Augmented Reality On Display

How might augmented reality technology be used to create meaningful interactive museum exhibits?

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The Development Blog for the Augmented Portrait Exhibit can be accessed online through the following link.

https://efeiumr9ezencv8gsvmm.vuw-test.sandcats.io/

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00.Abstract

The aim of this thesis is to explore augmented reality technology and the methods in which it can be applied to museum displays to enriching the experience of visitors. Artefacts within museums have rich histories which are not always apparent. This is due to the way artefacts are currently displayed and the way information is communicated in exhibitions. This project will set out design guidelines to inform the development of augmenting museum experiences. These guidelines will provide criteria and parameters for the use of augmented reality in museums, and will also be accessible to museum staff to create or enhance existing exhibits for visitors.

The guidelines will be produced through a combination of different contextual research methods and will inform a final designed case study. These contextual research methods include: completing a practical exploration of augmented reality exhibits, reviewing museum practice and conducting a series of interviews directed at augmented reality experts. Once these guidelines are produced they will be tested using research through design and human centred design methods in a final case study. The findings of this thesis aim to emphasise how augmented reality is a tool for enhancing the communication of contextual history. It also forms the basis for further research into how augmented reality's combination of virtual and physical worlds can broaden our experience of the museum space.

Thesis Statement

Augmented Reality Technology can be used to enhance museum exhibitions, by allowing visitors to virtually interact with museum exhibit content and enabling the communication of authentic contextual information.

Objective, Methods, Results and Conclusions

Museums are places where people explore history, science and culture. We often look to them as purveyors of knowledge and learning which we can trust. However, to continue to be relevant, museums need to constantly update their exhibitions and technology to meet the demands of visitors (Wyman, Smith, Meyer & Godfrey, 2011). Through initial research I learned that museums are adapting exhibition environments to develop interactive exhibition spaces. These spaces allow visitors to become more involved with the content of an exhibition (Calcagno & Biscaro, 2012). I intend to follow this trend and use a new technology, augmented reality, and research how to enhance and improve the presentation of display objects in museum exhibits.

Augmented reality projects virtual images into physical space. The use of this technology will create interesting opportunities for visitor interactions and will impact presentation of the information that an exhibit offers. This technology also stimulates visual learning and problem solving skills (Billinghurst & Duenser, 2012) that would promote learning and knowledge retention through these exhibits.

Although augmented reality is a new technology, it has massive potential in many fields of study (Javornik, 2016), due to its unique methods of showcasing virtual information in a physical space (Billinghurst, Poupyrev & Kato, 2001). It is ideally suited to exhibit design and it would be worthwhile to explore its use in this context.

Keywords

Augmented Reality, Mixed Reality, Museum, Exhibit, Exhibition, Display

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01.Introduction

Context and Value of Research

I was involved with augmented reality from a young age (figure 01). My dad worked in the Human interface technology lab, or HIT Lab, based in the University of Canterbury. The HIT Lab is well known as innovators in augmented reality technology and I was used as a guinea pig for many of the technology tests and experiments. This interest and exposure started when I was 9 years old and ever since I have been interested in the applications of this technology. My aim is to use augmented reality to enhance museum exhibits, enabling different methods of communicating information and ideas to the public like other interactive exhibits.

Museum exhibits are designed to engage visitors and effectively communicate the information they display (Calcagno & Biscaro, 2012). But, what if museums used augmented reality technology to altering exhibits with virtual images and enhance visitor interactions? This could revolutionise museum practice as instead of updating the physical state of museums displays, curators could change the virtual space surrounding a display instead. Additionally, this has the effect of placing the focus of the display back on the physical display artefacts, as visitor would have the option to view an exhibit through either an augmented or physical view. This research is intended to consider methods in which this technology can be applied to museum exhibits.

01. Jonathon Magic Book (Bishop, 2007)

Definition of Key Terms

Physical Reality

Physical reality is the real world and is unaffected by virtual images stimuli.

Augmented Reality (AR)

Augmented reality is a visual technology that combines and aligns real and virtual images in a physical environment. This technology allows a user to interact with these virtual images in real time allowing them to 'augment' their physical reality (Azuma, Baillot, Behringer, Feiner, Julier & MacIntyre, 2001).

Museum Exhibits

Museum displays that showcase display objects and items (Lord & Piacente, 2014, p.8).

Display Objects/Items

Any two- or three-dimensional exhibition object, such as an artefact, a painting, and illustration, or a specimen (Bogle, p.361). These items are often of significance culturally to the visitors viewing them, such as, artefacts of a civilisation, specimens of a continent, or the interactive apparatus of science (Lord & Piacente, 2014, p.8).

Research Aims and Objectives

I aim to discover how this technology can be used to create meaningful interactions with an audience. In the first and second phases of my research, I will assess the current practices in both exhibition design and augmented reality. This will establish a set of guidelines which will inform future design practice. Finally, I will develop and design my own augmented reality exhibit which will put the ideas and concepts I have explored in my research into context. My project has the following aims and objectives to research these ideas and develop this technology in this context:

Aim 1

Explore augmented reality and museum exhibition practices by developing an augmented reality exhibition.

Objectives

1A) Design and develop an augmented reality exhibition based on the Downstage Theatre Company to be exhibited in the National Library of New Zealand.
1B) Test the exhibition's technology with visitors.
1C) Analyse the results of the exhibition.

Aim 2

To critically assess augmented reality and museum exhibition design.

Objectives

2A) Identify and analyse contemporary museum exhibition practices.

2B) Conduct interviews which will examine augmented reality technology through the perspective of an expert.

2C) Map relations between objectives 1C, 2A and 2B to inform design guidelines for future design practices.

Aim 3

To design, build and test an augmented reality application which augments museum display objects.

Objectives

3A) Design, develop and prototype an augmented reality application for an existing museum exhibit.

3B) Test the application interactions with users.

3C) Complete a case study of the augmented reality museum application and access it compared to Objective 2C's design Guidelines

Research Methods

Aim1

The first section of this thesis will seek to Objective 1A by producing high fidelity prototypes (Martin & Hanington, 2012, p.138) as they are refined in functionality, look and feel. This methodology was derived from similar steps that Google took with the development of Google Glass AR. During development, they used rapid prototyping to create an early working mock-up in less than a day (Chi, 2017). This also suited the limited time that the project required before it was opened to the public.

Objective 1B will use usability testing (Cockton, 2016; Martin & Hanington, 2012, p.194) to isolate and identify the unsuccessful aspects of user interactions by testing users and their interaction with the exhibits. This method will require ethics approval.

In Objective 1C, these issues will be analysed in a Usability Report (Martin & Hanington, 2012, p.192) which takes the list of issues from Objective 1B and compiles them into a report that lists and clearly outlines them. This is used in design research practice to isolate problems so they can be fixed or improved in future development. This report will be used to inform future design practices in Aim 3.

Aim 2

In Objective 2A, a literature review (Creswell, 2014) will be conducted to explore contemporary museum exhibition practices (Simon, 2010; Decker, 2015; Wyman, Smith, Meyer & Godfrey, 2011).

Objective 2B will begin with a semi-structured interview (Crouch & Pearce, 2013) targeted at augmented reality experts. These interviews will be conducted to gain an insight into augmented reality in professional practice as well as an understanding of current trends within the industry and will require ethics approval. These interviews will be conducted with a range of industry professionals in this field such as: augmented reality developers, academics and technicians. The qualitative data from these interviews will then be evaluated through a thematic analysis (Schwandt, 2007).

A textual analysis (McKee, 2003) of my usability report (Objective 1C), literature review (Objective 2A) and thematic analysis (Objective 2B) will then be carried out in Objective 1C. Through this analysis process, the themes and ideas that are generated will form the basis for design guidelines which will shape the design process of the augmented reality exhibit output in Aim 3. This will compile and analyse all research conducted in Aim 1 and Aim 2 and will discuss the best practices derived from that information (McKee, 2003).

Aim 3

Aim 3 will cover a more practical approach to this design research. Through an empirical, research through design (Alonso & Keyson, 2012) methodology a reality exhibition prototype will be developed in Objective 3A. This methodology will be informed through the guidelines and specifications generated in Objective 2C and will use a design thinking structure (Plattner, Leifer & Meinel, 2014).

Testing of this augmented reality prototype (Objective 3A Output) will then commence in Objective 3B. This testing will be conducted on users using usability testing (Cockton, 2016 & Martin & Hanington, 2012, p.194). This method is based on user reactions to physical interactions which highlight the shortcomings of the prototype so they can be addressed in future iterations. Ethics approval will be needed for this stage of testing.

The final stage of my project, Objective 3C, will compile the information created through Aim 3's development process into a case study (Creswell, 2007) involving the augmented reality exhibit that was produced in Objective 3B. The development process of the augmented reality exhibit will be blogged and the case study will be based on this blog's initial hypotheses and observations. This blog will include the use of participatory design methods (Martin & Hanington, 2012) and will ground the findings of this thesis research.

02.Methodologies Applied

Prototyping

Prototyping is the tangible creation of a project at various levels of resolution (Martin & Hanington, 2012). This method is mainly used for the development and testing of ideas. A prototype is usually the realisation of product, or its interface concepts, and is a critical feature of the design process. Its main benefit being the quick testing of a tangible design concept by the designer, design team, clients and potential users. Design prototypes are defined by their levels of fidelity.

Low-Fidelity Prototyping

Low-fidelity prototyping is common throughout early ideation of a project. Paper prototyping is a common technique for prototyping software and interface design. Others include: concept sketches, storyboards or sketch models. Low-fidelity prototypes are an excellent tool for testing out ideas and concepts early on in a project.

High-Fidelity Prototyping

High-fidelity prototypes, unlike Low-fidelity prototypes, are usually refined products. These prototypes often have the basic functionality of the final product. When used in testing with users, they can provide a response based on usability or interaction which is an indication of the product's functionality.

Research Through Design

There are three main methods of design research (Frayling, 2003, p. 1-5):

- research into design;
- research through design;
- research for design.

Research through design is composed of the design process itself. This includes development work, documentation, experimentation and iteration (Frayling, 2003, p. 1-5). Research through design uses the design process as a research activity. Burdkick (2003) states through implementing design thinking, in the act of designning, builds up a knowledge of design and enhances design practices. Documentation is critical in this method as it promotes reflection on the design process and offers opportunities to synthesise and integrate alterations to the design.

Usability Testing

'Usability testing focuses on people and their tasks, and seeks empirical evidence about how to improve the usability of an interface' (Gould & Lewis.1985, p.300).

Usability testing is an evaluative method that allows a designer to observe an individual's experience. The user is given a set of tasks which they complete over the course of the testing. Through the observation of these tasks, this method is designed to help developers identify the issue or bad user experiences so that they can be fixed and tested again for the project to reach completion.

Usability tests are designed around tasks that represent typical end-user goals. These tasks should be reflective of the actual goals that users would have when they operate the product.

Jacobsen, Hertzum and Bonnie's (1998) method of usability tests typically follow the format of the 'think-aloud protocol' technique. When recording these tests, the focus remains on the following errors that a user can experience:

- Understands the task but can't complete it within a reasonable amount of time;
- Understands the goal, but must try different approaches to complete the task;
- Gives up or resigns from the process;
- Completes a task, but not the task that was specified;
- Expresses surprise or delight;
- Expresses frustration or confusion for not being able to complete the task;
- Asserts that something is wrong or doesn't make sense;
- Makes a suggestion for the interface or the flow of events.

Something to note, as with other methods of gathering data, is that the number of participants in the test directly impacts the number of problems that are detected (Virzi, 1992, p.457-468). Jacobsen, Hertzum and Bonnie (1998) believe that the number of evaluators can also result in more problems detected with the product. From this evidence, when using this methodology, the testers must be aware of these effects so they can make the correct judgement on how to approach the usability testing process.

Usability Report

The usability report is informed by empirical evidence, often gathered through usability testing, and is useful for compiling and analysing the data gathered from these kinds of methods. The goal of the report is to clearly outline which parts of the user experience should be fixed or improved. The layout below is based off Martin and Hanington's (2012) usability report layout in the book *Universal Methods of Design.*

Executive summary

Describes the most serious usability problems first using content and context. Provide a section which is directed at each target group (age based).

Total problems found

For each problem detected, write a short paragraph which includes frequency, impact and persistence. Optionally, use participant quotes to ground these problems.

The list of problems that will be fixed

Identify, prioritise and fix the most severe problems first.

Reports on positive findings

Similar to the executive summary, but based on positive results.

Task and scenario descriptions

Include all the information that demonstrates the tasks and scenarios are robust and representative to effectively get a range of usability errors.

Literature Review

Literature reviews are an integral part of academic papers. They are also a useful component of any design project which requires collecting and synthesising research on a given topic. Literature reviews are a method of secondary research, but the amount of content and ideas they can cover makes them critical for both design research and practices.

A literature review does not summarize everything from each source. Martin and Hanington state that this method 'should converge information in a synthetic way, such that connections can be drawn between references, while maintaining relevant focus on the design project' (2012, p.112).

Key Informant Interviews

Interviews are a method for direct contact with participants, with the intention to collect first-hand accounts of experience, perceptions, attitudes and opinions. Key informant interviews concentrate on people who have specialised or have expert knowledge in a subject. Conducted well, Key Informant interviews can shed valuable insight into advanced topics and thinking on the subjects discussed. Martin and Hanington (2012) recommend if the research is designed for expository purposes, then an unstructured format would work best for these interviews in order to let the conversation and ideas come naturally.

