Therefore, we must gather participants' opinions about the app's with regards to these measurements.

- UI - refers to the set of elements (such as canvases, buttons, etc.) that users interact with to control what they see or their next course of action.
- UX - refers to how users feel about the interactions that resulted from the improvements to the UI.

Ultimately, UI and UX designs must align in order to address the heuristics we followed, proposed by Sutcliffe and Gault (2004), to develop the VR application. This usability evaluation will also determine the effort the users have to go through in order to achieve a goal while using the application.

After gathering feedback regarding their experience with the proposed VR app, there is still a need to further probe for more opinions about the following:

- The app's effectiveness at communicating information
- User's visitation intentions

The overall aim is to examine the correlation between the measured variables and how informative the tourist spot appeared in the VR app can affect the user's intentions of visiting.

6.2 Framework/Protocol

Participants were asked to sit on a swivel chair for the duration of the evaluation in spite of the app's functionality of being able to rotate the view horizontally using the controller. This allows for greater mobility and flexibility when they wish to be fully immersed by physically rotating their body and heads.

Figure 6.1: *A participant wearing and holding the equipment, experiencing the VR app during the evaluation, all the while sitting on a swivel chair.*

Data were gathered using questionnaires through Google forms, which were anonymised. In addition, the "think aloud" protocol was also applied throughout, which means notes were jotted down of the significant events such as their memorable comments, when they needed help, etc. The evaluation process lasted approximately 15 minutes and it consisted of 5 stages:

1. **Introduction**
   A brief description and the purpose of the project were first introduced. They were made aware of the structure of the evaluation process and its approximate duration. They were also informed that they are able to stop participating at any time. These details are stated in the introduction of the Google forms prior to the pre-study questionnaire.
2. **Pre-study questionnaire**
   This is the first questionnaire on the Google forms that they filled up. As mentioned, the purpose of this stage is to discover their general background regarding the tall ship, virtual

reality and tourism. A summary of the ship's history was presented, however majority of the volunteers did not read this description, skipping to answering the series of questions. The average duration spent on this stage was approximately two minutes before clicking next, which then asks them to get the demonstrator's attention for the next stage.

3. **The VR experience**
   Participants were then guided in wearing the daydream VR headset, as well as given the controller. Firstly, they were given a crash course in what the application can do. They were verbally instructed in where to look in the virtual world as they perform actions on the controller. They were made aware of the different scenes available that they can explore. The crash course only took roughly 1 to 2 minutes, depending in how they seemed comfortable being on their own in the virtual world. Once this happened, they were notified that the headphones will be put on so they can explore independently. Prior to this, they were informed that they are allowed to talk, ask questions and they were reminded that they can leave the experience at any time. The average duration spent at this stage was 11 minutes.
4. **Post-study questionnaire**
   They were then asked to fill up the final section of the questionnaire while their experience is still fresh in their mind. The purpose of this set is to determine what they think of the app in terms of its UI and UX so that we are able to infer its overall effectiveness. This is also the best source for gathering positive and negative feedback since it is anonymised. The average duration spent at this stage was also 2 minutes.
5. **Wrap-up**
   The evaluation has completed and the volunteers were thanked for participating. They were also given the opportunity to ask any questions even though no data was recorded at this stage.

6.3 Information About Subjects

Subjects were recruited through the word of mouth, which also meant that the project was open for some discussions. I believe that this has made the recruitment process even simpler as people proactively volunteered out of curiosity based on the feedback from the participants who have already experienced the app. This has also benefited the evaluation process as having prior knowledge of what to expect during evaluation could have meant that they were less likely to drop out during evaluation.

Twenty participants have evaluated the VR in total and their age range and background demographic are illustrated in Figure 6.2 and Table 6.1 respectively.

Evidently, majority of the participants were at the ages between 18 and 25. This could mean that results to questions related to the usability of the app could be more positive as it is assumed that the younger generation is quicker at getting a solid grasp on using the technology. On the other hand, having 35% of participants that are over 25 could also mean that results to questions related to passing on knowledge could be more positive as it is assumed the the older generation takes more interests in cultural heritage. This is backed up by McIntyre (2007) who stated that nationally, museums have a fairly old visitor profile compared to the population as a whole.

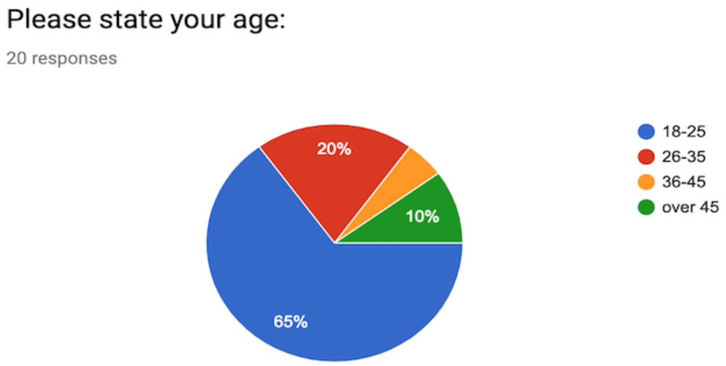


Figure 6.2: *The age range of all participants.*

As a fellow Computing Science student, it was inevitable to recruit other fellow Computing Science students as participants. Great effort was placed to round up other participants from different background. In the end, half of the participants were Computing Science students. This could have benefited the project as more critical feedback could be left in terms of the technical aspects of the project, as well as opportunities for them to provide technical suggestions to improve the usability. On the other hand, having half of the participants as non Computer Scientists could also mean that this is an opportunity to take their feedback as insights into how the project could be improved to extend to the general public.

Background	**Number of Participants**
Computing Science Student	9
Computing Science/Business Management Student	1
Immunology PhD Student	1
Philosophy Masters Student	1
Serious Games and VR Masters Student	1
Bar Manager	1
Accountant	1
Senior Engineer (Product Conformance)	1
Marine Biologist	1
Doctor	1
Nurse	1
Web Developer	1

Table 6.1: *The demographic background of all participants.*

6.4 Results/Discussion

This section will discuss the results of the evaluation based on the answers obtained from the post-study questionnaire and the notes jotted down from the think aloud protocol during evaluation (Appendix D). The results will be summarised both quantitatively and qualitatively. This will be split into subsections since the post-study questionnaire was split into UI, UX and overall experience. In each, an analysis of the results will be derived based on what are known about the participants from the pre-study questionnaire and what are known about the design of the application. The analysis will continually refer to the objectives of the evaluation.

The sections under UI and UX in the post-study questionnaire required participants to rate specific designs of the app. They needed to rate on a scale of 1 to 5, 1 being towards the negative feedback and 5 being towards the positive feedback of the scale. The average rating of each question is then calculated. These average ratings are summed up to obtain the total mean rating. These numerical values can be found in Table 6.2 and 6.3. We will refer to the ratings as "score" since it indicates a level of success each design has achieved.

6.4.1 User Interface

The UI design of the app achieved a score of 78.6%, which is derived from the total mean rating. The lowest score obtained was the intuitiveness of the map scene and the highest score obtained was the virtual environment appearing as a museum ship.

Question	**Mean Rating**
How well did the environment seem as a museum ship?	**4.3**
How self-explanatory was the main menu, i.e. the map scene?	**3.7**
How consistent was the various displayed information?	4.1
How natural did the 3D effect, such as the sea, seem?	3.8
How natural did the view seem when you were walking around?	3.75
Total Mean Rating	**19.65 (out of 25)**

Table 6.2: *Quantitative data showing the average rating(score) each user interface design has achieved.*

There have been some positive feedback with regards to the map scene such as liking the way information was displayed as text and image "holograms". Ironically, one participant commented about the use of scrolling was "intuitive". However, the low rating is confirmed by some suggestions. A scenario during the evaluation was when the participant clicked a button under "Select scene to explore", the first assumption was that the action would teleport the participant to the scene. Instead, an arrow appeared on the button pointing towards the main canvas. This was an indication to look at the main canvas where there is more information about the room/scene and another button called "Go To Scene", which is the button that will carry out the teleportation. Another participant pointed out that it would've been easier if the button itself had executed the task rather than making the user figure out where to look in the map scene. One other comment that summarises the map scene was "The map scene was confusing at the start as I did not know what the different buttons did but it was easy to use after learning it." In hindsight, the map scene can be greatly improved if users were shown less canvases and less buttons at a time or per action. The map scene may have been too overwhelming for the users, resulting in confusion in what to do next.

The positive feedback with regards to the virtual environment as a museum ship is also justified by some comments. For example, one participant liked the "detailing of the different 3D models". Another participant shouted out during the VR experience; "I went on the ship, and this really does resemble it. I remember these steep steps!".

6.4.2 User Experience

The UX design of the app achieved a score of 79.3%, which is derived from the total mean rating. The lowest score obtained was from the concentration on absorbing information and the highest score obtained was not feeling unwell (i.e. motion sickness) during their VR experience.

Question	Mean Rating
How easily did you learn to use the application?	3.8
How easily did you learn to navigate in the environment in different situations?	4
How easily were you able to anticipate what would happen next in response to the actions that you performed?	4.2
How much were the rotation and moving direction of your character consistent with your actions on the controller?	4.15
How well did you concentrate on absorbing information rather than on the device used to perform activities?	**3.6**
Did you feel unwell during your VR experience?	**4.3**
How aware were you of events occurring in real-world around you?	3.7
Total Mean Rating	**27.75 (out of 35)**

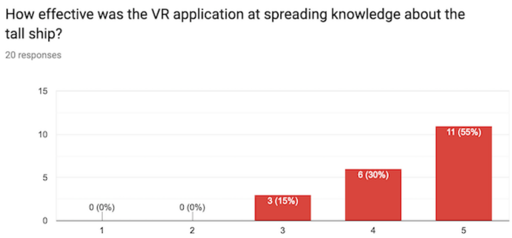
Table 6.3: *Quantitative data showing the average rating(score) each user experience design has achieved.*

Absorbing information during their VR experience could be correlated with the fact that the intuitiveness of the map scene also received the lowest score in the previous section. The map scene includes a lot more facts than in the virtual ship, and so some participants may have not paid much attention to the information presented in the map scene because the interactions within was more difficult. They may have chosen to walk around in the virtual world because this was simpler to navigate. One participant, who was over 45 years old, said "I wasn't reading because I was concentrating on the controller". The same participant then added: "Most of what I experienced was great, but because I didn't quite know how to use it (because I'm old and bad with technology) a lot of what was great, was lost on me.". On the contrary, the reason of the low score of this aspect of the UX design could be correlated with the lack of participants who are interested in cultural heritage and tourism. These factors could in turn be correlated with the fact that majority of the participants don't often visit tourist attractions based on our pre-study questionnaire. One memorable participant seemed to be very immersed during the VR experience, all the while absorbing information. The participant was amazed at the fact, presented in the map scene, that the masts were as high as two double decker buses. Participant then switched to the scene containing the virtual masts, looked up and evaluated whether or not it actually was as high as two double deckers buses. Reading more information while in the virtual ship, participant shouted, "Can't believe the captain brought his wife on board, poor woman!". The same participant even added a helpful suggestion; "I think that having virtual people on the ship such as a captain who you could interact with, even in a basic fashion where some text appears as if he's talking to you, would enhance the experience greatly. I felt a bit lonely in the scene, it wasn't natural to be on the ship by myself.". This is a very informative insight as it may seem frightening being alone on a ship in the middle of the ocean. Having virtual characters around such as the captain is also a good idea for a "sail back in time" experience.

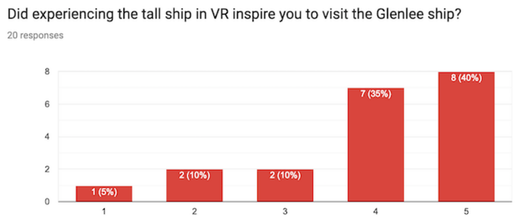
The highest score of 4.3 towards whether or not participants felt nauseous during their VR experience proves that the app follows the design heuristic 4 (Close coordination of action and representation), described in literature review. There is a large concentration towards the scale of not feeling unwell at all. Two people answered that they felt very unwell during the experience. One theorised that it was because of wearing eyeglasses. The other participant withdrawn from the experience five minutes into walking around the virtual ship as the participant suddenly felt unwell. However, the post-study questionnaire was still answered. This sparked up a discussion regarding the participant's sea sickness issue when travelling on a boat such as a ferry. This may have suggested that the VR app is effective as the participant seemed to be immersed into the sailing experience since the sea sickness would be naturally felt anyway while on a boat in the real world. The app was developed in a way that also avoids motion sickness by cropping the camera to only focus on a small area on the users view during movement (Figure 5.3b). This was aided by a Google Daydream Element described in Chapter 5.2. I believe that the app was successful in avoiding motion sickness, however, some individuals are naturally more prone to motion sickness.

6.4.3 Overall Experience

In order to achieve the aims of the evaluation, the participants were asked of their opinions on the effectiveness of the app at spreading knowledge and how inspired they are at visiting the real ship after experiencing the VR. The quantitative data are shown on figure 6.3a and 6.3b. It can be clearly visualised that there is a high concentration towards the positive answers in response to the questions.



(a) Participants' ratings of their opinions regarding the effectiveness of the app at spreading knowledge after the VR experience. 1 being not very effective and 5 being very effective



(b) Participants' ratings of their visitation intention after their VR experience. 1 being not at all inspired and 5 being very inspired

Figure 6.3: *Bar graphs illustrating the summary of participants' answers to the corresponding questions about their opinions based on their overall VR experience.*

There is a correlation between the results related to the effectiveness of the VR at spreading knowledge and the results gathered from the pre-study questionnaire. 45% of the participants have never heard of the tall ship prior to the evaluation and according to the post-study question, the average rating they have rated this aspect is a high 4.4 with 55% of them strongly agreeing. This indicates that they have learned new information about the ship after their experience.

Participants' visitation intentions, however, did not show much of a change. 50% of the participants have never visited the museum ship before this evaluation. Even though the average rating this question has achieved is a fair 3.95, only 50% of them have strongly agreed that they were very inspired in visiting the ship. This could mean that most people who were very inspired were also the same people who have not visited the ship.

6.4.4 Other Discussions

This section will discuss some miscellaneous highlights that occurred during the evaluation.

One participant was curious during the experience if it was possible to jump out of the ship. The curiosity was put to test and was successful. The participant was able to get out of the water by clicking the app button to return to the map scene, from where can be transferred to another or the same scene at default position. This sparked up an entertaining challenge between some participants who were friends where they must find a way to jump out of the ship and into the water. Only two other participants were successful. This bug was discovered by the curious participant, but interestingly turned into a feature.

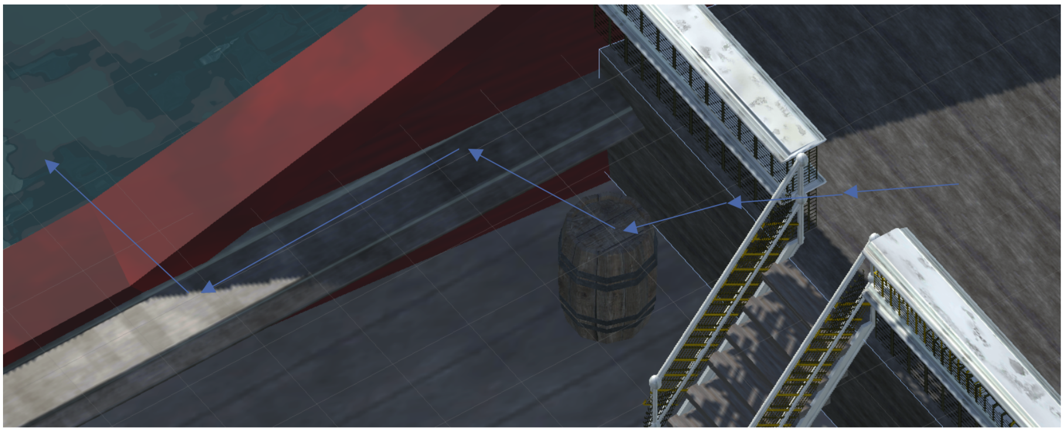


Figure 6.4: *The spot where it is possible to jump out of the ship and into the water; the corner of the lower level of the weather deck where a barrel is placed. The arrows represent the trail of the participants. Some participants walked on the upper level through the narrow area between the barrier and steps. Then, they used the barrel and the platform on the side to continue to walk towards the water.*

6.4.5 Feedback Summary

Key Negative Feedback

- "I wasn't reading because I was concentrating on the controller."
- "It made me feel a bit sick. I think it was because of my glasses."
- "I don't like it when the view is restricted to one spot when moving around."
- "The orbs get in the way sometimes."

Key Positive Feedback

- "Animation of water is very realistic."
- "It's quite easy because the use of scrolling is very intuitive, useful."
- "The sound is very atmospheric. If it was silent, it would be a different experience."
- "I went on the ship and it really does resemble it. I remember these steep steps!" (Figure 6.5)

(a) Field Study Photo *(b) Virtual Environment Screenshot*

Figure 6.5: *The steep steps that one participant was referring to during the VR experience.*

7 Conclusion

7.1 Contributions

The innovation virtual reality has touched a lot of industries including tourism and the crossover between virtual reality and cultural heritage is becoming a trend in the field of research even more recently. However, there are still not many VR applications that put those research into the field. Therefore, the aim of this project was to develop a mobile VR application showcasing one of Glasgow's rich cultural heritage, The tall ship, Glenlee, that resides by the Riverside museum.

The main objective was to design the application in a way that spreads knowledge and changes users' visitation intention positively.

Literature review was required to initially provide insights into how VR can be successfully designed and identify aspects to avoid from similar projects. A field study was also carried out where the actual museum ship was visited to take a closer look of the physical objects to help for 3D modelling, as well as to gain a deeper understanding with regards to its history. Next, a variance of the iterative waterfall model was conducted during the design and implementation stage of the project. This means that requirements were concurrently gathered as the VR application was being developed. Finally, the delivered VR application was evaluated by 20 participants in order draw a conclusion whether or not the objectives were met.

Evaluating the application was not as simple as asking participants after their VR experience whether or not they were inspired to visit the physical ship and whether or not they have gained new knowledge. More measurements were gathered in terms of the app's user interface (UI) and user experience (UX) designs so that detailed analysis can be done to identify the significant usability factors that contributes to how objectives were met and to the success of the project.

In summary, the feedback of the app's UI and UX were mainly positive, highlighting that the virtual environment appeared as the museum ship and the application was straightforward to use. It is believed that these massively contributed to the fact that the main objectives were met, indicated by the results stating that majority of the participants were convinced that the app was effective at spreading knowledge and majority were inspired to visit the Glenlee ship. The overall success of the app was also hinted by the supervisory team when it was suggested that the Scottish Tourism Industry should be contacted as the project has potential to be progressed further.

7.2 Future Enhancements

The major limitation that could be addressed in order to improve the application's purpose of spreading knowledge is **making a simple tweak to the map scene**. It was observed during evaluation that some participants found the map scene confusing in the beginning of their experience, as already mentioned. This could be due to the fact that there may be an overwhelming number of canvases and buttons around the user to begin with. This could have been a major reason why the question "How well did you concentrate on absorbing information rather than on the device used to perform activities?" has received the lowest score within the UX design of the app. This in turn could have affected the outcome of the research, specifically with regards to the question "How effective was the VR application at spreading knowledge?". A suggested enhancement to improve this is to provide users with one canvas as the main menu in the map scene rather than multiple ones. A visual prototype of this suggested approach is shown in Fugure 7.1 for further clarity.

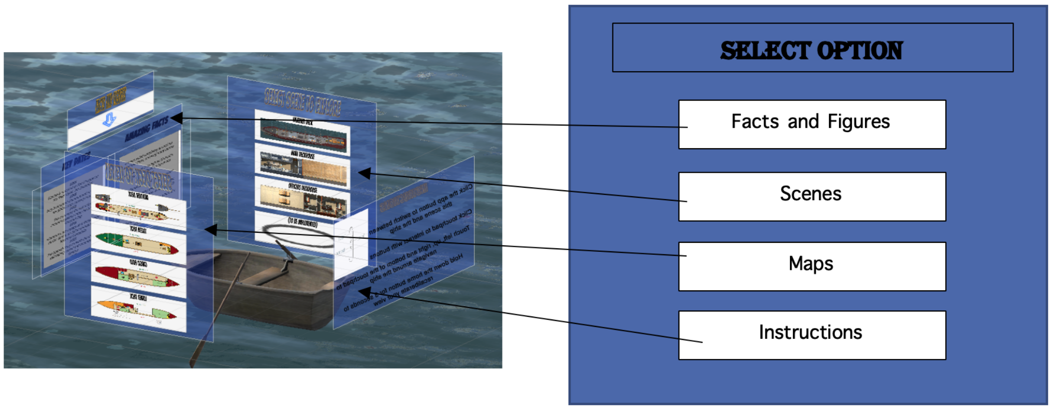


Figure 7.1: *Prototype of a suggested enhancement. The image on the left is the current design of the map scene and the prototype is on the right hand side. Each button in the prototype would lead directly to their corresponding canvas pointed by the arrow. These canvases would execute the same behaviour, but with a back button to return to the main menu. This approach gives users less options to view at a time and changes corresponding to actions would be much more noticeable.*

Another enhancement that could be implemented to improve usability is **providing guides in where to go in the virtual environment**. Whilst the map/main scene includes maps that help users identify the location of each room/area on the ship, users can easily get lost exploring the large virtual ship. The scenes are already populated with many blue "orbs" that spread knowledge about the history of the ship, so perhaps a different kind of signage should be used to direct users to some locations. For example, an arrow pointing to a location with a signage stating "This way to the main deckhouse".

If participants encounter **more animations and interactions** during their exploration, the application would be most likely perceived as more engaging and enjoyable. Therefore, incorporating this theory would enhance the application greatly. One example, as suggested by one participant, would be to apply animation to the virtual doors. The users could extend their dominant hand that is holding the remote to reach the virtual door knob, and when the knob recognises that the controller is interacting with it, then the door should mimic either an open or close animation depending on the next action of the user's arm.