Textual Analysis

A textual analysis is used to combine the ideas and theme of qualitative data so it may be analysed (McKee, 2003). This methodology is useful as it is designed to succinctly summarise and present an array of ideas.

Case Study

> 'The case study is a research strategy involving in-depth investigation of single events or instances in context, using multiple sources of research evidence' (Yin, 2002).

Case studies can be used to study the effects of new innovations in technology or ideas. Bresli & Buchanan (2008) state that case studies need to:

- determine a problem;
- make initial hypotheses;
- conduct research through interviews, observations and other forms of information gathering;
- revise hypotheses and theory;
- tell a story.

03.Key Concepts

A Taxonomy of Realities
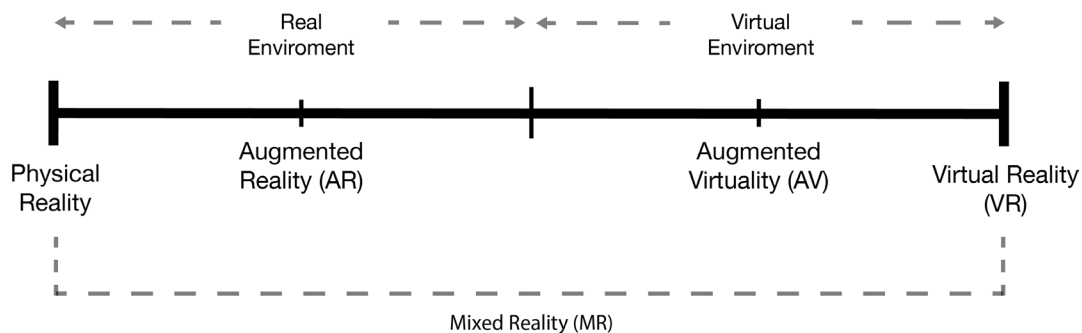
02. **Virtuality Continuum Diagram (based off: Milgram & Kishino, 1994)**

To understand augmented reality, it must be in relation to the virtuality continuum (figure 02). This continuum defines and creates a taxonomy of the different subclasses of reality based on how they merge the real and virtual worlds.

The virtuality continuum (Milgram & Kishino, 1994) is a linear graph that depicts the environmental extremes at both ends of the graph. The left extreme defines environments consisting solely of real objects (defined below), and the right extreme, defines environments consisting solely of virtual objects (defined below), an example of which would be a conventional computer graphic simulation. Everything in between these extremes has a position on the graph that relates back to how many virtual objects or qualities that reality has.

People often believe that a virtual reality (VR) environment is one in which the participant or observer is totally immersed in and able to interact with a completely synthetic world. This world may mimic the properties of some real-world environments, either existing or fictional. However, it can also exceed the bounds of physical reality by creating a world in which the physical laws (space, time, mechanics, material properties) are not in effect. The VR label is also frequently used in association with a variety of other environments, to which total immersion does not necessarily pertain, but which does fall somewhere along a virtuality continuum. Virtual reality in this context is placed on the virtuality continuum alongside other subclasses of reality-related technologies that involve the merging of real and virtual realities and objects. These realities are referred to generically as mixed reality (MR). The overall objective of the virtuality continuum is to 'formulate a taxonomy of the various ways in which the "virtual" and "real" aspects of MR environments can be realised' (Milgram & Kishino, 1994, p.2).

Distinguishing objects and environments

Virtual from Real

For the virtulaity continuum (Milgram & Kishino, 1994) to make sense, it is necessary to make the distinction between the concepts of real and virtual objects and environments. To do this we must make three distinctions:

First Distinction

The first distinction we must make is defining the operational definitions of both virtual and physical objects:

- **Physical Reality/Objects -** Real objects are any objects that have an actual objective existence.
- **Virtual Reality/Objects -** Virtual objects are objects that exist in essence or effect, but not formally or actually. For a virtual object to be viewed, it must be simulated, since in essence it does not exist

Second Distinction

The second distinction concerns the issue of image quality as an aspect of reflecting reality. Large amounts of money and effort are being invested in developing technologies which will enable the production of images which look 'real', where the standard of comparison for realism is taken as direct viewing (through air or glass) of a real object, or 'unmediated reality' (Naimark, 1991).

Third Distinction

The third distinction we make is on virtual images in the field of optics. A virtual image can be defined as an image which has no luminosity based at the location which it appears, meaning no light emanates from a virtual object to interact with any physical objects or environments. With respect to MR environments, therefore, we consider any virtual image of an object as one which appears transparent.

Define Augmented Reality

03. Augmented Reality Tree (2017)

Augmented reality is placed on the left half of the continuum as by definition it is based in the real-world environment. However, due to its use of virtual objects in this environment, it is closer to the virtual half of the continuum. Augmented reality is a technology that supplements the real world with virtual (computer-generated) images. These virtual images are designed to coexist in a physical environment like other physical objects. Azuma, Baillot, Behringer, Feiner, Julier and MacIntyre (2001) state that augmented reality has the following three properties:

- Combines real and virtual objects in a real environment;
- Runs in real time;
- Aligins real and virtual objects with each other.

Strong and Weak Augmented Reality

Currently there are two types of augmented reality hardware that allow for different augmented experiences to be achieved. Often this is due to the processing power of the platform that the augmented reality is based on. These experiences will be classified in this thesis as 'strong' or 'weak' augmented reality.

Weak augmented reality is defined as augmented reality with basic interactions and with little-to-no tracking. Examples of this include Pokémon Go's augmented view, as well as most mobile-based augmented reality due to their limited processing. These experiences do not align virtual images in physical space using proper position tracking; instead they use overlays and sensors to create the illusion of true position tracking.

Strong augmented reality experiences have advanced tracking, often mapping the whole room with sensors that creates a virtual mesh, which allows position tracking with visual content aligned in a physical environment. These platforms also enable varied interaction opportunities such as speech recognition, gestures controls and gaze tracking.

Types of AR Displays

See-through

An augmented reality that places virtual images in the real environment which enables the user to see with no additional video feed of that environment. This type of augmented reality display is mounted on headsets, glasses and other platforms that allows the user to see the physical environment around them, offering a larger field of view and immersion.

Video-based

This augmented reality view places virtual images in a live video feed that the user can see. Its feed is collected through a camera and is projected on a screen with the virtual images overlaid onto it. This type of augmented display is mainly used in mobile and monitor-based displays and offers a limited field of view based on the camera. These displays are widely available.

Use of Augmented Reality

Augmented reality was not properly developed until early 2001 due to technical restrictions. As a result, it does not have many clear applications as a technology. Many researchers such as Billinghurst and Denser (2012), are still testing out its capabilities and exploring how best to utilise them. In a case study they conducted, an augmented reality project called The *Magic Book* (note this case study is described in the design precedents section) was used to gain insight into augmented reality's value in education. From the results of this case study, Billinghurst and Denser have indicated this technology is well suited for classroom education. They explain:

> 'AR's high level of interactivity enhances learning, particularly for students who learn through kinaesthetic, visual, and other non-text-based methods ... Such applications motivate students to explore their surroundings and collaboratively develop their problem-solving skills' (Billinghurst & Duenser, 2012, p.62).

Although this case study proves augmented reality's benefit as an educational tool, Billinghurst and Denser also noted that the applications of augmented reality, in this field, could be explored further. They identified that the root of this problem was often the content which augmented reality

displays. Each experience should be designed from the ground up with consideration to the context it impacts. Overall, thoughtful design will aid in maximising the impact augmented reality has on its audience.

Recently, augmented reality software has been built into mobile devices. Javornik (2016) is interested in the marketing aspects of augmented reality and believes that its application on mobile devices hold interesting opportunities. This opinion is shared with Billinghurst and Duenser (2012) who claim that 'with mobile devices, users can have an augmented reality experience anywhere' (p.58). Mobile platforms can vastly improve augmented reality's ability to 'embed our world with a different kind of materiality' (Liberati, 2016, p.27). Mobile platforms can empower users to create their own personal narrative while they control their mobile device. Augmented reality is designed to be 'something that allows us to perceive whole new parts of the world' (Liberati, 2016, p.27). From this research, it seems that it has the ability to create interesting experiences.

The Museum Effect

Defining the Museum Effect

The museum effect is a phenomenon that was first described by Alpers(1991) in the article, 'A Museum a Way of Seeing'. This effect, when used in the context of a museum, isolates something from its world and transforms it into an art piece, to be observed and reflected on (Alpers,1991, p. 27). This effect determines that the presentation of the exhibit will have some effect on the viewer. Furthermore, everyone's interaction will be uniquely different as everyone sees the world based on their own perceptions. 'We vary; the work is constant' (Smith, 2014, p. 67). This 'way of seeing' assumes that each display object is being presented on a pedestal. By isolating each display object, visitors are more easily allowed to observe, but by taking each artefact out of context the curator could remove crucial information in which the user can use to better understand the object's true nature. As the museum effect defines how a visitor views display objects, trying to overcome it is pointless and instead a designer should seek to work with it as it keeps with the museum objects' authentic nature.

A Way of Seeing, the right way to look at an exhibit

To enhance this effect, it is paramount to understand that people often take objects at their face value. This is not how people should view works, but according to Smith (2014) it is often how they do. In order to change the individual's perceptions on an art piece they must have access to more knowledge in order to gain greater insight. This problem can be approached by a twofold solution discussed by Smith (2014) in his book *The Museum effect: How Museums, Libraries and Cultural Institutions Educate and Civilise Society.*

'First, we need to encourage visitors to trust their own viewing, enjoying and reflecting on works as they see fit… And second, we need to show people that for many works, insight to the work can lead to a more satisfying interaction with it. And that the knowledge of specific works, artists, schools and periods of art can lead to more generalizable skill in looking at particular works.' (Smith, 2014, p.140)

This solution offers an interesting paradox. How can we present objects like they are artistic pieces that are isolated from their original context, while also giving the user an opportunity to gain the knowledge required to understand this context?

Presentation Options and the Paradox of Help

Contemporary museum practice presents additional information through a variety of media and technology (Smith, 2014, p.147). These technologies allow for immersion and insight to the exhibitions, but each has its pros and cons through its method of providing context to museum pieces. Another theory that must be considered when attempting to enhance the museum effect is the Paradox of Help. Helping users become more engaged with the museum display object is fine, if the information being added does not take away from the visitor's pleasure of discovering things on their own. Smith states that this effect is also a concern in the field of teaching or helping people in general, as it is important that people learn to develop their skills independently. This is so they are not reliant on the information being provided to dictate the way they think. These effects are an important thing to consider when using these forms of media to enhance the museum effect and create a better experience for the visitor.

The Museum Effect and Augmented Reality

By isolating display objects museum displays can allow visitors to see these items, without context, as the museum effect intends. However, augmented reality could augment the physical space with virtual images which convey this context. This would allow the viewer to personalise their experience and have the best of both worlds whilst still staying true to the authenticity of the museum effect as a way of seeing.

04.Design Precedents

Aurasma Mobile Application

Aurasma, created in 2011, is an augmented reality software that is available as a mobile application for marketing and advertising (*Aurasma Mobile Application*, 2016). It has the capacity to recognise and map real world images and then overlay them with computer graphics. These overlays are only seen when viewed through the mobile application. Although this is a clever application for this technology, its use in marketing and advertising is limited. No user could tell which physical objects are mapped with virtual overlays without the application being open and scanning all the time. This serves as a reminder that augmented reality is still in its infancy, although from what this application presents, it has potential for changing methods of advertising and marketing.

Cooper Hewitt Pen

The Cooper Hewitt Pen, created in 2015, is a device which visitors use for interactions with certain exhibits in the Cooper Hewitt, Smithsonian Design Museum (*Cooper Hewitt Pen*, 2016). The Cooper Hewitt Pen is designed to emphasise play. This is achieved by making gamified exhibits throughout the museum that can be manipulated by the pen. It also stores each experience that is visited to a personal website, to later be reviewed by the visitor. The pen encourages engagement with the exhibits on a personal level, giving control over the museum experience. This interactive nature has been identified by The Cooper Hewitt Museum as an important aspect to focus technology on. The Cooper Hewitt Pen proves that if designed appropriately, technology can revolutionise how we experience museums in the future by making interactions appealing and targeted to visitors.

Dino Autopsy

INDE's travelling Dinosaur Exhibition 'Dino Autopsy' was created in 2015 and is an augmented reality exhibition that has travelled around China (*Dino Autopsy*, 2015). It allows visitors to view and interact with dinosaurs rendered with augmented reality technology. The exhibit consists of an empty stage which has been mapped virtually with animated dinosaur models. These models can only be viewed through a mobile device application or through a big screen which has a live video feed and an augmented reality overlay. This exhibit is a great example of how augmented reality can be used to present information to an audience as the large presentation space allows for life-size dinosaur models. This gives the exhibition content scale and grandeur. The downside of this is that without its technology, Dino Autopsy is just an empty stage. This is perfect for its role as a travelling show but not ideal for an established exhibition.