To create an even more immersive "sail back in time" experience, **virtual characters can be added** in scenes where they carry out tasks they did while on board. Furthermore, an interactive storytelling experience can be implemented as an option for users if they prefer to be guided throughout their VR journey rather than explore on their accord. An example of this would be the captain telling related stories as he walks around with the user in the virtual world. He could be the "guide", instructing the user how to interact with the controller to see some animations. All the while, some other virtual characters can be seen in the background as they perform old fashion activities, like navigating with the wheel. This suggested enhancement overcomes the unusual feeling of loneliness on the ship.

7.3 Future Directions

The application was developed following software principles and heuristics, one of which was the open/closed principle by Meyer (1988); modules should be open for extensions but closed for modification. Incorporating this has greatly benefited the application since only three areas out of plenty were able to feasibly implement due to time constraints. The overall source code and with the help of unity's architecture should be able to add more scenes to integrate other areas into the VR app. **Implementing a new scene** is independent from other scenes and a few additional modules are required into the map scene to tie the new scene with the whole application. In summary, only additions of elements (such as GameObjects, code, etc.) are required, there is no need to alter existing code. These are all provided that software and hardware versions remain the same or similar.

Some of the models used in the virtual environments have been obtained from Unity Asset Store and TurboSquid, and the rest of the models were created from scratch using Unity's own 3D modelling Plug-in, ProBuilder. Although these tools are enough to add the desired aesthetics in the virtual environment, there exists some platforms enabling designers to **develop higher quality 3D models**. Software like Maya and Blender are mentioned in several legitimate sources that suggests top best Unity compatible tools when creating assets (such as in UFO 3D). The same tools allow creation of virtual characters or selection from default avatars, in which features can be changed and animated. For this project, the latter option will suffice as knowing the facial features of the characters is a trivial aspect of the users' learning process. Although, the outfit of the characters must match the era the virtual world is conveying. Therefore, experimentation of external tools are recommended when creating specific, complicated 3D models and characters. These are created and animated (if necessary) within these external tools, then exported and imported into Unity.

When choosing to implement an interactive storytelling experience as suggested in the previous section, **the official audio that are used by visitors in the real museum can be requested to integrate it into the application**. The real museum's official audio is recommended so that information presented by the application aligns to the information conveyed at the physical museum. If this audio is obtained, it must be examined whether or not it is suitable for the purpose of the app. For example, if the captain is storytelling, then the audio must reflect a man's voice since all captains that have sailed the tall ship had been men. Otherwise, it can be recreated by recording a man's voice. The audio must be edited to play during appropriate moments of the VR experience. However, in the case where the official audio may not be suitable at all, information from the books in Figure 3.2 can be used to create a storytelling audio.

When evaluating the next release of this application, or a similar project, it is important to ensure that there is a higher number of participants and that they are more diverse. The evaluation protocol could also be changed to a different setting such as using a published evaluation tool. For example, System Usability Scale (SUS) by Brooke (1986) can be followed as it provides a scoring system that results into a reliable measure whether or not the application is usable.

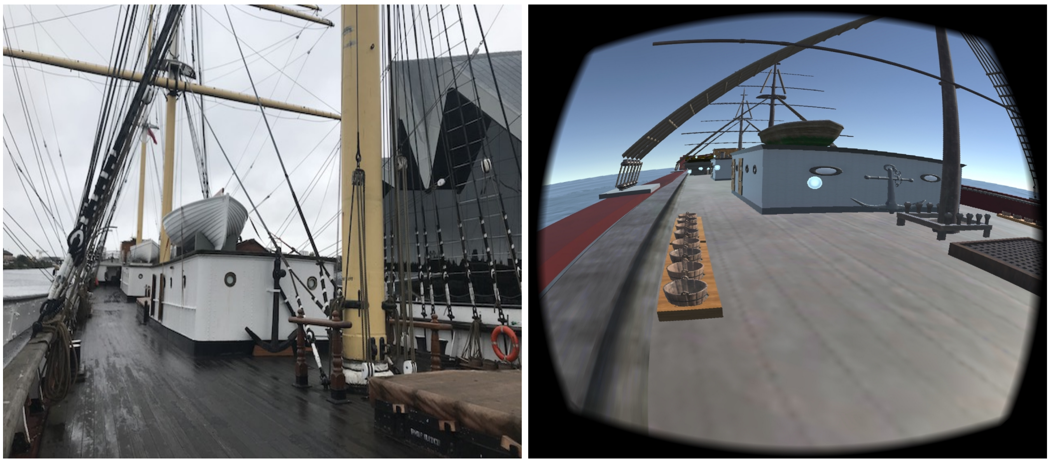
A Appendix - Field Study Photos and Virtual Environment Screenshots

A.1 Weather Deck

(a) in each of the following Figures are the field study photos and (b) are the virtual environment screenshots.

(a) *(b)*

Figure A.1



(a) *(b)*

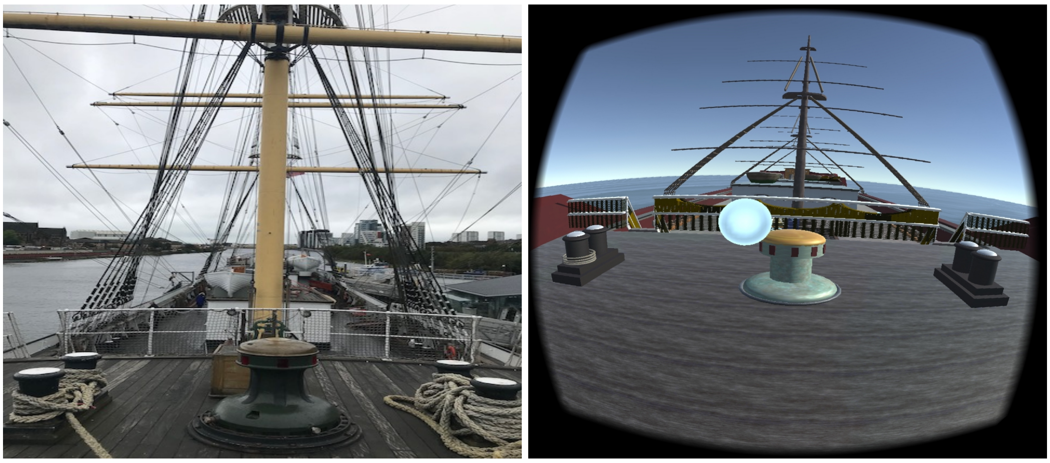
Figure A.2

(a) *(b)*

Figure A.3

(a) *(b)*

Figure A.4

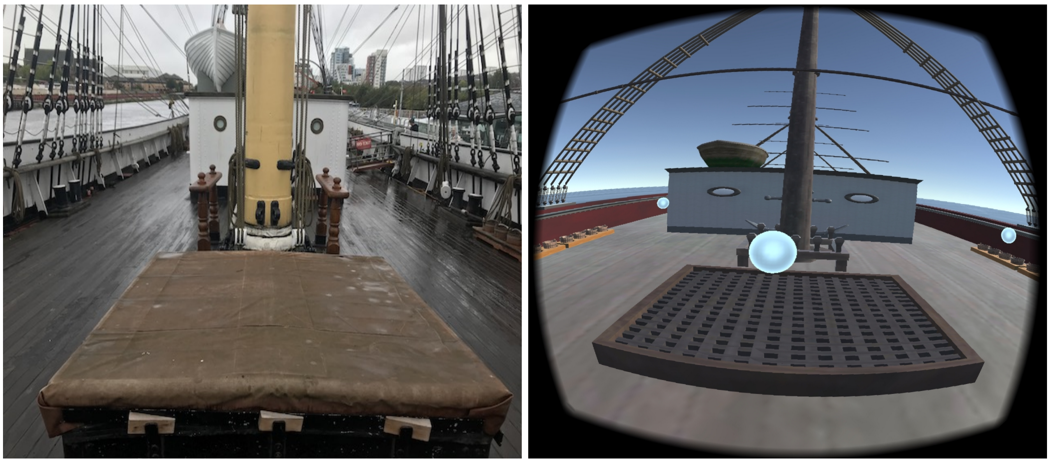


(a) *(b)*

Figure A.5

(a) *(b)*

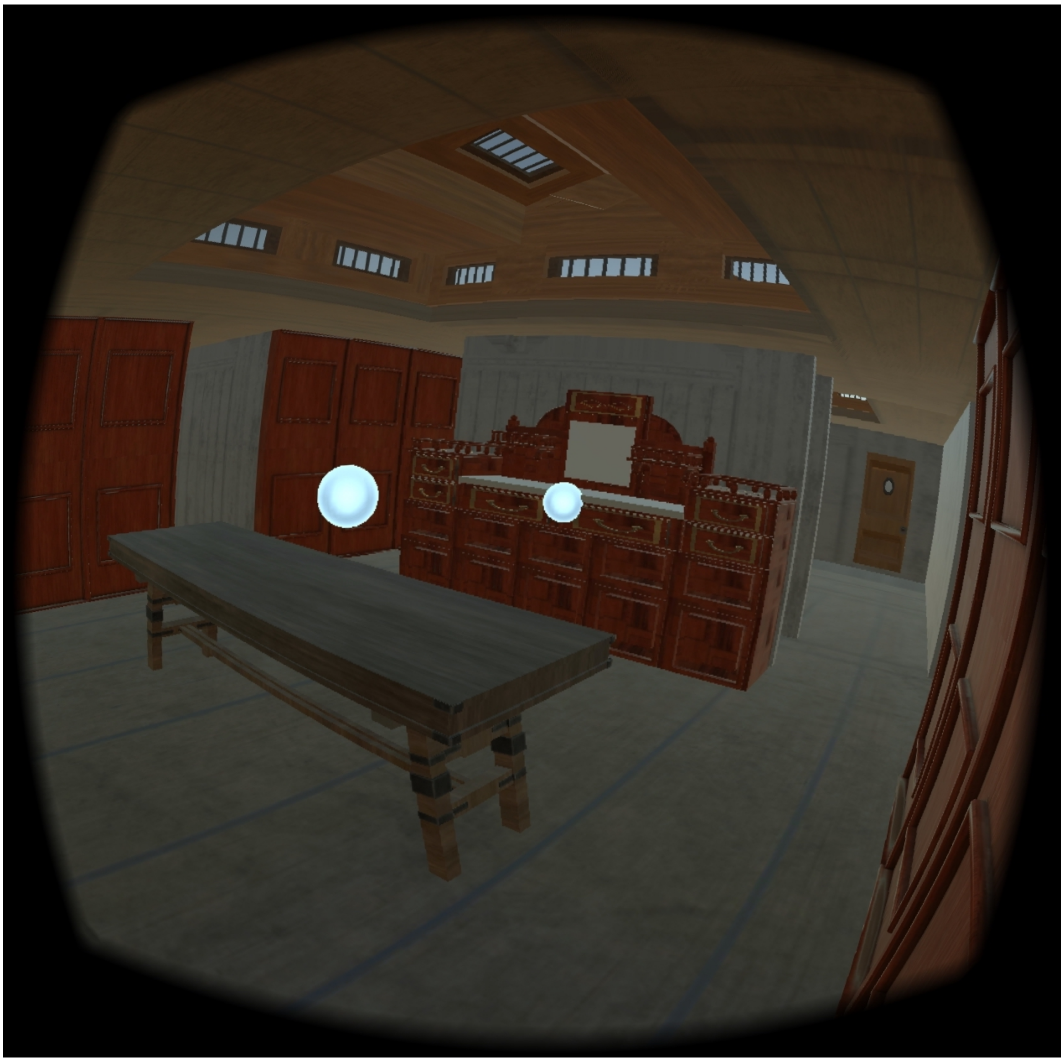
Figure A.6

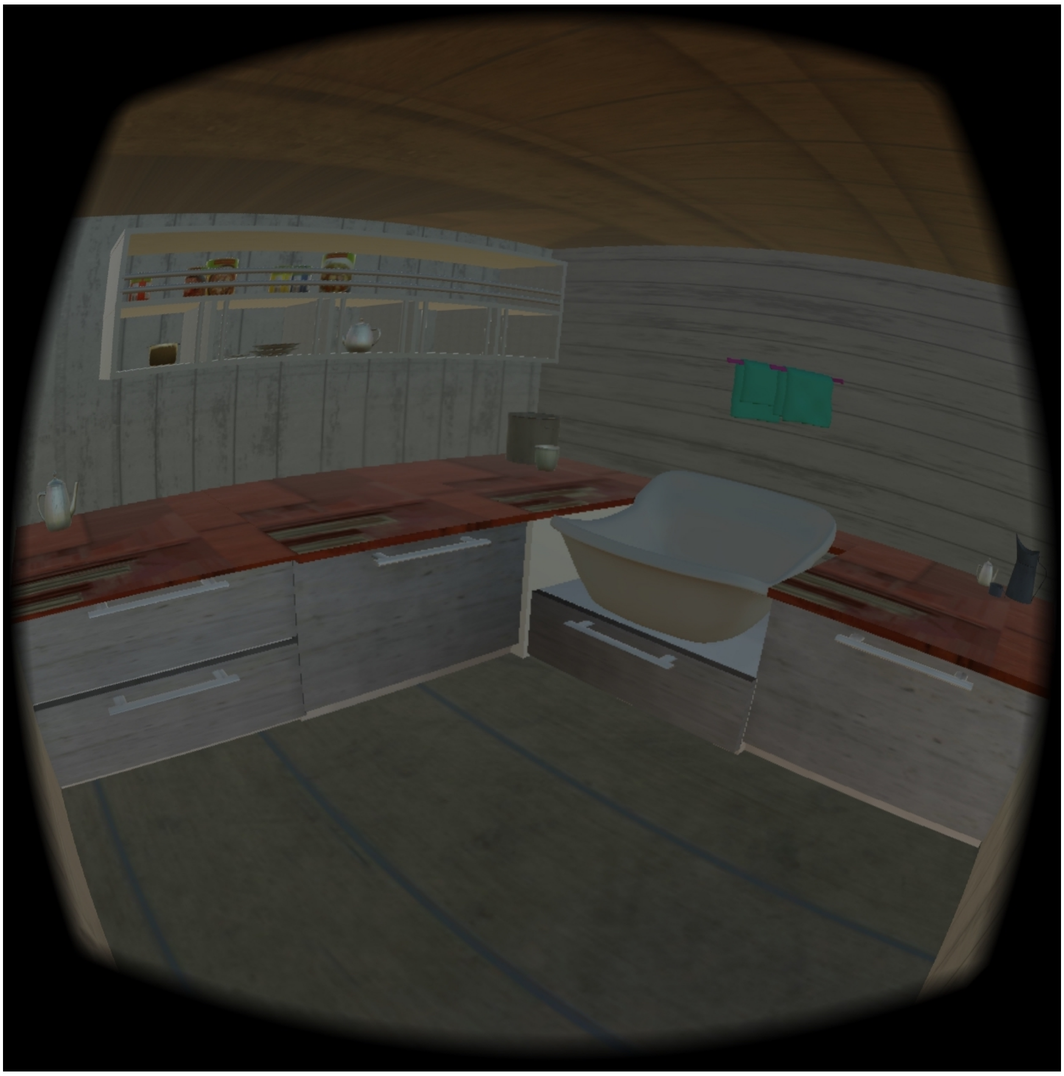


(a) *(b)*

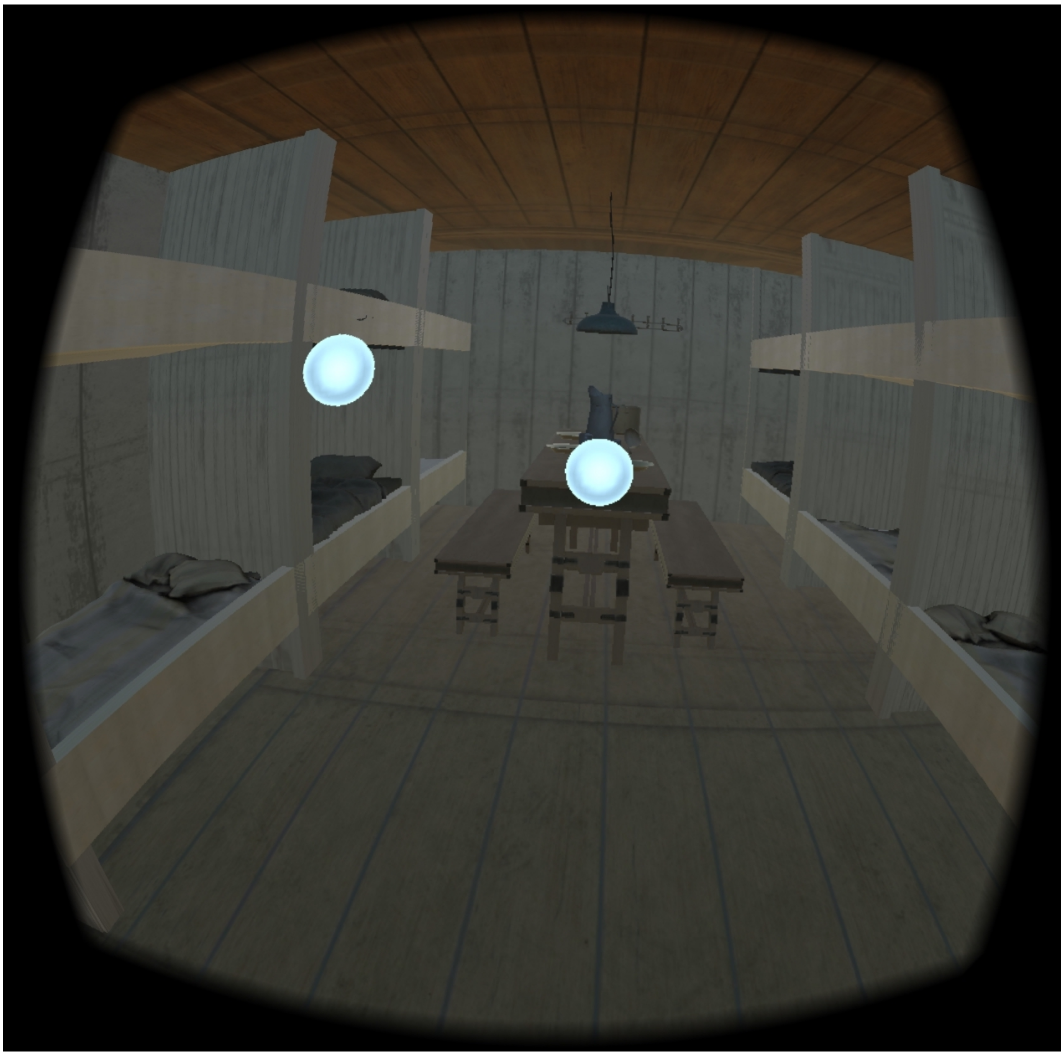
Figure A.7

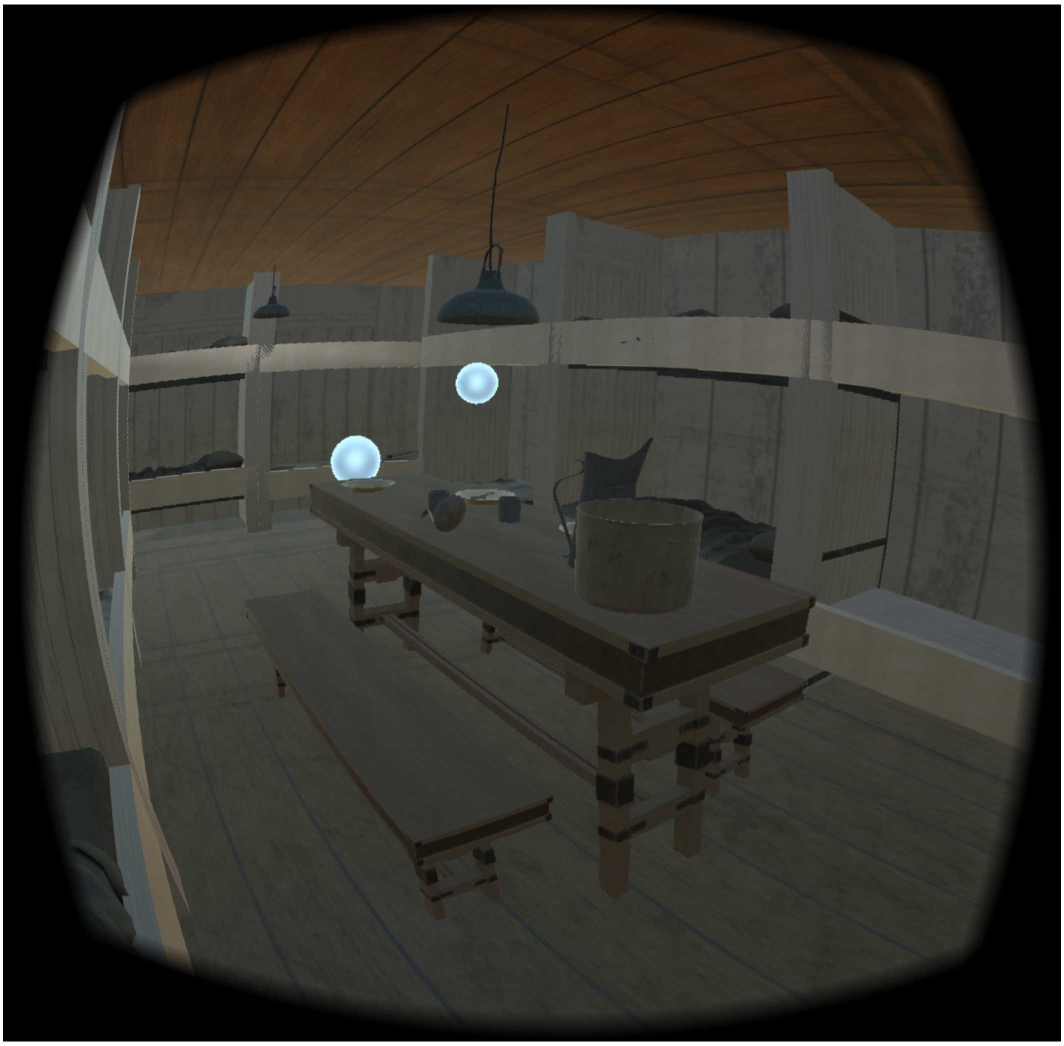
A.2 Officers Deckhouse





A.3 Main Deckhouse





B Appendix - Ethics Forms

B.1 Image of Participant Consent Form

Consent from participant in Figure 6.1

Department of Computing Science

University of Glasgow

I give consent to Frances Ramirez for an image of myself carrying out the evaluation of the Virtual Heritage application to be included in the dissertation.