04. Aurasma Augmented Reality (2017)

05. Cooper Hewitt Pen (Cooper Hewitt - Smithsonian Design Museum, 2015)

06. Magic Book (Bishop, 2007)

⊚ Totodile / CP428

07. Pokémon Go Augmented View (2017)

08. Snapchat Lens (2017)

Magic Book

The Magic Book, created in 2001, is an augmented reality display in the form of a book (Billinghurst & Poupyrev, 2001). Using a hand-held, heads-up display, virtual models appear on the pages of the book, reminiscent of a pop-up book. This project was an early example of augmented reality applications and even today, still holds up as a solid concept, mainly in the way its content links to the narrative of the book. Its example could be followed in relation to the importance of a strong narrative within museum exhibitions by ensuring the content is of the same standard aesthetically and practically.

Pokémon Go

Pokémon Go (*Pokémon Go Wiki*, 2017), created in 2016, is an augmented reality game that is played on smartphones. It uses the phone's sensors to send real location information to allow its players to discover Pokémon, small creatures, positioned on a virtual map of the real world. The game was created by Niantic, who is also known for creating Ingress, the augmented reality mobile game that utilises global positioning system technology (GPS) to fuel a sci-fi story encompassing the entire world. Ingress currently has 12 million downloads worldwide.

Pokémon go is not true augmented reality, but a form of weak augmented reality. This is because its virtual images are not truly aligned with the physical world. Pokémon Go instead uses the camera view with a user interface (UI) overlay that is positioned using a phone's gyroscope and accelerometer. This creates the illusion of a virtual object in physical reality, which can be debunked by moving the phone forward and backward. When this is done, the virtual objects remain the same distance from the phone, whereas if they aligned with the physical world, they would retain a fixed position in space. Adding more interaction with the virtual images would also make this application more interesting. Despite its flaws, this precedent is an easy application to understand and allows the public access to augmented reality. Pokémon Go's mass adoption and capture the public's attention shows how much potential augmented reality has.

Snapchat

Snapchat is a multimedia photo sharing application that was created in 2011 (*'Snapchat'*, 2017). This mobile application incorporates a 'Lens' feature that was introduced in September 2015 (Katzowitz & Machado, 2017). The 'Lens' allows Snapchat users to overlay their selfie photos with virtual images by tracking their face, in real time, using face detection technology. Later in November 2015, Snapchat also launched the 'World Filter' feature (Katzowitz & Machado, 2017). This feature also overlays virtual images onto the user's images without the use of face detection to align the virtual images. Instead virtual images are aligned on screen by the user to modify any image that the user takes. The Snapchat 'Lens' and 'Filter' shows how basic use of augmented reality can alter images easily and how this technology can elicit joy from simple interactions.

05.Downstage Exhibition

Overview

As part of this thesis research, this exhibition is an early exploration into augmented reality and its use in practice within a formal exhibition. The work was completed in tandem with a team of design students from Victoria University and was presented and exhibited in the New Zealand National Library from 22nd August until 11th November, 2016. Over the six weeks the development team completed six high-fidelity prototypes which served as exhibits.

Description

The exhibit's content was based on the Downstage Theatre Company. This theatre company was the first and most enduring professional theatre company in New Zealand. Its existence was just short of fifty years, which by international standards is a significant lifespan. Each exhibit focused on a separate production performed by Downstage and showcased some form of augmented reality technology. These six productions include:

- *End of the Golden Weather*
- *Prisoners of Mother England*
- *Shuriken*
- *As You Like It*
- *Hedda Gabler*
- *Niu Sila.*

Technical Considerations

Through our exhibits, we tried to explore different variations of augmented media to determine which methods would work best within an exhibition setting. We were particularly interested in how different types of virtual media would explore the content in interesting ways and push the boundaries of what we could show the visitors. These include:

- face mapping;
- augmented videos;
- augmented models;
- augmented text.

These forms of media were chosen to research different methods of use for augmented technology.

Software and Mobile Platform

ARToolkit is an open-source augmented reality software. It was the main software used to create the augmented reality functions of each exhibit. ARToolkit has functionality to enable marker-based tracking and is optimised for mobile devices. On a mobile platform, ARToolkit's software recognises a marker image and maps the virtual content onto the marker, using it as a virtual anchor point. It then displays the virtual images aligned on a screen through a video-based augmented display.

Apple iPads served as the main mobile platform for our augmented reality experiences. We used the iPad's inbuilt camera to enable ARToolkit's video-based augmented reality as well as other sensors such as the accelerometers for specific exhibits.

User Considerations

From the beginning of this research project, the National Library's stated that their main demographic were the Patrons of the National Library. This demographic was identified in the age range of 40 and above. The National Library stated that this group may not be used to new technology. Specifications to meet the target demographic were designed to mitigate this potential issue. These specifications included:

Weak Augmented Reality Interactions

Each augmented reality experience was kept simplistic, but was different enough to challenge every visitor's perceptions of interactive exhibitions and augmented reality technology.

Operation Instructions

Instructions were included at each exhibit. These instructions explained to the visitor how to work the technology using a step-by-step process so each exhibit could be operated independently. To ensure that they would have the best results for viewing the exhibits, these instructions also defined the key conditions in which the technology would work best.

Exhibition Outputs

09. **End of the Golden Weather Augmented Exhibit (2016)**

End of the Golden Weather

The *End of the Golden Weather* is a play with distinct themes; New Zealand's beach culture in the 1920s-30s, unrest caused during the Queen's Street riots and union marches in 1932. The exhibit created for our exhibition was centred on these themes. The concept was to explore these ideas through a video and audio experience. This experience would represent this era, with the goal of the experience being a representation of nostalgia. The video was displayed as an augmented virtual object. This object was mapped to a poster of the play, with ARToolkit using it as a natural feature-tracked (NFT) marker.

Time constraints were placed on the video. It was a minute long and would play on a loop that was initialised every time the augmented experience was initiated. The archival images and footage displayed in the video were sourced and digitised from the National Library's collections. These included:

- Tunapuna Beach in the 1930s, which expressed New Zealand's beach culture.
- Union Riots of Wellington (1932), which demonstrated the unrest of the time.
- Recordings from the Downstage production of the *End of the Golden Weather*.

The video was made to the specifications which had been pre-planned and then iteratively developed through editing.

A physical constraint of the exhibition space itself was an echo. Due to this. headphones needed to be worn during the exhibit experience to hear sound clearly. This limited the exhibit to one visitor at a time.

10. **Prisoners of Mother England Augmented Exhibit (2016)**

Prisoners of Mother England

Prisoners of Mother England is a play about British immigrants who have begun a new life in New Zealand. There are strong themes throughout this play of alienation, national pride and being an outsider. The initial concept for an exhibit based on this play was to use the multitude of production images from the library collections as NFT markers. This would enable virtual images to be placed over these production images in virtual reality. These virtual images would reveal other media that related to the strong themes from the play, as discussed above.

Unfortunately, after testing a basic concept build of this application, it was found that an iPad could not track all of the NFT data we built augmented reality display. Every time the iPad started, the application crashed. To fix this a looping video slide show was created using all production media that was collected. This slideshow was made into an augmented virtual video and mapped onto the main production image of the exhibit.
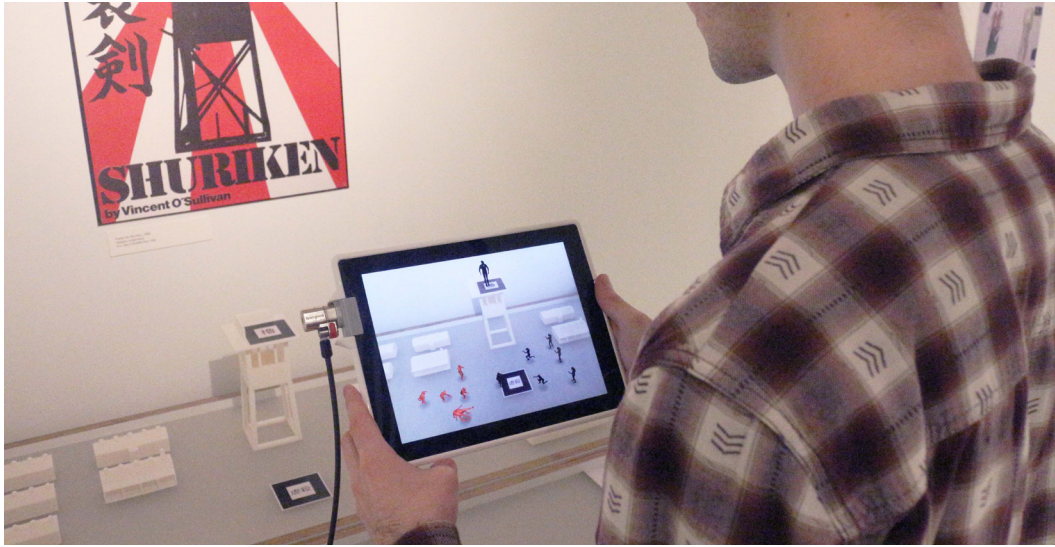
11. Shuriken Augmented Exhibit (2016)

Shuriken

The production of *Shuriken* is a recount of a horrific section of New Zealand's history. It is set at Featherston Camp, which was where New Zealand kept captured Japanese soldiers during World War II. This camp was the site in which 48 Japanese and one New Zealander were killed in a massacre carried out by New Zealand soldiers. As this was the most shocking aspect of the play itself, we wanted to reconstruct this scene within the exhibit.

This was the most complex display in the exhibition. It required many different parts to create. We reconstructed a section of Featherston camp using 3D printing. Among these models were small square markers which, when viewed through video based augmented reality, populated the camp with animated virtual models. The models were created in Maya, a 3D modelling program, then animated using motion capture data recorded in Victoria University's Media Design School motion capture lab. Motion capture creates realistic animations that can be rigged to 3D models by tracking the movements of participants in motion capture suits.

**12.** **As you Like It Augmented Exhibit (2016)**

As You Like It

As You Like It was a play written by William Shakespeare. It was performed by the Downstage Theatre Company after they moved into the Hannah Playhouse. The main idea behind the *As You Like It* exhibit was to create a life size, virtual re-creation of the interior of this playhouse. This exhibit would examine the space since moving to the Hannah Playhouse was such an important part of the Downstage Theatre Companies history.

The 3D interior model of the Hannah Playhouse and the various objects that filled it were created through close examinations of architectural plans, as well as other images in the library's collections. These helped to create a structurally accurate, virtual representation of the space. The textures used to cover these models were all originally created and inspired through the images and first-hand written accounts of the interior by members of Downstage.

These assets were then imported into the Unity game engine and lit, using virtual lights, to better represent what the playhouse would look like during a production. This scene was imported into our augmented reality application and uploaded to an iPad. The iPad uses its accelerometer to help position where the user looks in the virtual playhouse. So, in this way the IPad can be used like a window into a virtual world.

To link the virtual experience, in the iPad with the exhibition space, a vinyl decal of the iconic stage carpet was placed on the floor. A Visitor using the experience could then use this as a visual cue coupling the physical and virtual settings.
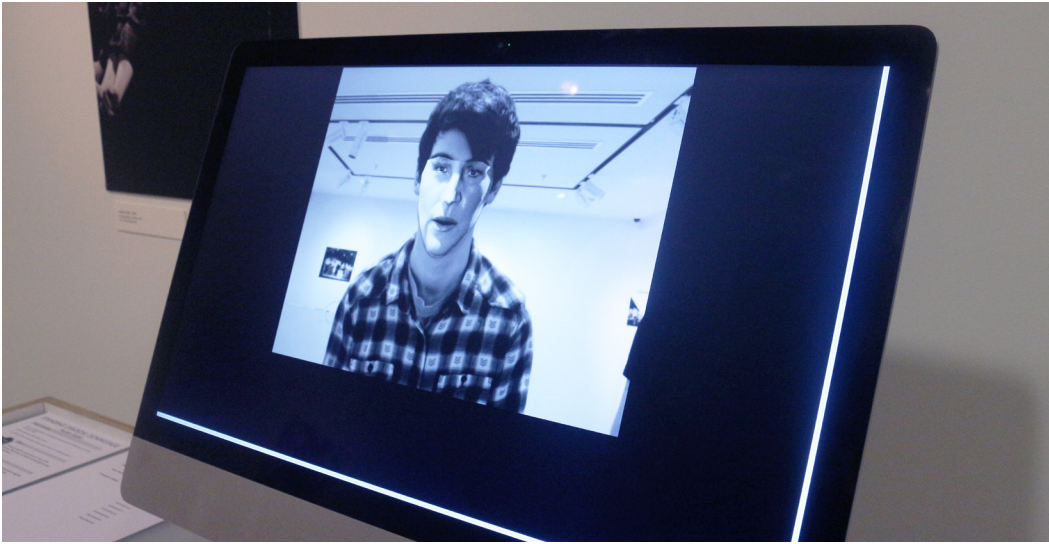
13. Hedda Gabler Augmented Exhibit (2016)

Hedda Gabler

Within the *Hedda Gabler* production, Hedda is the main character and the focus of the story is based around her manipulation of the other characters. This exhibit was designed to present her importance within this production. The concept for this exhibit was to put the visitor in the shoes of Hedda herself by using face tracking technology. Face tracking, much like Snapchats filters, uses augmented reality that is mapped to a user's face with virtual images. The virtual mask was animated as it covered the visitor's face, to better show the fractured psyche that made up Hedda's character.

The exhibition was created entirely from web technologies using an open-source JavaScript library called CLMtracker to track points on the user's face. The programme overlays an image as a digital mask. The overlaid mask for this exhibition was created from an image of Hedda in the National Library's Downstage Collection. This mask was then put into Adobe Photoshop and an animation was applied to it. The final application is contained in a webpage hosted on a webserver with all functionality added in accompanying JavaScript. The webpage was then presented in an iMac which used the machine's webcam for a live video feed of the visitors.

14. Nui Sila Augmented Exhibit (2016)

Nui Sila

Nui Sila is a production about friendship and Pacifica culture in New Zealand. The initial concept for the *Niu Sila* exhibit was to showcase its writers, Dave Armstrong and Oscar Kightley. The National Library collection featured an in-depth analysis of the play, including interviews which were showcases in the exhibit. Aspects of this analysis would be projected as augmented text which would appear over portraits of the two writers, using their images as NFT markers. Footage of a scene from the Nui Sila production performed by the Downstage Theatre Company would also be augmented similarly using a production image as the marker.

Unfortunately, like the *Prisoners of Mother England* exhibit, the iPad crashed due to multiple NFT markers being present within the application. Due to time constraints, the exhibit was scaled back by keeping an edited version of the production footage. It was a shame that all the work that had been created for this exhibit could not be included.

User Testing and Usability Report

This report was based on user tests conducted after the exhibition was opened. This was due to the six-week time constraint placed on the development of the exhibition. None of the solutions were implemented into the design of the exhibition while it ran, however the research gathered here has given valuable insight into the application of augmented reality technology in a display which will inform further research in this thesis.

Executive Summary

From the findings, the context surrounding the augmented content was not clear as it was the only content in most of the exhibitions. This issue is created from a lack of information surrounding each exhibit and a reliance on the exhibition to deliver this context. Every person who conducted the user testing encountered this issue in one form or another. Three age ranges were targeted in the user testing; 25 or under, 26-55 and 55 and over.

25 or under/26-55 Contextual problems

Users from these two age ranges did not understand the exact context of the exhibitions. Future designs of augmented reality exhibitions need to ground the experience in physical reality which the technology then augments. Otherwise people will say they 'don't get the point of it' or 'don't understand what this is in reference to.'

55 and over Technology-based Problems

Users in this age range found using the technology the biggest hurdle to overcome. Some did not fully understand the use of augmented reality and just thought some of the content went 'full screen'. Some did not know how to work the iPad used as a platform for the augmented reality experiences. However, once they became familiar with the experiences this became less of an issue, but is still an initial obstruction to consider.

Total Problems Found

- The context of the augmented content was not clear This is due to a too much virtual content and a lack of physical content.
- Three users did not realise that augmented videos were positioned in space so they did not take full advantage of the properties offered in the augmented reality platform. In video content, especially users just chose to stand still to consume the content which made its augmented reality less impactful.
- All the users who watched the augmented videos had no idea of the videos' length or any other

information regarding videos. They also thought that the video length should be at most under one minute as holding the iPad for longer than that became tedious.

- The size of the augmented video was too large, forcing all the users to move themselves to see it in the best orientation. Many users also had to lean or contort their body slightly to get the screen in the best viewing position.
- The older users were unfamiliar with the basic functionality of iPads. However, once this was explained most could operate them without too much trouble.
- Some of the 3D models were performing unrecognisable actions in the animations we used. This led to them being unrecognisable to some users (such as the guards shooting guns).
- The *As You Like It* experience could have been more interactive and explained better. The biggest problem with it was that people did not initially understand what space they were in.
- Due to potential thefts iPads were secured by tethers to the plinths by each exhibition. As they allowed about a '1-1 ½ metre clearance' they severely restricted movement to the user and often made holding the iPad uncomfortable.
- Most markers for video content were slightly too low. When the experience was initiated, the viewing, angle was uncomfortable for the user, especially with the addition of tethers.
- While the instructions for each exhibit helped explain its functionality, they were not refined enough to fully help most users understand everything about using the iPads and augmented reality.

List of Problems that will be Fixed

The context of the augmented content was not clear as it was the only content in most of the exhibitions. The content that is created should be present in the physical environment also to ground the augmented content. Audio could be included in the future to explain the ideas and context behind each exhibit clearly. This could be constructed like an audio guided tour that has been used in museums previously.

Some users did not realise that augmented videos were positioned in space so they did not take full advantage of the properties of the augmented reality platform. A better explanation and introduction to the technology could help with this. The tethers also had a part to play in this as they limited the user to a certain field of movement. In the future a short tutorial (optional in case someone is familiar with the technology) could be an effective solution to solve this issue.

Most users who watched the augmented videos had no idea of the videos' length or any other information regarding videos. The addition of a timecode and other video information would be useful. As suggested by the testers, the length of the video should also be capped to ensure user engagement is not lost.

Reports on Positive Findings

There was a distinct note of surprise when each user interacted with the *Shuriken* Augmented Exhibit and the Virtual Instance *As you Like it* Exhibit. They really enjoyed the virtual content. In *Shuriken,* the fact that tangible virtual models populated the physical environment was the most interesting aspect. In the VR experience, the best part was the user guided experience with the user having complete control over the exploration of the scene.

Users seemed to enjoy the new way to experience ideas in an exhibition through augmented reality. They liked how they could control their view once they understood how it all worked. Most noted that it could be made more immersive but understood how it could create exciting new experiences within exhibitions.

The tracking and stability of the virtual images was great if the users operated the iPads properly. All the content worked in real-time with not lagging or graphical problems. This made the user experience more pleasant and did not interrupt their experiences. This result is down to our testing of the limits of the software and only including a strict number of markers and virtual objects to suit these limitations.

In *Shuriken,* the mix of virtual models in a physical environment was very interesting to the users. All users just like the mix of technology and could experience the content of the exhibition in a new and novel way. Many people moved closer to the models to get a more detailed view and one user noted that the use of drop shadows to create the illusion of physicality in the virtual models was a great addition.

Task and Scenario Descriptions

Leading up to the usability tests, a request was sent out to the New Zealand National Library to provide four staff who were varied in age and experience to use for user testing. This request was also sent to students at Victoria University. This was answered by three students. The user testing conducted features seven people representative of all the main age groups I wanted to test:

- 25 or under;
- 26-55;
- 55 and over.

Before testing, ethics forms were signed which stated that the audio from these tests would be recorded. Making sure that they were comfortable with these conditions. Participants were tested individually. They would interact with each of the six exhibits, without any direction or input from the researcher. While they were operating each exhibit, they would explain their actions aloud, including thoughts and feelings. This was recorded, non-intrusively, by an audio recorder. These testing conditions were designed to assume each user had no experience with the technology. After this, a short questionnaire was completed by each participant to gather important general information such as age range and other thoughts on the exhibition experience.

Findings

After working on this project, it is clear which aspects of augmented reality technology are successful and which are ineffective.

The motion capture and animated models used in the *Shuriken* exhibit worked the best as the animated models were effective at creating a narrative within the physical setting that was created. The augmented videos were also a compelling interactive experience for the viewer, however visitors did not engage with them as intended. Often the visitors just stood still and watched them then moved on, not realising that they could manipulate the viewing perspective by moving around the video while watching it. Further functionality and design considerations around the video content could improve the impact of this augmented content.

Unfortunately, due to the processing power of the iPads, the full experience of some exhibits was affected. In future research, proper testing of both the software and the platform should be conducted earlier.

The main feature of augmented exhibit design that must be emphasised is the mixture of physical and virtual objects. Augmented reality exhibits such as *Shuriken* received the best visitor response because of this feature. In this case the virtual models gave the physical, 3D printed buildings more context. This grounds the virtual objects and enhances the overall display.

In Aim 3's case study the focus of the augmented museum display should be on the physical display object, using the 'Museum Effect' theory (Alpers, 1991; Smith, 2014). This grounds the display through the artefact then the augmented reality technology could inform and enhance the context of the display virtually, offering 'two ways of seeing' a museum display.

15. Downstage Exhibition 1 (2016)

16. Downstage Exhibition 2 (2016)

17. As you Like It Augmented Exhibition full body (2016)

06.Literature Review

Purpose

To explore museum exhibit curation practice and methods and determine issues in their design or potential areas to improve using augmented reality technology (Simon, 2010; Wyman, Smith, Meyer & Godfrey, 2011).

Scope and Boundaries

This review will be limited to studies of museum curation and museum exhibits. By identifying design considerations and successful criteria for museum exhibit displays this review will inform design guidelines and success criteria.

Significance and Background

Since museums began, they have focused on many efforts from research, collecting and preserving collections (Lord & Piacente, 2014, p.9). However, the museum's main draw is the exhibits they present as these displays allow the public to discover and explore aspects of culture and history that they would not always have access to "by engaging their visitors on many levels" (Wyman, Smith, Meyer & Godfrey, 2011, p.463).

Through these exhibits, Lord and Piacente (2014, p.1) state that museums continue to enjoy an unparalleled public interest and trust. Surveys by the American Alliance of Museums and the Association for Canadian Studies demonstrate that the public places more trust in the information communicated by museums than the media, the internet, teachers and professors. This belief is fuelled by display objects such as artefacts or specimens which are seen by museum patrons as authentic and important.

However, after the turn of the millennium and rise of interactive technologies, many new ideas are being explored to revolutionise how museum exhibits should look and communicate. Museums must adapt their exhibits in order to accommodate these changes. From these ideas, it is clear audiences are looking for a new level of interactivity. Wyman, Smith, Meyer and Godfrey (2011) agree that museums must; "design experiences that not only entertain and capture attention, but also are able to convey complex information" (p.462). Lord, & Piacente (2014) echo this sentiment and continue that:

'Our definition of what and exhibition is has changed, as exhibitions can now be virtual; non-traditional, migratory and pop-up spaces play host to temporary displays; and social media have created amazing opportunities for participatory engagement and shifted authority away from experts to the public. And as time-constrained audiences demand more dynamic, interactive, and mobile applications, museum leadership, managers, staff and designers are rising to these challenges in innovative ways' (p.1)

Museum Terminology

Artefact. A man-made or a natural, two- or three-dimensional object having special value.
(Bogle,2013, p.359)

Caption. A small piece of text linking the object to the display around it.
(Velarde, 2001, p.66)

Display. A group of items having a commonality; part of an exhibit. Several displays can make up an exhibit.
(Bogle, 2013, p.361)

Display item/object. Any two- or three-dimensional exhibition object, such as an artefact, a painting, an illustration, or a specimen.
(Bogle, 2013, p.361)

Exhibit. A subdivision of an exhibition that has a common theme and usually contains several displays.
(Bogle, 2013, p.362)

Exhibition. The total area devoted to presenting exhibits and displays that have a common theme.
(Bogle, 2013, p.362)

Label/Exhibit label. Text that identifies and explains an item or artefact. It is usually brief and could contain an illustration.
(Bogle, 2013, p.364)

Museum. A building open to the public with a mandate to collect, safeguard, store and display objects of educational value.
(Bogle, 2013, p.365)

Defining Museum Exhibitions

While there are many reasons go to a museum, the main draw that museums have are their exhibitions (Falk & Dierking, 2000). The display items that are on show are often of significance culturally to the visitors viewing them, such as artefacts of a civilisation, specimens of a continent or the interactive apparatus of science (Lord & Piacente, 2014, p.8).

There are three main factors that define a museum exhibit: education, entertainment and authenticity. These factors distinguish museum exhibits from similar exhibits, such as trade show exhibits, and are determined by isolating the aspects that museum exhibitions uniquely offer a visitor.

Education

The main point of difference is education. Museum exhibitions succeed if they educate their visitors about their subject matter. Lord and Piacente believe that this factor is very important in general but especially if the theme of the exhibition is didactic in its approach or heavily features science or history topics (Lord & Piacente, 2014, p.10). Wyman, Smith, Meyer and Godfrey (2011, p.462) state that museums exhibitions must have the ability to convey complex information.

Entertainment

As museums have become more popular, they have appropriated and adapted many of the techniques used by other attractions such as audio visual shows and other experiences common to theme parks in order to offer a more engaging and entertaining atmosphere. Lord and Piacente (2014, p.11) think that the criteria for success here is more concerned with how engaged visitors were and how long did they stay engaged. With the persistent question being asked, 'Are we having fun yet?', Wyman, Smith, Meyer and Godfrey (2014, p.462) explain that capturing the audience's attention is important to help facilitate their education. Skilful use of contemporary technology and social media can significantly enhance a museum's ability to entertain through personal visitor experiences (Simon, 2010).

Authenticity

The final main factor in what defines the museum exhibition is their presentation of what visitors consider to be authentic. One of the key successes for museums in general is the ability for their visitors to place their confidences in the authenticity of the experiences that museums can offer (Lord & Piacente, 2014, p.1). This is often capitalised on through presentation of the original display object's, artefacts or works of art.

This effect is compounded through the internet and social media in which millions of images have been shared of these original objects. This advertisement has been a boon to museums as it allows potential visitors to profit (in knowledge) of the visual evidence of their collections but also creates the draw for visitors to come in and experience 'the real thing'. This being the authentic, gestalt experience that only a museum can provide.