Participant Signature: ________ Demonstrator Signature: ________

B.2 Ethics Checklist

Department of Computing Science
University of Glasgow

Ethics checklist form for 3rd/4th/5th year, MSc IT/CS/ACS projects

This form is only applicable for projects that use other people ('participants') for the collection of information, typically in getting comments about a system or a system design, getting information about how a system could be used, or evaluating a working system.

If no other people have been involved in the collection of information, then you do not need to complete this form.

If your evaluation does not comply with any one or more of the points below, please submit an ethics approval form to the Department Ethics Committee.

If your evaluation does comply with all the points below, please sign this form and submit it with your project.

---

1. Participants were not exposed to any risks greater than those encountered in their normal working life.

   Investigators have a responsibility to protect participants from physical and mental harm during the investigation. The risk of harm must be no greater than in ordinary life. Areas of potential risk that require ethical approval include, but are not limited to, investigations that occur outside usual laboratory areas, or that require participant mobility (e.g. walking, running, use of public transport), unusual or repetitive activity or movement, that use sensory deprivation (e.g. ear plugs or blindfolds), bright or flashing lights, loud or disorienting noises, smell, taste, vibration, or force feedback

2. The experimental materials were paper-based, or comprised software running on standard hardware.

   Participants should not be exposed to any risks associated with the use of non-standard equipment: anything other than pen-and-paper, standard PCs, mobile phones, and PDAs is considered non-standard.

3. All participants explicitly stated that they agreed to take part, and that their data could be used in the project.

   If the results of the evaluation are likely to be used beyond the term of the project (for example, the software is to be deployed, or the data is to be published), then signed consent is necessary. A separate consent form should be signed by each participant.

   Otherwise, verbal consent is sufficient, and should be explicitly requested in the introductory script.

4. No incentives were offered to the participants.

   The payment of participants must not be used to induce them to risk harm beyond that which they risk without payment in their normal lifestyle.

5. No information about the evaluation or materials was intentionally withheld from the participants.
   Withholding information or misleading participants is unacceptable if participants are likely to object or show unease when debriefed.

6. No participant was under the age of 16.
   Parental consent is required for participants under the age of 16.

7. No participant has an impairment that may limit their understanding or communication.
   Additional consent is required for participants with impairments.

8. Neither I nor my supervisor is in a position of authority or influence over any of the participants.
   A position of authority or influence over any participant must not be allowed to pressurise participants to take part in, or remain in, any experiment.

9. All participants were informed that they could withdraw at any time.
   All participants have the right to withdraw at any time during the investigation. They should be told this in the introductory script.

10. All participants have been informed of my contact details.
    All participants must be able to contact the investigator after the investigation. They should be given the details of both student and module co-ordinator or supervisor as part of the debriefing.

11. The evaluation was discussed with all the participants at the end of the session, and all participants had the opportunity to ask questions.
    The student must provide the participants with sufficient information in the debriefing to enable them to understand the nature of the investigation.

12. All the data collected from the participants is stored in an anonymous form.
    All participant data (hard-copy and soft-copy) should be stored securely, and in anonymous form.

Project title Virtual Heritage App

Student's Name Frances Ramirez

Student's Registration Number 2168154

Student's Signature Framirez

Supervisor's Signature L Murtagh

Date 05/2/2019

C Appendix - Pre-Study Questionnaire Responses

User Evaluation - Virtual Heritage VR app

Thank you for agreeing to taking part in this study. It should take approximately 10-15 mins to complete.

The study itself is conducted within Virtual Reality (VR) and you will be wearing a VR headset. You will also need to have full use of both of your arms and hands. You will be seated throughout. IF YOU HAVE ANY PRE-EXISTING CONDITIONS WHICH INCLUDE:

- Heart problems
- Epilepsy
- Severe motion sickness
- Neck injuries
- Arm injuries
- Claustrophobia

Please let the demonstrator know immediately.

If at any point in the experience you feel motion sick or unwell, please let the demonstrator know and remove your headset. If you do not wish to continue at any stage, please do not hesitate to stop.

If you have any questions before, during or after the experiments then please ask the demonstrator as they will be happy to help.

Your data will be kept anonymous and will only be used for research purposes, including this questionnaire and the data from the experience.

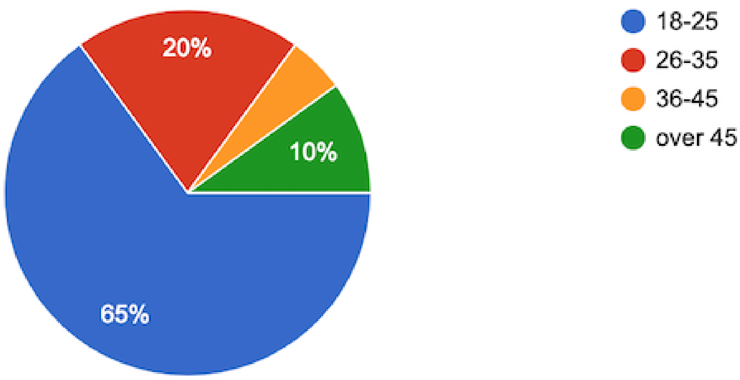
NEXT

Pre-Study Questionnaire

The Glenlee ship, or better known as the Tall ship, is at the Riverside museum floating on the River Clyde in Glasgow. It is the remaining great Clyde-built sailing ship left in the world, which makes her a great prominence to the whole maritime trading history of the United Kingdom. What makes it a historic ship is that it has travelled around the world since 1896 for over a century experiencing traumatic events as a different kind of ship each time; a cargo ship, a training ship, and now a museum ship. Tackling countless storms were not easy, especially around the infamous Cape Horn, in which it managed to survive fifteen times despite having a well-deserved reputation as one of the most dangerous shipping lanes on Earth. Glenlee's longest recorded voyage was 1,269 days and maintaining endurance during this, and numerous more voyages, greatly depended on the men harnessing the wind for power. There is a remarkable story of life at sea under sail that is behind the hard work, frequent danger and constant challenge. The Clyde Maritime trust returned the tall ship to its berth at Riverside in 1992 and opened to the public as a museum ship in 1999 after its initial restoration. Based on the few remaining artefacts, such as a daily deck log, the ship today recaptures the era it was under sail. The Clyde Maritime trust, a registered Scottish Charity, aims to create an awareness of the maritime heritage of the River Clyde. They depend on support from the public and other donors to fund the upkeep and restoration of this historic sailing vessel. It ensures that it is continued to be a meaningful landmark and to further enable understanding of life at sea under sail.

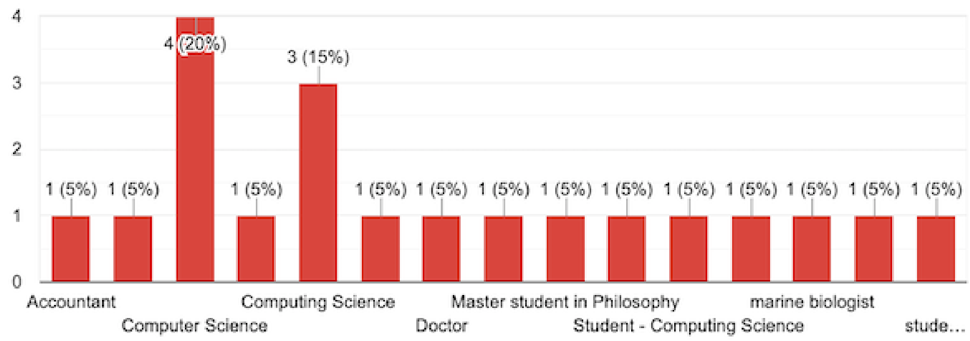
Please state your age:

20 responses



Please specify your profession, or course if you are studying:

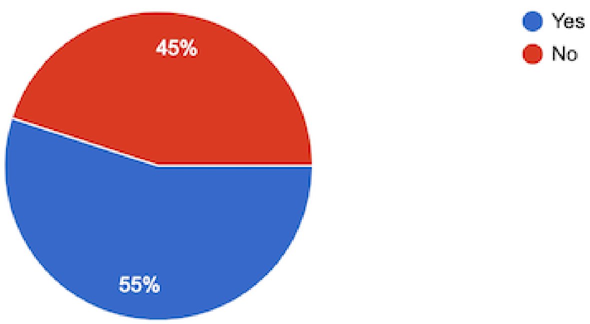
20 responses



Your knowledge about the tall ship, Glenlee.

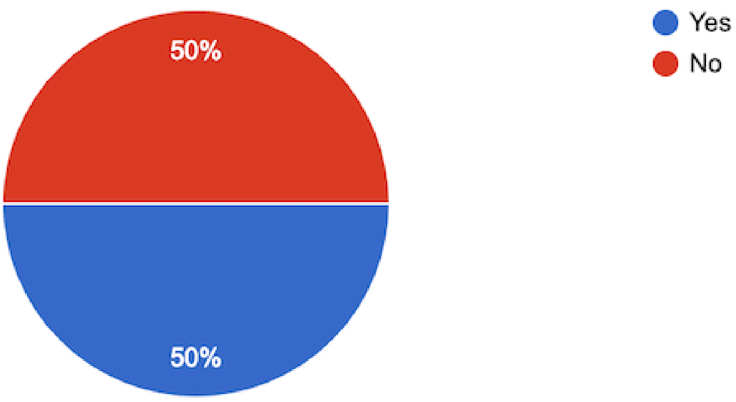
Have you heard of the tall ship, Glenlee, prior to reading the provided summary?

20 responses



Have you visited the Glenlee ship?

20 responses



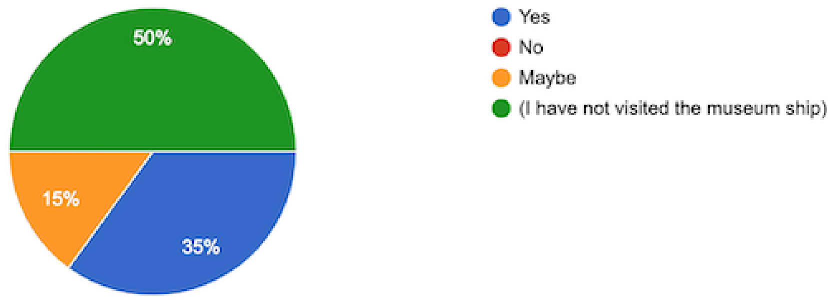
If you have visited the ship, please specify which aspect of your visit of the ship did you find the most interesting? (e.g. Ship design, ship history, life under sail etc.)