Authenticity is important as it allows the visitor to find meaning within an exhibit. The visitors only have cause to trust the meaning created by this experience or the object due to the confidence they have in the authenticity of them (Lord & Piacente, 2014, p.12).

Exhibit Curation Practice

In exhibits, a curator cannot rely on a human presence that explains the context of the content and display items. Therefore, the curator of an exhibit needs to employ subtle means to reach and communicate with as many different types of visitors as possible. Velarde specifies that, 'Displaying to sell, delight, persuade and enlighten deals with the same basic commodity: three-dimensional, informative space' (2001, p.3). As such every aspect of this space must be considered and designed so it communicates effectively and accurately.

Common Elements of Museum Exhibits

Display Objects

Display objects, also known as display items, are the central focus of an exhibit or display (Bogle, 2010, p.361). These display objects can be any two- or three -dimensional thing, such as an artefact, a painting, an illustration, or a specimen. Exhibits also include display objects to communicate ideas in a three-dimensional and visual manner such as special models which diagrammatically explain subjects too complex for either words or illustrations (Velarde, 2001, p.56). Exhibits and exhibitions are mainly built around these display objects so the presentation of these objects is one of the most important aspects of curation and exhibition design.

Labels and Captions

Labels and captions are the most basic form of media for the communication of information to a visitor. The label is often the more informative and descriptive (Velarde, 2001, p.66). They often identify the display object they are associated with and are found adjacent to these objects. Labels and captions must be designed to communicate this concisely and effectively so they do not take up too much space. On occasions, both labels and captions are overused which can lead to ineffective communication of relevant information. Smith (2014, p.150-154) states that this media requires visitors to shift their way of seeing from viewing to reading which can break up the overall experience of an exhibit. Wall text and labels are also fixed and tell the visitor what they should know but can limited in the information they provide.

Tools and Technology

To continue to be relevant museums need to constantly update themselves to meet the demands of visitors (Wyman, Smith, Meyer & Godfrey, 2011). Museums are adapting exhibition environments to develop interactive exhibition spaces. These spaces allow visitors to become more involved with the content of an exhibition (Calcagno and Biscaro, 2012).

Audio Tours/Recordings

Audio tours are a technology in which audio recordings are played to deliver contextual information to a visitor. Smith (2014, p.150-154) describes two main forms of audio tours: random access or structured podcast. Structured podcast tours play along a chronological path, taking the visitor through a structured narrative throughout the exhibition. Random access differs slightly as they offer the visitor the ability to plug into stops along the way, giving them more freedom to experience the exhibition in many ways (Dierking & Falk, 2000). Audio tours allow the visitors to view and listen to information while making them widely adopted by museums and art galleries whereby visitors can concentrate on the displays while receiving deeper contextual information at the same time (Li and Liew, 2015).

Video Tours/Displays

Video tours give the user relevant information on a subject or display in the form of a video or short film. This information often adds context to the object or exhibition it concerns and is framed and edited to explain it succinctly. There are also some cases where this technology is used as an introduction, providing a quick overview to the subject matter. Smith (2014, p.150-154) explains that video displays will compete with display objects for visual attention. They do however allow an audience to quickly gain information in a way they can understand, making them powerful tools for communicating ideas.

Defining Museum Display Methodologies

Modes of Exhibiting Collections

Modes of exhibiting collections define how an exhibit communicates with visitors based on the methods used to display museum collection items. There are four main modes in which a display can be characterised (Lord & Piacente, 2014, p.126). They are as follows:

- Aesthetic
- Contextual
- Process
- Visible Storage

Aesthetic

An aesthetic display is an exhibition technique whereby a work of art or artefact is presented as an individual object to be appreciated in its isolation (Alpers, 1991). There is often very little contextual information available in relation to the display item as it often speaks for itself (Lord & Piacente, 2014, p.126-127). The emphasis of the exhibit is placed on the display item itself and not on supporting material. This mode of display is most used in art galleries, with museums using it depending on the character of the collections they use.

Contextual

This display mode is concerned with communicating the nature and context of an object (Lord & Piacente, 2014, p.127-128). By building the context around a display item, the goal of this mode is to give the item relevance by showing its place within the bigger picture of its culture or history. This display can help a visitor better understand the history of an object which often reveals its meaning or importance in a clear way. When put in context objects can tell compelling stories.

Process

Process communicates how something works or why it occurs. This display mode relies on communicating through contextual and supporting information. An emphasis placed on this information which explains a sequence of actions or behaviours in detail and the outcome of these processes (Lord & Piacente, 2014, p.128).

Visible Storage

Visible Storage is used to maximise the number of items on display. Examples of viable storage displays include shelves of books or drawers containing insect collections. This display mode works best for the casual viewing of many display objects (Lord, & Piacente, 2014, p.129).

Museum Exhibit Design Considerations

In terms of presenting exhibits in exhibitions it is important to remember that there is no formalised presentation format as no exhibition content is the same. This makes it imperative that exhibits are structured in a way in which visitors can navigate information clearly. Exhibits must be displayed and presented in a common framework that enables visitors to subconsciously understand the patterns through the display area so that information can then be communicated effectively.

Accessibility

As museums are a place of knowledge and learning for the public, visitors must be considered when designing and curating exhibits. This is to ensure their exhibits can communicate to the broadest diversity of the public (Dierking & Falk, 2000). Although some exhibits may be more focused on a particular group of people, engagement of a broad spectrum of visitors benefits everyone (Lord & Piacente, 2014, p.28-29). While some of the design considerations discussed later cater to some of these groups, the following list contains common accessibility considerations for visitors.

Physical Disabilities
People's eyesight varies and not all visitors are physically able, such as individuals in wheelchairs, resulting in a viewing-height difference (Velarde, 2001, p.126). A short list of common disabilities/ physical states are:

- Bifocals;
- Short sighted;
- Blindness;
- Deafness;
- The physically disabled.

Language
Due to their cultural standing, museums are often visited by foreigners and tourists. Museums should make some effort to enable the translation of ideas and concepts so these visitors are not alienated and unable to understand. Bogle (2013, p.188) explains that the success of an exhibition depends on how well everyone is participating in the experience and understands the content.

Rhythm and Consistency

An exhibition must have a clear consistent framework or pattern for a visitor to subconsciously follow (Bogle, 2013, p.278). This consistency should be designed by the curator and be incorporated through an informative and graphic rhythm. To achieve this standardised design, rules should be selected to make this framework consistent throughout the exhibits in an exhibition. Velarde relates the typefaces and sizing of text to be almost an identical practice (Velarde,2001, p.73).

Scale and Space

The composition and spatial design of an exhibit are determined by the scale of the display object. As displays are three-dimensional spaces, the curator must understand the relationships between the size and the space around these objects. Both Velarde and Bogle agree with this. with Velarde clarifying the relationship by stating that, 'A very large object on a huge stand will look normal, but if it is apparently cramped in, its scale will be exaggerated' (Velarde, 2001, p.95). He also comments on the quantity of objects creating their own unique spatial relationships, such as massing similarly themed small objects like medals, to focus on their common theme. This proves how important spatial consideration are in exhibit curation. From these examples, it is clear that the very large and the very small always create areas of particular interest (Bogle, 2013, p.283).

Viewing Distance

In successful exhibits, information and text must be easy to read. This can be achieved through matching the viewing distance of a display with the reading distance of these texts (Smith, 2014, p.150-154). Often this simple rule is not followed, forcing the visitor to move between the label's reading distance and the display's viewing distance which disconnects the display with its text. The reading and viewing distances are also affected by the scale of the display itself. The curation of these larger displays and their larger viewing distances often makes for difficult reading distances. Velarde also considers the human element as he states that:

> 'the print must be big enough to read the normal sighted, myopic, long sighted, or middle aged or elderly...if there is a label describing some object it should manifestly be placed next to an object with a reading distance that corresponds to the viewing distance' (Velarde, 2001, p.72-73).

Evaluation Criteria

Every museum exhibit must strive to communicate information to the visitor(educate), to promote visitor engagement (entertain) and prove the validity of the information it provides (authenticity). This is what makes museum exhibits so effective as a medium of presentation within museums. In conclusion, four criteria have been identified, based on Lord, & Piacente's Evaluation Criteria (2014, p.28-29). This evaluation criteria analyses the research completed in this review and defines the factors of a successful museum exhibit.

Curation of Information

This criteria looks to determine if the exhibition communicates new information by introducing new ideas, context and perspectives. These criteria do not focus on the method of communication but the nature of the information itself (Lord, & Piacente, 2014, p.28-29). Does the exhibit have something new to say? Furthermore, museum exhibits have an inherent authenticity that must be maintained (Lord, & Piacente, 2014, p.10-12), but often show display objects out of their original context. As such the information presented by a successful exhibit should be cited and encourage visitors to think critically about the information showcased in an exhibit.

Transformative Visitor Experience

This criteria is focused on how an exhibition can create and enable the communication of knowledge. Does it try to do this in new and innovative ways? How does the exhibit use time and space to create an experience for the visitor? Transformative experiences often leave a lasting impression and help the visitor retain knowledge (Calcagno and Biscaro, 2012; Simon, 2010). Exhibits designed in this way can provide an experience that will not only capture attention but be able to convey complex information (Wyman, Smith, Meyer & Godfrey, 2011, p.462).

Self-Directed Visitor Experience

Dierking & Falk (2000) have describe museums as public pools of information and free choice learning environments. This criteria is concerned with ensuring that museum content is adapted so that a visitor can experience it in many different ways.

Accessibility

Museums are institutions for the public benefit so their content should be able to be consumed by everyone. Successful museum exhibits should have considerations to be able to engage with the full diversity of people within the public (Lord & Piacente, 2014, p.28-29). Before an exhibit is undertaken, the scope of visitors should be determined and understood to ensure successful interactions with as many people as possible.

07.Analysis of Interviews

Mark Billinghurst

Mark Billinghurst is a professor at the University of South Australia and has been researching augmented reality for about 20 years. As well as teaching classes about augmented reality, he is now leading his own research lab. The class is a mix of virtual and augmented reality and teaches students how to design these experiences using the Unity engine with the goal of building mobile-based AR and VR experiences.

Billinghurst became involved in augmented reality research when he was a PhD student at Washington University, during the mid-nineties. The tracking software available at that time had made augmented reality possible. Billinghurst, who was interested in collaborative technologies, thought augmented reality could be used to communicate concepts and ideas. This was the focus of his PhD.

Billinghurst has a high level of expertise in augmented reality and he is one of the most highly published researchers in this field. Throughout his career, he has developed some core key augmented reality technologies such as the ARToolkit's visual tracking library. Currently Billinghurst is also involved with a venture capital firm working in augmented reality companies.

Tom Furness

Tom Furness is a professor at the University of Washington in the College of Engineering. Furness has appointments in the faculty of Engineering, Electrical Engineering, Mechanical Engineering, Air and Astro, and Human Centred Design in Engineering. Furness was a founding director of the Human Interface Technology Lab (HIT Lab) in the University of Washington. He later co-founded two other HIT Labs. One based at the University of Canterbury, New Zealand and the University of South Australia, Australia. Furness is also the general manager of two augmented reality research labs. These are called Rat lab LLC and Pulse Tectonics LLC. Recently he founded a non-for-profit organisation called the Virtual World Society.

Furness's whole career has been dedicated to augmented and virtual reality. Starting in 1966, he was working on fighter cockpits for the United States military, creating see-through augmented displays and virtual heads up displays (HUD). In 1971, Furness began work on the first video-based augmented reality, the Visually Coupled System. This system was the first augmented reality that was head stabilised and was designed for use in fighter jet cockpits. Furness left the, military in the eighties to work at the University of Washington and has been there ever since.

Linda Lieu

Linda Lieu is an honorary associate professor from the University of Technology, Sydney. Previously, Lieu was directing postgraduate programmes in interactive media within the Institute for Interactive Media and Learning, then moved to the Faculty of Engineering and IT, continuing the same role in this facility. Lieu is currently working with the Business School, directing post graduate studies in Arts, Creative and Cultural Industries Management.

Lieu has experience working with augmented reality through her time working with interactive media at the University of Technology, Sydney. This experience is from a business perspective and based on student projects she helped manage. These projects were focused on digital disruption and how augmented reality technology could upset established industries and businesses.

Augmented Reality Development Methods

An emphasis on design research was a common theme within all the subjects. Design research is focused on using design thinking methods to define and create the scope of a project before it is undertaken. As Furness stated, one must ask a series of questions to do this:

> 'What is this supposed to do? Then, for whom is it supposed to do it? And then, Why? … Then you get into the constraints and assumptions you are going to make about this. This is all problem characterisation. Then you start coming up with a solution.' T Furness (personal communication, January 14, 2017)

Lieu also stated that in terms of questions, contextual questions must be asked surrounding the functionality of a design as these factors often determine whether a design is considered successful or not.

The research lab teams of both Furness and Billinghurst both use practical design methods which are similar to those of agile development. This development style structures the development of projects they work on, enabling them to refine and monitor their projects progression.

The Augmented Reality Industry

Furness finds currently that not many people know the difference between augmented reality and virtual reality. Often he finds that describing the industry by comparing the two types of technology is the best way to ground and contextualise them both.

> 'If you look at business analysts they say that VR is going to be 30-billion-dollar domain over the next few years but AR is going to be a 120-billion-dollar domain. They see AR as being a larger boom and they are basing this on how consumers will actually use things.

Just like wearable technology, AR is going to have more applications with wearable type devices people use in the real world.

VR on the other hand you are isolated from the outside world, you are in this virtual world that is situated in a design studio or your home, but you are not out in the world. When they look at the enterprise applications and they look at industry, advertising and things like that. Those are going to drive the augmented realities. VR will be driven by games and education, cinema and films, entertainment.' T Furness (personal communication, January 14, 2017)

With this great uptake in funding and business, Billinghurst states that there are three areas that need to be advanced to improve augmented reality technologies overall.

Tracking software

Tracking software allows augmented reality technology to map and align physical environments with virtual objects. Companies have recently made leaps and bounds in the field of tracking technologies in indoor spaces. Called spatial tracking, this software tracks a whole room and is able to position appropriate content within this set space, meaning there is less reliance for marker tracking.

'For example, Microsoft HoloLens have a very good indoor tracker that can track you very accurately when you are inside a room.' M Billinghurst (personal communication, January 13, 2017)

Furness agrees that HoloLens have accomplished the basics of two types of tracking: gesture controls and spatial tracking, which allows more complex interactions and added that these will only improve with each iteration of the device.

Display Technology

Display technology is the interface which presents the augmented reality view. These displays can be video-based or see-through. Current display technologies are video-based as these kinds of systems are easier to build and access. However, upcoming changes in display technologies are moving more towards see-through displays as they are far more immersive due to the wide field of view.

Furness stated that companies, such as Lumus, have been creating very thin see-through displays that are good for AR. These displays are the basis of new head-mounted displays (HMD) that will become far more prevalent in five years, according to Billinghurst.

The Virtual Retinal Display is another version of augmented display that is currently being developed. This technology scans virtual images directly onto the retina, allowing for either a virtual reality of an augmented reality display depending on how much transparency these virtual images have. It was, and still is, the only display that has the luminance to create a truly high

quality, wide field of view, see-through augmented reality display. This technology is the basis on which the Magic Leap is built, which is also a new augmented reality system.

User Experience

User experience is the overall impact and experience of a person using a technology, based on how easy or enjoyable it is to use. In terms of user experience, Billinghurst, Furness and Lieu all agreed that the biggest impact of augmented reality on the mainstream consciousness was Pokémon Go. Using a small amount of augmented reality, Pokémon Go has revolutionised how the mainstream view augmented reality as well as gamifying augmented interactions which the public enjoyed. Billinghurst and Furness say that augmented reality experiences should be considered in terms of user experiences. In their research labs, this aspect of each augmented reality project's design is thoroughly tested during development.

Future Advancements in Augmented Reality

HMD

The next big trend that will impact augmented reality will be the rise of head-mounted displays (HMD) in the next four-five years. Billinghurst states this is not only because of the rise of virtual headsets which sets a precedent, but also as a compulsory development in the quality of user experience using augmented reality technology. Current AR is mainly handheld and this change will provide the user with more varied options for interaction including gesture controls.

Navigation

One field that both Furness and Billinghurst agree that is worthwhile for augmented reality is navigation or wayfinding. Currently there are minor attempts into augmented navigation through apps like Pokémon Go using methods such as geo location but these are not yet accurate enough. Once head-mounted displays are more socially accepted, see-through augmented navigation through these headsets would not be far behind.

Business

Lieu also mentioned that the amount of funding going into this technology (120 billion according to Furness) will create big impacts on business investments. However, she also noted that there was a drop-off in engagement of the mobile augmented reality applications, using Pokémon Go as an example. Considering this, the next stage of business investments of this technology may be in creating augmented reality hardware to facilitate better lasting user interactions.

Advances in Augmented Reality Hardware

Smart Phones

Billinghurst states the rise of smartphones 'lead[s] to a huge increase of the experiences people have with augmented reality' (2017). This is due to all the features of current smartphones today. They come with accelerometers and compasses creating handheld, mobile, augmented reality displays. The other defining factor of these phones are the miniature graphics cards they house. Furness states that this hardware has made all the difference, as its ability to make this and other technologies possible is just amazing. 'That means by 2010-11 there were hundreds of millions of people who had access to AR in their pockets' (Billinghurst 2017).

Processors

One aspect that is paramount for current advances in augmented reality technology are the processing capabilities of current smartphones. This hardware allows smartphones to compute tracking algorithms quickly, giving the phone the ability to track the world in real time. The best thing is that the mobile phone's possessing power, image processors and sensors are getting better each year, allowing for better tracking in any physical environment, outdoor or indoor.

Accessibility of Technology

Billinghurst states that augmented technology is already available to the public through technologies like smartphones, which almost everyone in the western society has access to. Furness agreed with this statement but also added that there should be a distinction between what kind of augmented technology people have access to. Whether strong or weak.

Weak augmented reality is much like Pokémon Go's use of augmented reality, a gimmick with basic interactions and little-to-no tracking. Stronger experiences are like the Microsoft HoloLens, with special tracking and rich interactions such as speech, gestures and head-tracking. Currently smartphones are the best platform for weak augmented reality interactions, but in the future once hardware improves, everyone could have a strong augmented reality experience in their pocket.

Lieu agrees that smartphones at present are the best devices for accessibility but thinks they could be used in more novel ways to augment the world. This does not have to be visual augmentation but audio-based augmentation. This audio-based content could also be inclusive and promote accessibility to those who do not have great eyesight or other visual-based disabilities.

Limitations of Augmented Reality

Negative implications of this technology are based around the social stigmas of society. These aspects pertain to two different forms of augmented reality handheld and head-mounted displays (HMD).

HMD

The main case study that both Billinghurst and Furness used to describe the social implications of HMD was the Google glass and its failure. Furness states that:

'The pushback that people got as a result of wearing something and the social side of it. When you are meeting a person or talking to a person that's wearing one of these google glasses you are wondering, what are they doing? Are they scanning me? Are they taking pictures of me? What is showing up on their display that I don't see?' (Furness 2017)

Handheld

Handheld augmented reality pertains mainly to smartphones and can carry the similar stigmas within some societies. This is often due to these handsets being used in inappropriate ways as they can be used to invade others' privacy.

'In the USA, people that used hand mounted AR technology, like on their phones or tablets, walking around the real world looking at virtual content through a layer and about 20% of them had a negative experience where people thought that they were filming them or taking a photograph where people thought they shouldn't be, or didn't know what they were doing making fun of them walking around looking stupid holding their phone up.' M Billinghurst (personal communication, January 13, 2017)

He did go on to clarify that some locations did accept this activity more than others and that this could be normalised more easily than HMD.

Location

Both Lieu and Billinghurst alluded to locations as an issue, based on the context of the location. Using the Pokémon Go controversy as an example:

'People don't want people playing Pokémon Go outside their house or church or the holocaust museum. Washington DC was in the news as a PokéStop and they didn't want

people playing inside or on the grounds. So, I think there are still some areas to be addressed.' M Billinghurst (personal communication, January 13, 2017)

Mobile/Smartphone Augmented Reality

Lieu discussed that in most application developments, generating an application for multiple devices can be an issue for developers. These include different screen sizes and camera sensors that can affect an application's performance.

Examples of Augmented Reality

An innovative use of this technology is in the realm of medicine. For example, there is an augmented vein finder that uses ultrasound data to locate veins for doctors. Then with augmented projections, it places virtual images of the veins on the patient.

Lieu, Billinghurst and Furness all mentioned that Pokémon Go was a good example of augmented reality being taken up by the masses. Other examples were interactive in nature and involved large installations in public places such as bus shelters and Waterloo Station.

Augmented Reality in Museums

Museum AR should be used to enhance the physical artefacts within an exhibit according to Billinghurst. Furness elaborates on this by stating that AR should:

'... add something you can't see. Help people see inside objects in a museum, see historical context or the site where they were found. This history of the object itself.' T Furness (personal communication, January 14, 2017)

The experience from this technology could help the objects extend beyond their own physical limits and give the user much more information and context.Less successful experiences would be detached from this physical museum content or when using the wrong kind of technology, especially if a more streamlined experience could be designed in its place. Billinghurst explains it as:

'...not having technology for technology's sake. Like having a picture that triggers AR that takes you to a website or something. That is not a good use of AR you could use QR codes or something like that instead [fit for purpose].' M Billinghurst (personal communication, January 13, 2017)

Augmented Reality on Display

This aspect of technology can not only affect users but overcomplicate things for museum staff.

Furthermore, there have been some interesting examples of how one can extend beyond a museum's physical walls. In Wellington, there are a lot of Māori, historical pā sites scattered throughout the city. In a museum, if someone wants to learn about early Maori, they could use an app which allows them to walk outside the museum, at the same time using wayfinding cues (arrows and tags) to help them find some of the locations mentioned earlier in the museum.

Fitness for purpose is also an issue when it comes to some cultural aspects of museum exhibits. Furness states that any technology should never interfere with the gestalt one gets from being in a particular space.

08.Design Guidelines

The following is a summary of augmented reality user testing findings, literature review and professional interview textual analysis. It is designed to compile and list the best practices that were discovered through this research to inform the final case study of this research. These guidelines are theoretical and based around producing an augmented experience which delivers contextual information to the visitor using an augmented reality platform. They will include:

- **augmented exhibit evaluation criteria** - a list of important factors to create a successful augmented exhibit;
- **augmented reality exhibit considerations** - a list of important aspects of current augmented reality;
- **platform recommendation for augmented reality content in museums** - a detailed examination of smartphone technology and ability to be used as a platform for augmented reality experiences.

Augmented Exhibit Evaluation Criteria

These criteria have been adapted from the museum success criteria found in the museum literature review (page 42). These criteria also are based around the use of video-based smartphone augmented reality technology.

Curation of Information

This criterion looks to determine if the exhibition communicates new information by introducing new ideas, context and perspectives. It does not focus on the method of communication, but the nature of the information itself (Lord, & Piacente, 2014, p. 28-29). Using augmented reality, this can be accomplished through digital means as the technology offers a platform for multiple formats of information. These include text, audio, video and other interactive digital media.

Museum exhibits have an inherent authenticity that must be maintained (Lord, & Piacente, 2014, p. 10-12). However, museums often show objects out of their original context. Augmented exhibits should make efforts to link the user back to the original source of the information if possible. Using digital connections, augmented exhibits should feature some form of connection to the original digital collection. This would not only allow visitors to think critically about the information showcased in an exhibit, but also enable them to explore the vast collections that museums preserve.

Transformative Visitor Experience through Augmented Interactions

This criterion is focused on how an augmented exhibit can enable the communication of knowledge. Augmented reality displays should try to emphasise an inherent mix of physical and digital images to do this in novel ways. The state of the technology as it stands in its early stages of development should automatically leave a lasting impression. However, an understanding of the limitations of both the software and hardware (platform) is paramount to ensuring the strong or weak augmented interactions run smoothly for the visitor. Augmented exhibits designed in this way can provide an experience that will not only capture attention but also allow the user to immerse themselves in the information they view.

Self-Directed Visitor Experience

As public pools of information, museum exhibits are considered to be free-choice learning environments as Falk and Dierking (1992) have incisively put it. As such this criterion is concerned with ensuring museum content is adapted so that a visitor can experience it in many different ways, if they so desire. When using an augmented reality exhibit, the visitor should be able to access all the information that an exhibit has to offer in multiple forms, if possible. This should be enabled through the user interface and interactions that the visitor uses.

Accessibility

Museums are institutions for the public benefit so their content should be available to everyone. A successful augmented museum exhibit should have functions which enable it to engage with a diverse range of people. Before an augmented exhibit is undertaken, the scope of visitors should be determined and understood to ensure successful interactions with as many people as possible.

Augmented Exhibit Considerations

Traditional Exhibit Considerations

Rhythm and Consistency

An exhibition must have a clear, consistent framework or pattern for a visitor to subconsciously follow (Bogle, 2013, p. 278).

08.Design Guidelines

Scale and Space

The composition and spatial design of an exhibit are determined by the scale of the display object and the impact of the visual hierarchy as a whole (Velarde, 2001, p. 95).

Viewing Distance

In a successful exhibit, information and text must be easy to read. This can be achieved through matching the viewing distance of a display with the reading distance of these texts (Smith, 2014, p.150-154).

Technical Considerations

Aligning Physical and Virtual Objects

A mix of physical and virtual objects is the most successful combination when communicating information in an augmented exhibit. This mix of objects grounds the exhibit in a physical environment while presenting the context of the physical object through virtual content. Small details such as giving the virtual objects realistic lighting, as seen in the Downstage Exhibition's Shuriken exhibit (page 25), also strengthens this relationship. Through the marriage of these two realities, powerful experiences can be communicated in context.

Context and Use of Virtual Content

Often when using abstracted virtual models which require the user to give them meaning, the context of the exhibit can be lost. This can be due to the virtual objects not being in the right context or, in the case of the Downstage exhibition, a reliance on the exhibition programme to deliver this context (which the users did not always have access to, or did not read). This disconnect has a dramatic effect on the communication of ideas through augmented reality and often occurs when the exhibit has a focus on the augmented content instead of the subject it is based on. The relationship of physical and virtual objects could be improved by utilising the virtual objects to support existing physical objects and act as a peripheral tool. An augmented exhibit should keep the physical object as the focus of the exhibit and only use virtual images as vessels to deliver contextual information. Augmented reality augments physical reality.