10 responses

Ship Exterior
Ship design - it's much bigger inside than you think it is. You can keep going down stairs to lower levels you didn't know was there.
The sails
The design of the ship
cannot remember, it was big though
Cargo hold
Switchboard/generator
interior
I don't remember much - it was 3 years ago
The history behind the ship.

Would you visit again?

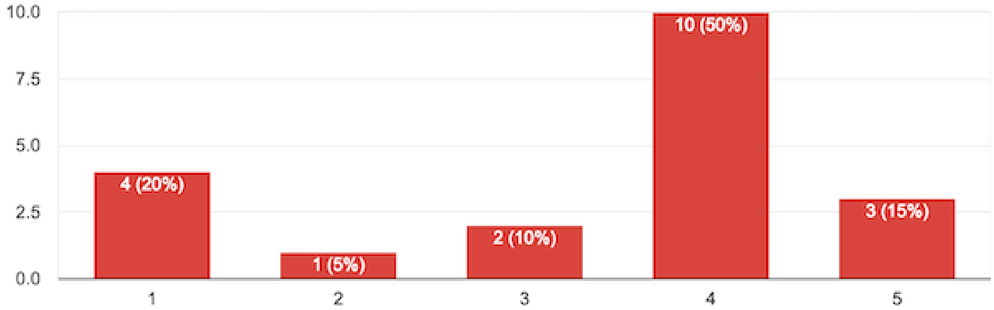
20 responses



Your experience with any VR technology.

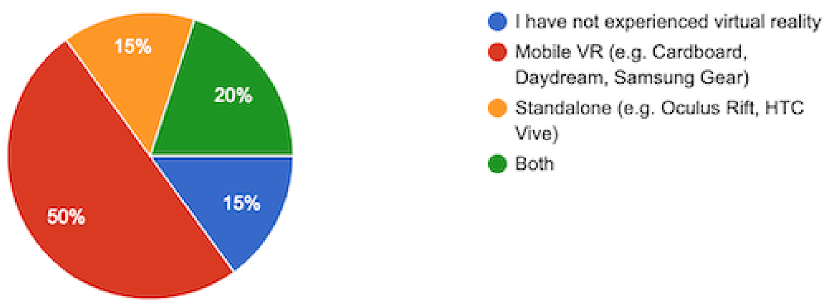
How interested are you in any technological innovation?

20 responses



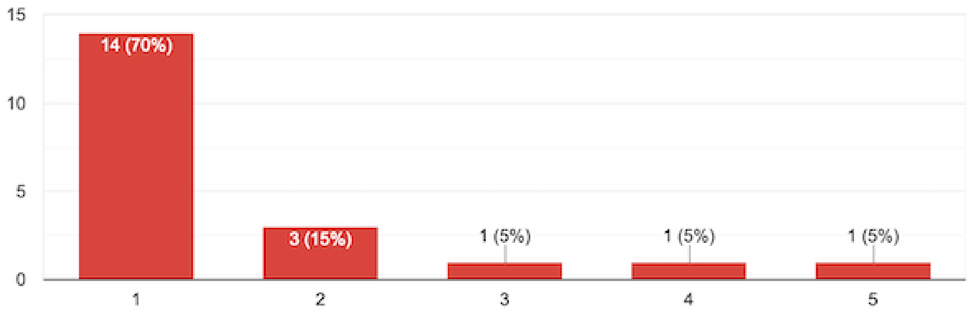
What kind of Virtual Reality device have you used?

20 responses



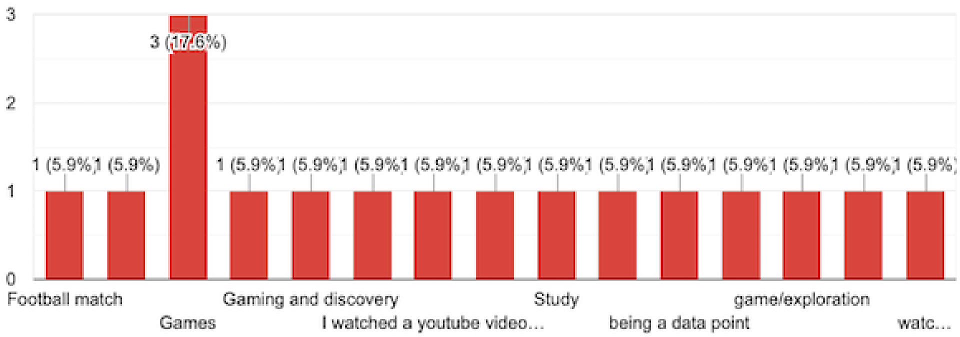
How often do you use a VR device?

20 responses



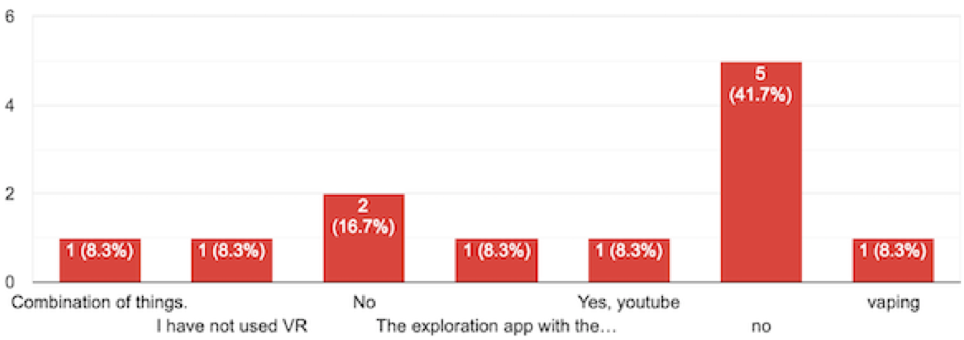
What do you use virtual reality for? (e.g. Gaming, watch videos, explore places, etc.)

17 responses



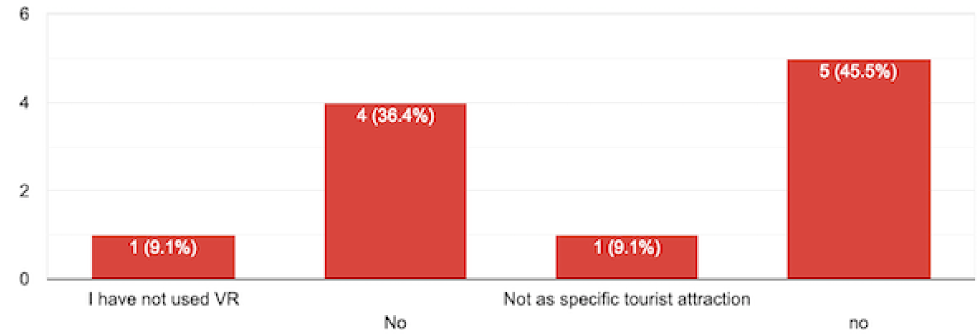
Have you experienced a VR app that is used to spread knowledge? If yes, please specify...

12 responses



Have you experienced a VR app that promotes tourist attraction? If yes, please specify...

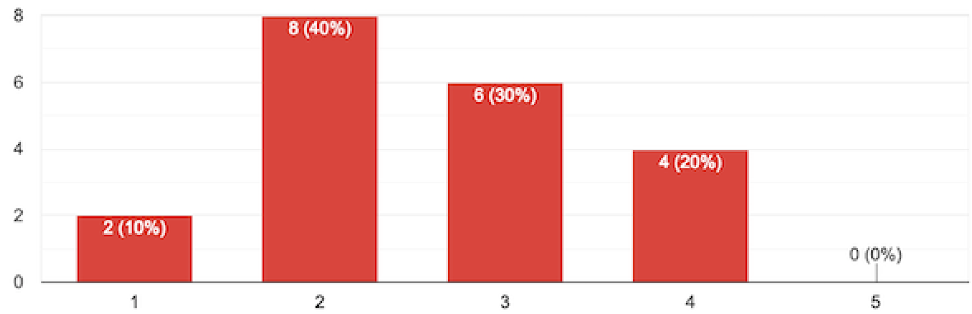
11 responses



Your perspectives on tourism.

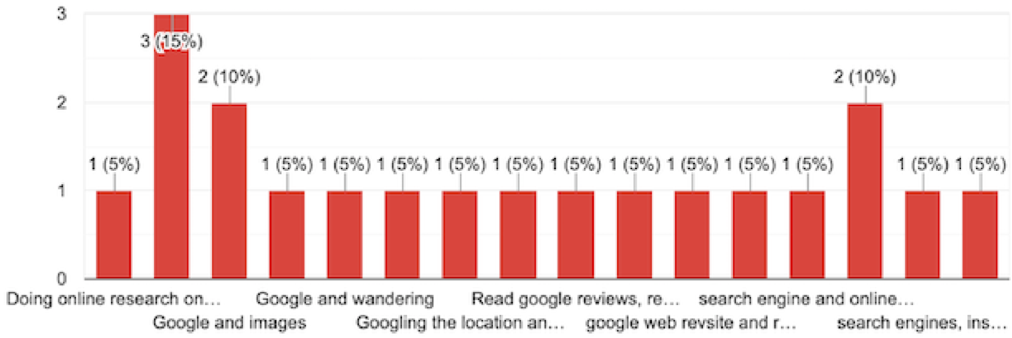
How often do you visit tourist attractions?

20 responses

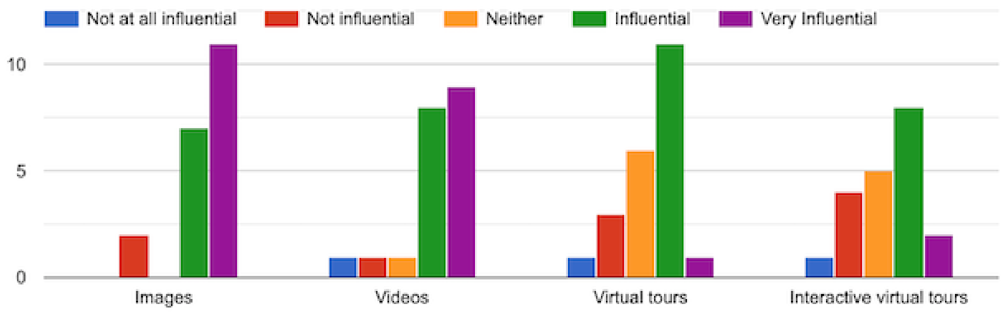


How do you normally familiarise yourself with the tourist destination you plan to visit? (e.g. search engines, images, videos, reading the attraction's history, etc.)