Interactive Virtual Content

Users react positively to virtual objects which have basic elements of user interaction. These interactions are commonly called weak augmented reality. Basic interactions should aim to create a method in which the visitor can self-direct and initiate their own experiences, such as tapping to initialise virtual content.

Stability

If virtual images are unstable due to poor tracking, it can severely impact visitors' experience with an augmented exhibit. The exhibit should feature little-to-no shake, lag or glitching. Efforts should be made in the design process to test and understand the limits of the projects tracking software.

User Considerations

Social Stigmas (Location and Context)

Video-based augmented reality is often experienced via smartphones. Using technology on the platform can carry social stigmas when used in public spaces such as museums. Often these stigmas occur when other people see the use of handheld technology as being inappropriate or breaching their own privacy when used in a public space. For example, in Japan's Hiroshima Peace Memorial Park, Pokémon Go has caused issues with users abusing the parks grounds in Japan's Hiroshima Peace Memorial Park (Molloy, 2016). Individuals using the technology in public can also feel awkward or embarrassed with the attention that it brings, so it is important to consider how it impacts the surrounding space when designing augmented exhibits.

Familiarity with Augmented Reality Technology

At this stage, most users do not inherently know much about how augmented reality works. This is due to the state the technology is in at the moment and also lack of exposure to strong augmented reality experiences by the general public. However, users should not be treated as Luddites when it comes to design augmented experiences. New users will adapt in time. Much like current museum exhibitions, it can be just as beneficial to allow the user to explore and experience the augmentations for themselves.

Recommended Platform: Smartphones

Smartphones are the best platform at present for enabling the public's access to augmented reality content. This is due to inbuilt features such as cameras and sensors. Smartphones also contain miniature graphics cards that have enough processing potential to deliver reliable, if limited, augmented reality experiences.

Although more powerful head-mounted displays (HMD) for augmented reality do exist, the accessibility of these platforms does not yet rival that of smartphones. Smartphones have the potential to offer an augmented reality platform in the pocket of millions of people across the world, which makes them perfect for public museum space consumption.

Processors

Current smartphone sensors offer enough computing power to enable mobile augmented reality experiences. Contemporary smartphone processors allow smartphones to compute tracking algorithms quickly, giving the phone the ability to track the world in real time. This real-time tracking allows virtual objects to keep their position in space and while letting the phone react to the user's view and adjust the virtual objects realistically as if they were actually present in the physical environment. Another benefit of these smartphone processors is that they are being

constantly updated and upgraded with each new smartphone that comes out, meaning they will constantly get better as time goes on. Processors can also use data from phone sensors to alter and generate the virtual content that is present on the phone.

Sensors

Phones sensors can be used to alter the virtual objects produced by smartphone-based augmented reality. These sensors are built into a phone, so they can be called within the application's software and used in this way. Most modern phones contain the following sensors:

- **camera** - necessary to produce a real-time view for video-based augmented reality;
- **accelerometer** - used for movement-based interactions such as shaking the device;
- **compass** - used for geolocation-based augmented experiences and location data;
- **gyroscope** - used much like an accelerometer but can also be used for stabilising and phone orientation.

These sensors offer many opportunities for different user interactions as well as data inputs to generate virtual content. Each phone may be different so caution and testing will be required if any of these sensors are to be used for augmented experiences.

Multiple Platforms and Specifications

Not all smartphones share the same operating system, hardware and specifications.
Although modern smartphones are very similar in capabilities, there are many different models and types to choose from. This can create variety in the sensors -such as a camera's size and resolution-, screen size and power of each device. These parameters can affect the overall impact of a user's experience, or even make an augmented reality experience impossible if the correct specifications are not met or available. This is a limitation for all mobile development so it must be worked around and will affect the potential scope of the augmented project on this platform.

09.Augmented Portrait Exhibit

Overview

This case study will modify an established exhibit as a proof of concept for the augmented exhibit design guidelines (page 52). Using an established exhibit will narrow the scope of the project whilst providing a basis for the design. Structuring the case study this way also proves how augmented reality can impact already established exhibits without dramatically changing how museums are set up. After initial research and conceptual planning, the exhibit that will be used is the Wellington Harbour Board Chairman Display in the Wellington Museum.

19. Wellington Harbour Board Chairman Display 1 (2017)

Description

The Harbour Board Chairman display is an exhibit that presents a series of portraits of the men who were the chairmen of the Wellington City Harbour board. A small number of portraits will be augmented so they give the visitor contextual biographical information about each chairman. Visitors will use a mobile device or tablet to open the app and be able to initiate video-based augmented experiences through the camera of their device, using the portraits as markers. A mobile platform was chosen due to its accessibility as well as being an easy device to develop augmented applications for.

Technical Considerations

ARToolkit

ARToolkit, an open-source augmented reality software, will be used to run the augmented reality portion of this application. This software has functionality to enable natural feature tracking and is optimised for mobile devices. This will allow the portrait images of the harbour masters to be used as marker images. Used this way the portraits can also act as an identification for the virtual objects so each different marker image will initiate the correct content. ARToolkit is also available as a Unity plugin which will allow me to build the application in this Game engine.

Unity 5 Game Engine

Unity Game Engine will provide the digital platform for the exhibit application. Unity is a game engine that allows you to write code, scripts and systems for applications, then builds an application to function on different platforms, such as mobile devices. The engine comes with a range of developer ultilies to help speed up development, such as plugins, and is rather user friendly. Plugins will be researched during development if they are needed.

Xcode

As this application is going to be based on an iPad, Xcode is needed to compile the Unity build into an iOS application. Xcode is the only Apple-approved software which can achieve this and also offers necessary access to the sensors and peripherals, such as the camera that the augmented application may need.

Scope and Constraints

The initial aim of the study will be to meet the specifications based on the minimum viable product (MVP) stated below. Extra functionality will then be implemented based on importance according to the design guidelines and development time. The experience will be limited to three portraits. This will enable the focus of the project to be on the functionality of the application and less on the background research of each portrait. However, this will also emphasise the impact of this technology on multiple displays with the idea being that the application is scalable.The mobile platform will also be limited to an Apple iPad. This is due to three reasons:

- Development for this platform was conducted in the Downstage exhibits so it is a familiar platform to for this type of development;
- It has a large screen allowing for a bigger view of the augmented exhibit;
- They are easily accessed from Victoria University School of Design's Media Lab.

By limiting the platform there is also no concern about building to multiple different devices and operating systems which can be an issue for application development.

Minimum Viable Product

The minimum viable product application will meet the following criteria:

- Initiate an augmented reality experience based on the natural feature tracking of three harbour master portraits;
- Display augmented reality content designed around augmented text which informs the visitors about the displayed portraits.

Extra Functionality

The functionality described here is placed in a planned order of implementation. This may change during development. Additional functionality may be added based on the results of user testing.

- **interactive augmented reality nodes** - surrounding the portrait will be augmented and interactive nodes which when tapped will give the visitor access to additional contextual information.
- **audio recordings** - The ability for augmented text to be read out in audio playback form. This functionality will increase accessibility to the content of the display object.
- **augmented video integrations** - augmented video content which can be accessed through interacting with the information nodes or the portrait itself.
- **animations of portraits** - as above but in this case the portraits themselves are animated through augmented reality overlays.

List of Materials

Technology

- iPad (iOS mobile platform)
- Xcode
- Unity
- Unity plugins
- Markers/marker data

Physical materials

- Portraits of the harbour board chairmen (images)
- Images and extra data based on data and collections

Evaluation Criteria

The aim of this projects will be to build this exhibit based on the augmented exhibit design guidelines (page 52). These guidelines will form the basis of development that will be followed and will impact design decisions that are made during development of this application. Once the application has been finalised it will be accessed using these criteria.

Wellington Museum Demographics

Within the recent Experience Wellington, Wellington Museum Trust Annual Report, Wellington Museum received 133,470 visitors in 2015-2016 (Wellington Museum Trust, 2016, p.20). Furthermore, based on museum visitation statistics from the Ministry of Tourism's report on tourist activity (New Zealand Ministry of Tourism, 2009, p.2), international tourists make up 43% of museum visitors while domestic tourists make up 57% of museum visitors.
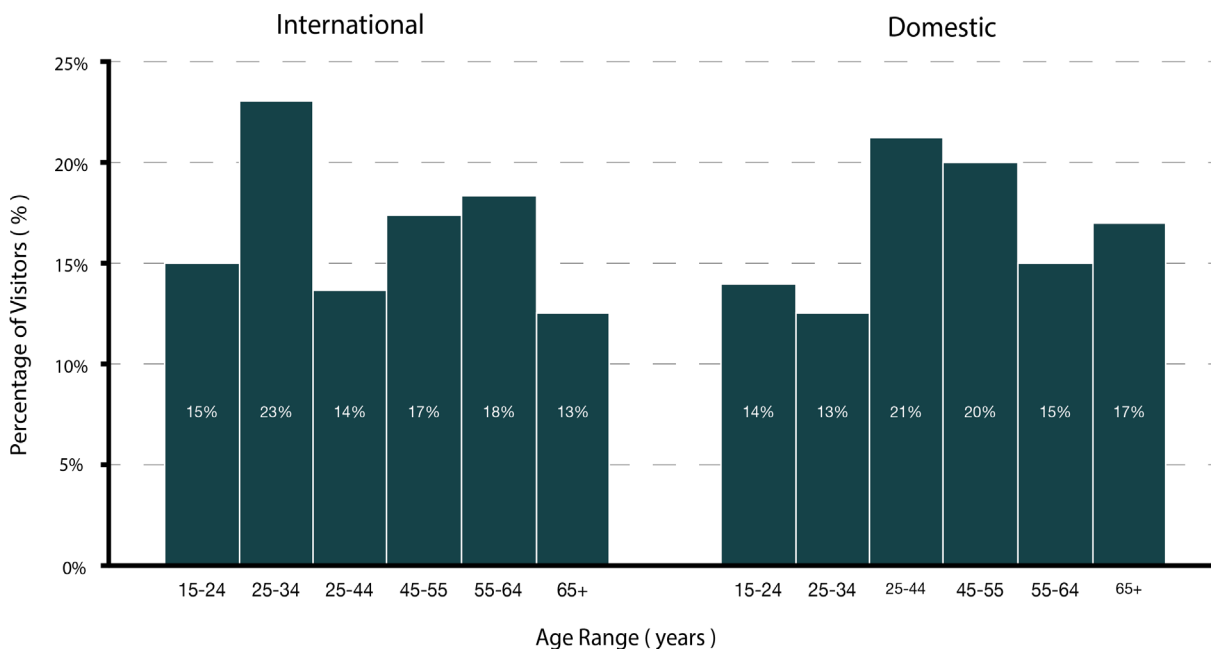
Age Ranges

International Tourists (New Zealand Ministry of Tourism, 2009, p.3)
Twenty three percent (23%) of international museum tourists were aged 25-34 years followed by those aged 55-64 years (18%), 45-54 years (17%) and 15-24 years (15%).

Domestic Tourists (New Zealand Ministry of Tourism, 2009, p.3)
Among domestic museum tourists, 21% were aged 35-44 years and 45-54 years. Seventeen percent were 65 years or older.

Based on this data, a larger emphasis on the younger domestic age demographic should be considered during the design process. However due to a relatively even spread of age ranges of both the domestic and international visitor statistics, a large age range should be consulted during user testing to ensure that all demographics are covered.

20. **Bar Graph: Age Ranges of Domestic and International Museum Tourists**

(based off data from : New Zealand Ministry of Tourism, 2009, p.3)

Exhibit Research and Analysis

Chairmen of Wellington Harbour Board

The Harbour board was established in 1880 and the first Chairman was notable businessman William Levin. The chairmen of the Wellington Harbour board were important Wellington personalities. Some were influential businessmen and 'self-made men'; others came from farming backgrounds. Most of the chairmen served on their local councils and commercial boards, while some even held the position of Mayor. Several of the chairmen had interests outside of business, using their influence and authority to support sport and the arts. Many harbour board chairmen were honoured by the Crown for their services to business and the community. The board disbanded in 1989. Nigel Gould was the last Chairman and is now the current Chair of CentrePort Limited.

Exhibit Design

The walls of the exhibition space are covered with the portraits of the Wellington harbour board chairmen. Contextual information panels were beside them, offering biographies and other information linked to each portrait through a position based key on the panel. Viewing and reading distances in this display were poor as the visitor must move in between the captions and the viewing position, and the key presented complications linking the contextual information to the displayed object.

Audio Tour

The exhibition space also includes an audio tour which was difficult to operate. Not only did multiple headsets fail to work as instructed but the audio that did was vague and did not offer targeted information which would have been more helpful and user-friendly.