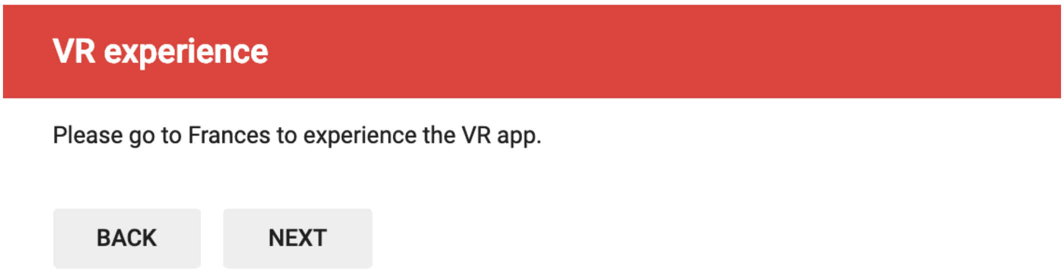
20 responses

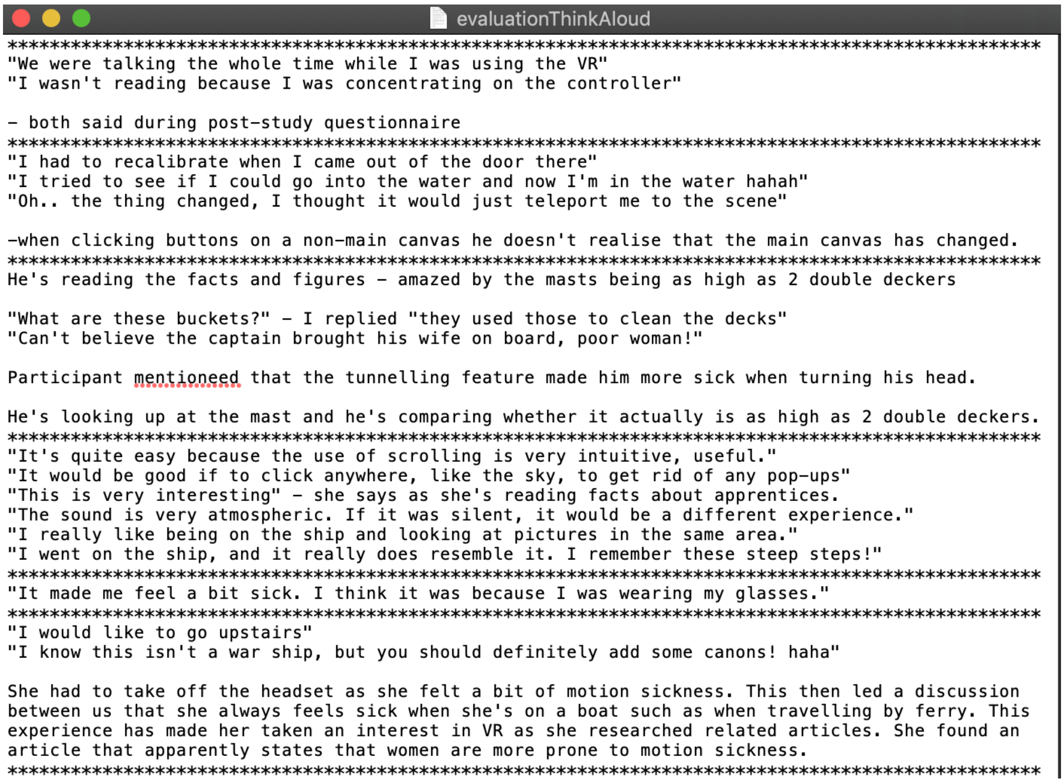


Evaluate how influential are the following methods of advertising a tourist attraction.



D Appendix - VR experience





evaluationThinkAloud

```
**************************************************************************************************
"We were talking the whole time while I was using the VR"
"I wasn't reading because I was concentrating on the controller"

- both said during post-study questionnaire
**************************************************************************************************
"I had to recalibrate when I came out of the door there"
"I tried to see if I could go into the water and now I'm in the water hahah"
"Oh.. the thing changed, I thought it would just teleport me to the scene"

-when clicking buttons on a non-main canvas he doesn't realise that the main canvas has changed.
**************************************************************************************************
He's reading the facts and figures - amazed by the masts being as high as 2 double deckers

"What are these buckets?" - I replied "they used those to clean the decks"
"Can't believe the captain brought his wife on board, poor woman!"

Participant mentioneed that the tunnelling feature made him more sick when turning his head.

He's looking up at the mast and he's comparing whether it actually is as high as 2 double deckers.
**************************************************************************************************
"It's quite easy because the use of scrolling is very intuitive, useful."
"It would be good if to click anywhere, like the sky, to get rid of any pop-ups"
"This is very interesting" - she says as she's reading facts about apprentices.
"The sound is very atmospheric. If it was silent, it would be a different experience."
"I really like being on the ship and looking at pictures in the same area."
"I went on the ship, and it really does resemble it. I remember these steep steps!"
**************************************************************************************************
"It made me feel a bit sick. I think it was because I was wearing my glasses."
**************************************************************************************************
"I would like to go upstairs"
"I know this isn't a war ship, but you should definitely add some canons! haha"

She had to take off the headset as she felt a bit of motion sickness. This then led a discussion
between us that she always feels sick when she's on a boat such as when travelling by ferry. This
experience has made her taken an interest in VR as she researched related articles. She found an
article that apparently states that women are more prone to motion sickness.
**************************************************************************************************
```

Figure D.1: Above screenshot illustrates the notes that I have jotted down during evaluation. Each division represents comments and events that has occurred during an evaluation by one participant.

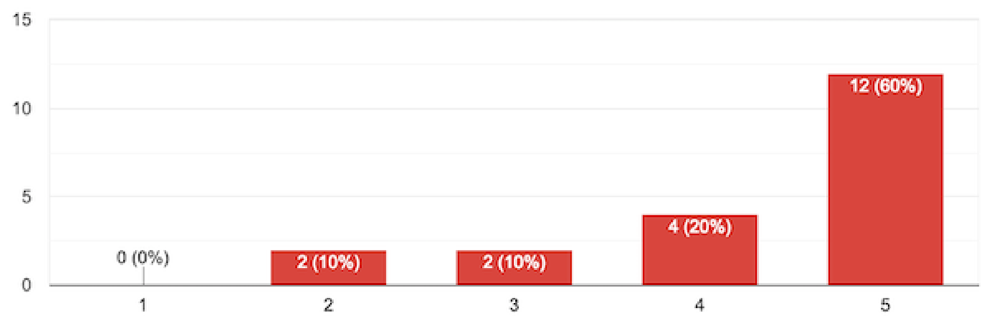
E Appendix - Post-Study Questionnaire Responses

Post-Study Questionnaire

User Interface

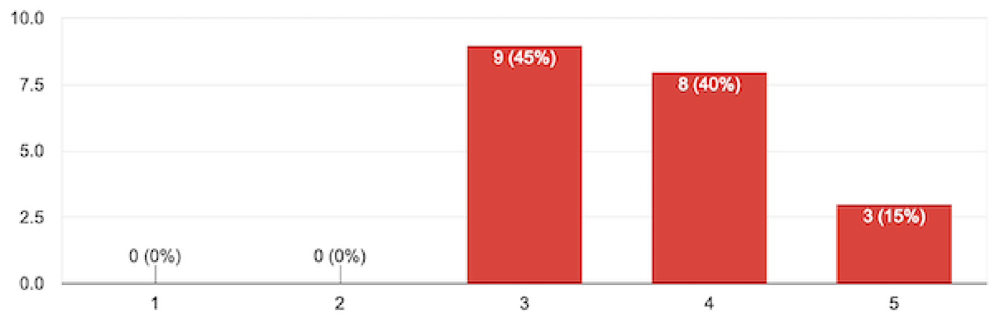
How well did the environment seem as a museum ship?

20 responses



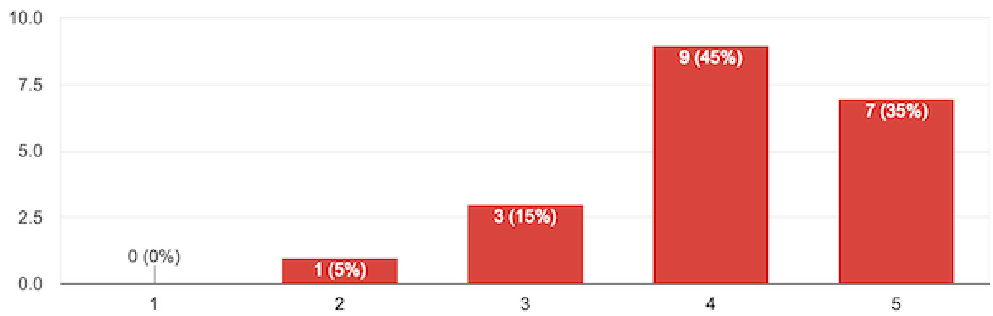
How self-explanatory was the main menu, i.e. the map scene?

20 responses



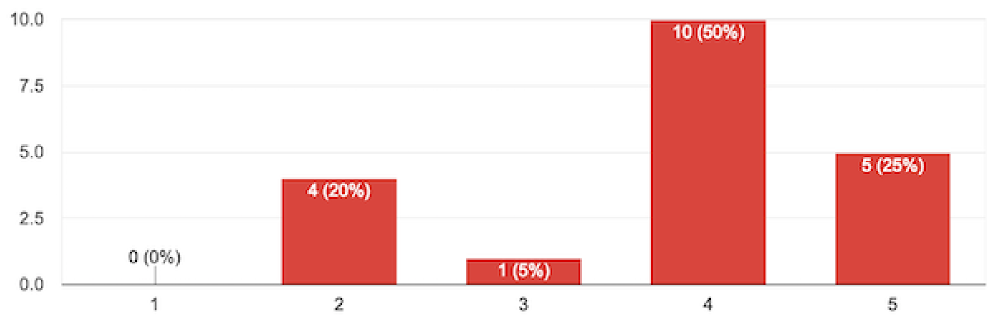
How consistent was the various displayed information?

20 responses



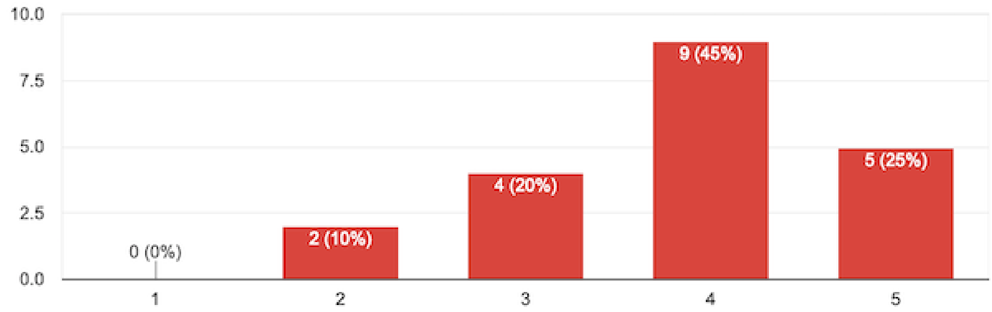
How natural did the 3D effect, such as the sea, seem?

20 responses



How natural did the view seem when you were walking around?

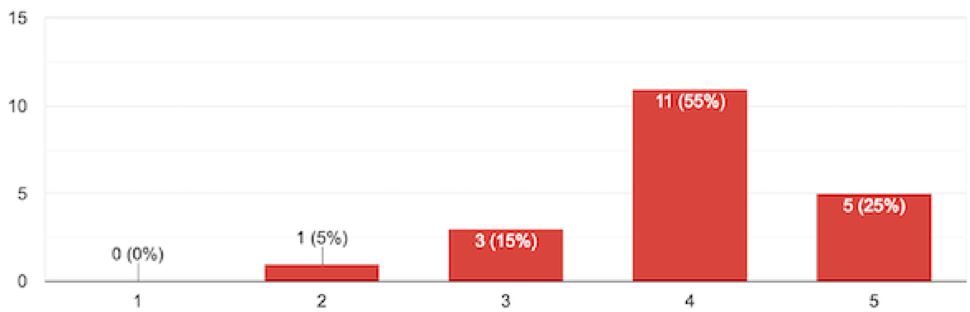
20 responses



User Experience

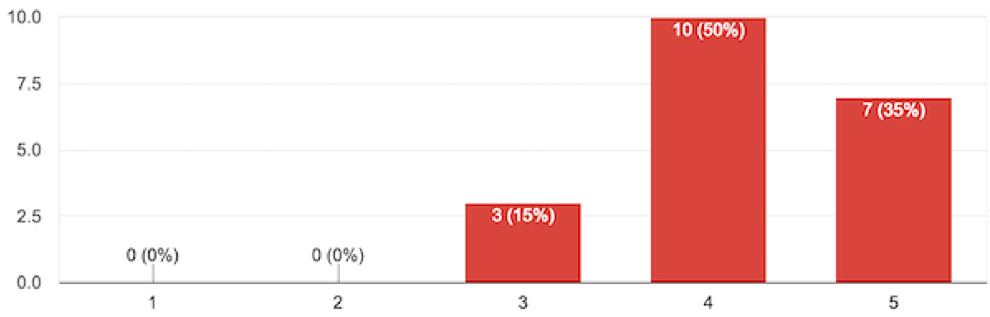
How easily did you learn to navigate in the environment in different situations?

20 responses



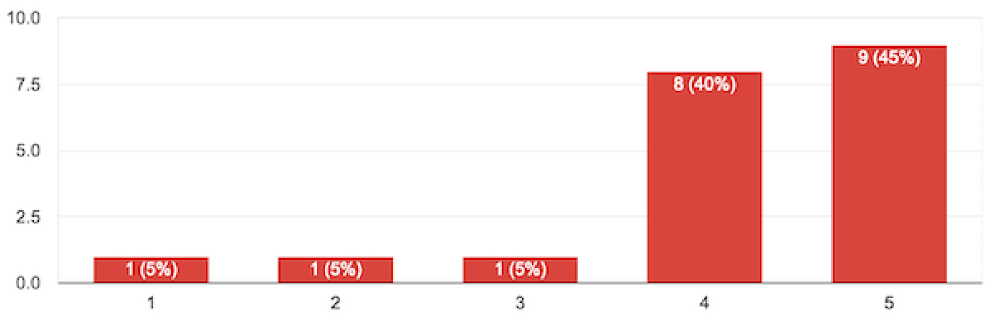
How easily were you able to anticipate what would happen next in response to the actions that you performed?

20 responses



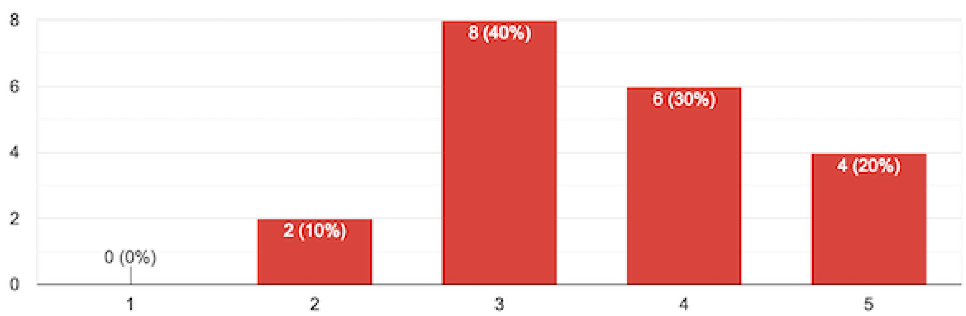
How much were the rotation and moving direction of your character consistent with your actions on the controller?

20 responses



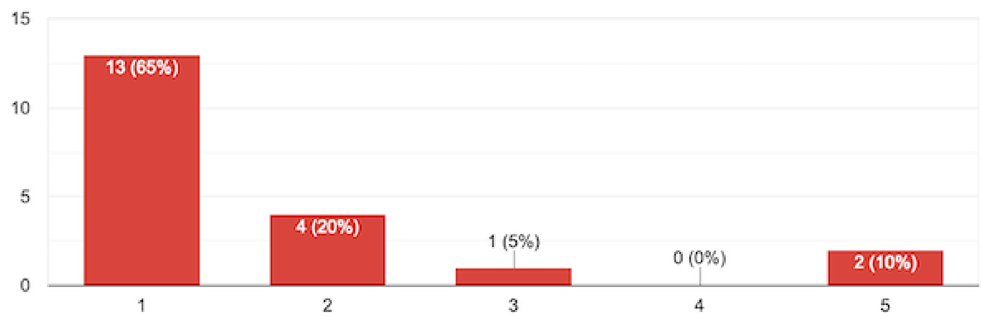
How well did you concentrate on absorbing information rather than on the device used to perform activities?

20 responses



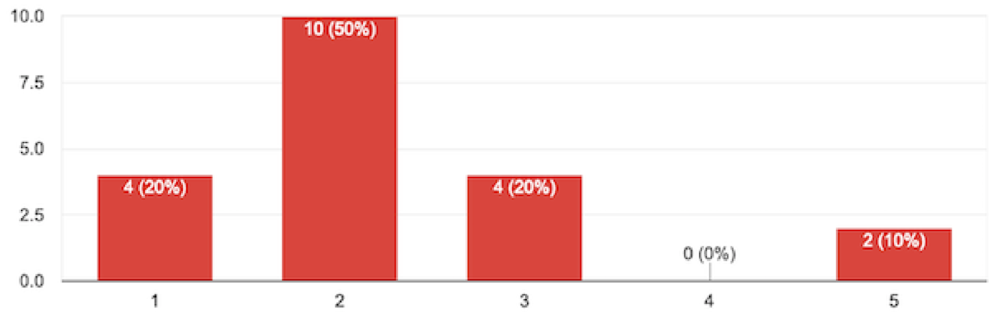
Did you feel unwell during your VR experience?

20 responses



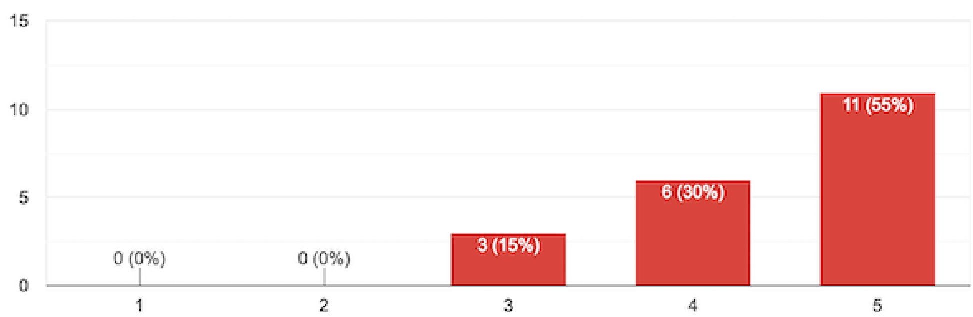
How aware were you of events occurring in real-world around you?

20 responses



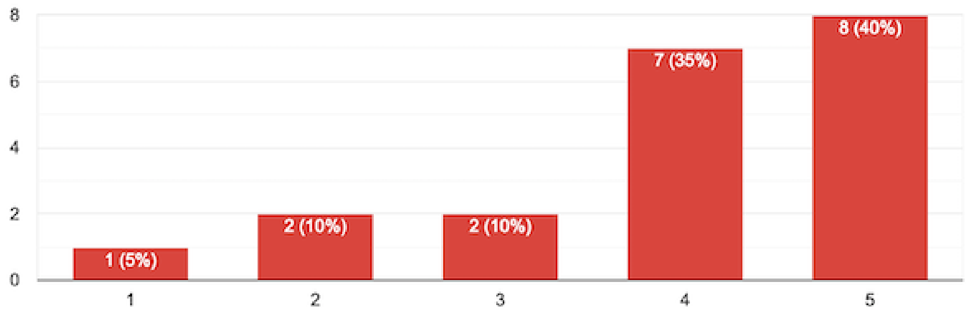
How effective was the VR application at spreading knowledge about the tall ship?

20 responses



Did experiencing the tall ship in VR inspire you to visit the Glenlee ship?

20 responses



Overall Experience

Which aspect of the VR app you liked the most?

20 responses

The ability to jump up onto the table - more interactive movement
I liked the main deck and being able to explore the ship
The sound as it created a really immersive experience, and the interactivity - the user can click to see images and move about the ship
The explorable scenes
The detailing of the different 3D models
Environment was very immersive
Interaction with the different map scene environments. I liked the different ways of displaying information i.e text and image holograms
was a lot to see and do in terms of moving around and going into different doors, was very realistic especially with the added sound
Being able to visually experience the ship before deciding whether to actually go
Exploring different decks
cute device, can see the potential
enjoyed the easy exploration
It draws you in to another world - it's a really odd experience, but great!
I really liked the graphic
novelty of the VR and the interactivity of the environment
It was a great app considering it was my first time using VR and knowing that this was also the first VR app the designer has created.
It was very easy to use, self explanatory.
Being able to learn and explore at the same time, just as you do in a museum.
It was an impressive app. A very good idea to re-create a museum rather than just games.

Finally, please specify if you have any suggestions that you feel could enhance the VR app's user experience:

20 responses

if you could press buttons with the VR headset rather than a controller cause couldnt see the controller so I sometimes pressed the wrong button
Being able to adjust the sensitivity of the remote (if you can't already)
Accomodate for motion sickness
make sure all of the signage has information associated with it
readable info panels as you walk around, more resolution
Better image ... higher definition images
Most of what I experienced was great, but because I didn't quite know how to use it (because I'm old and bad with technology) a lot of what was great, was lost on me.
moving through the information orbs and having the pop ups orient themselves towards the user
Being able to see the overall design of the ship from the outside.
the orbs get in the way sometimes
I think that having virtual people on the ship such as a captain who you could interact with, even in a basic fashion where some text appears as if he's talking to you, would enhance the experience greatly. I felt a bit lonely in the scene, it wasn't natural to be on the ship by myself.
Directions to say "Captain's cabin this way" with an arrow, or "masthead this way" or whatever to guide the user to the difference scenes.
The arrow pointing to a button would've been easier if it itself had executed the task, but i see why you did it this way, it encouraged me to view the ship layout first
On the deck with the 4 beds(?) i spawned in the air then fell down
The walking around and button controller were very intuitive.
Have the pop up information and images face the user rather than a specific direction
When looking at a description it could only be read from a certain direction. It would be better if the text would turn to face where you are.
no suggestions
More interactions would add an even more immersive experience. For example, the doors actually opening when "touching" it.
The map scene was confusing at the start as I did not know what the different buttons did but it was easy to use after learning it.
Being able to pick up objects

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