21. Wellington Harbour Board Chairman Display 2 (2017)

22. Sir William Appleton (Hocken Snapshop, 2012)

Portraits

Three chairmen portraits were chosen to narrow focus and scope of the development. This number was chosen as the application was designed to affect multiple displays. After revising the list of chairmen portraits, Sir William Appleton, Sir Charles J. B. Norwood and Harold Beauchamp were chosen.
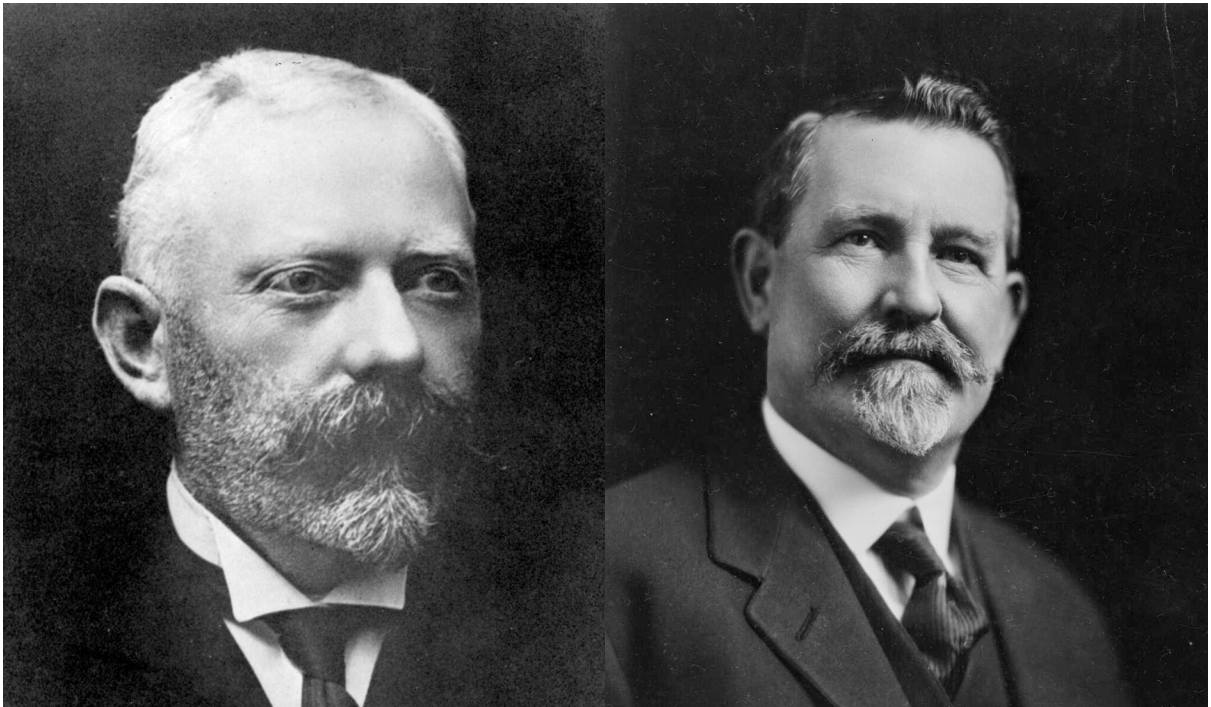
23. (left) Harold Beauchamp (National Library of New Zealand, 1910)

24. (right) Sir Charles J. B. Norwood (National Library of New Zealand, 1925)

Contextual Information

Information concerning the three chosen portraits was sourced from:

- The original display in Wellington Museum;
- Digital NZ Archives;
- Te Ara Digital Archives.

These are established collections that archive New Zealand history. Difference aspects of the chosen chairmen were researched and collated using these collections to show the diverse amount of information that an augmented exhibit could present about its subjects. For now, three interesting aspects of each subject were chosen. These include a bibliography and two other unique pieces of contextual information. Technically the amount of information that an exhibit could deliver to a visitor is limitless, as virtual objects are interchangeable on the platform that is being designed. This however would not fit within the scope of the project as creating a content management system (CMS) and the other technical requirements needed for this undertaking would be impractical. To do this a sever and full back end development would need to be produced.

A total of nine sections of information was written, three for each of the three chairmen.

Initial Development

Natural Feature Tracking

Generating Natural Feature Tracking Marker Sets

ARToolkit contains a program which generates natural feature marker sets. Natural feature tracking takes two-dimensional images or scans and creates tracking points that inbuilt tracking software use to position and anchor virtual objects in a physical environment. The three portrait images of the Wellington Harbour board chairmen were inputted into this program through the terminal to generate the marker sets.

When generating marker sets, each image is different, so the parameters of three variables must be adjusted within the script of this program.

Variable 1 DPI

The first variable is DPI (dots per inch). It is important to note that the higher the DPI, the larger the feature set and slower it is to load. The iPads mobile camera has a maximum resolution (DPI) so it is redundant to go over this. With all of these factors and after testing the best DPI was 150.

Variable 2 Threshold

The second variable that can be defined is its initialisation threshold. This has a range of 0–4. Zero meaning that only a few points have to be detected for natural feature tracking (NFT) to load and track, with 4 meaning that a high amount of points must be detected. Testing found that a value of 1 works best as it allows the user a little bit of time to get the scene initiated.

Variable 3 Tracking Points

The third variable is the amount of track points. This also ranges from a value of 0–4. The best option for this varies on the image. ARToolkit's documentation states that if an image has a lot of 'noise' then a lower number of track points is recommended. However if an image is clean or has been digitally created, then a setting of 3 is recommended. For the best results in the images that were used, tracking points at the value of 3 produced the best results.

Cleaning Up the Natural Feature Tracking

After visualising the initial generation of the tracking points, two of the images needed to be adjusted. This was fixed by cropping the portrait images to limit the amount of black space which was disrupting the ARToolkit NFT generator.

25. Visualisation of NFT Marker Set data (2017)

26. NFT Augmented Unity Engine Test (2017)
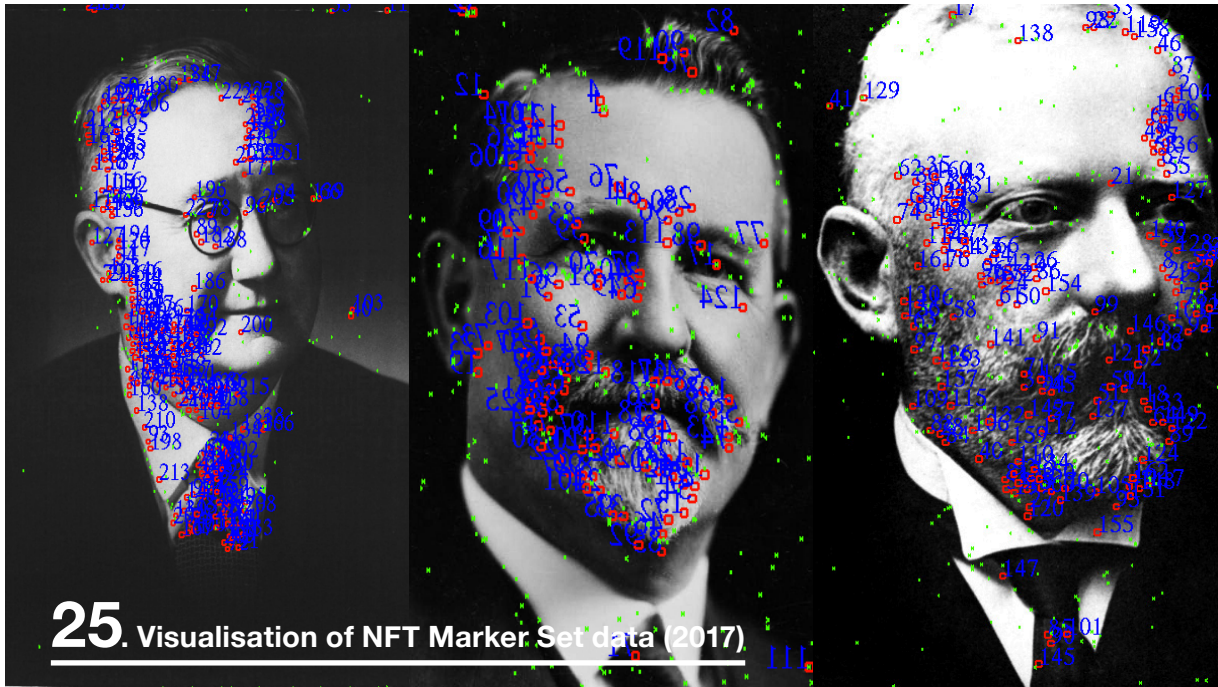
NFT Marker sets implementation in Unity Game Engine

The NFT markers were built into the same scene in Unity then linked to game objects which would appear when the NFT image materialises in the Camera View. Initial issues included poor game object sizing and positioning in physical space due to the different sized NFT tracking as well as poor tracking and virtual image stabilization due to poor lighting conditions.

Initial iPad Build Testing

This basic scene was then compiled in Xcode from within the iPad. The tracking had drastically improved as the Marker Images were fixed and not hand-held. The biggest issue this testing highlighted was that the iPad has the capacity to track only one NFT marker image at a given time. This was a known potential issue as something similar occurred in the Downstage exhibition. Future design decisions will be made around this limitation as there is no way to change the hardware being used.

27. iPad Test 1 (2017)

Initial UI and Graphic Design

To replace the placeholder buttons and graphics in the Unity build, graphical concepts were created. The basis for the graphics were drawn as ideation concepts before being designed digitally in Adobe Illustrator. During development in Illustrator, a colour palette was also generated for future reference in other graphic designs. The palette was based on the original exhibition in the Wellington Museum, using shades of greens and browns with white.

To design the augmented content for each portrait, visual representation concepts were made in Adobe Photoshop. These concepts focused on the typography and overall content design which again was designed to mimic the original style of the exhibition space.

Concepts for UI Selections

As the processor for the IPad cannot handle all the NFTs at once, a selection faction has been implemented.

Visual Icons will be used for this with the same colour scheme as the original labels in the room
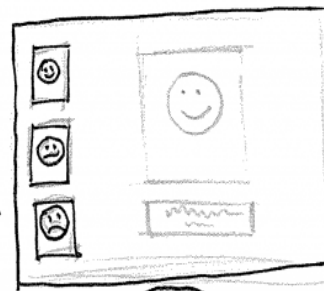
→ Just Visual or a label?

→ Side located UI eaiser acess with hands. (thumb

- Come up with digital iterations for these icons.

APPLETON

↘ Label?

28. AR Selector Ideation (2017)

Titles in Arial Bold
Subtitles in Time New Roman italic

Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic.

Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic.

Titles in Arial Bold
Subtitles in Time New Roman italic

Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic.

Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic. Body text in myriad arabic.

29. (right) AR Sector Concepts (2017)

30. (left) Typography, Colour Palette and AR Panel Concepts 1 (2017)

31. Typography, Colour Palette and AR Panel Concepts 2 (2017)
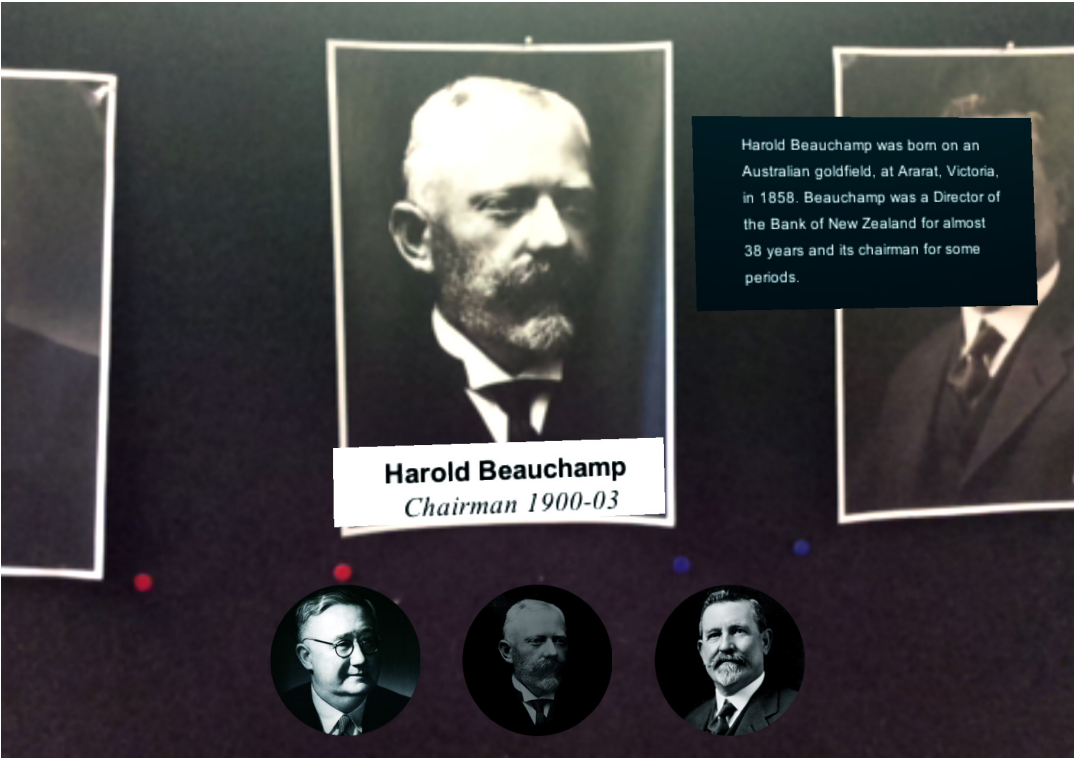
32. MVP iPad build Screenshot (2017)

Minimum Viable Product

The application meets the minimum viable product criteria by initiating an augmented reality experience based on the natural feature tracking of three harbour master portraits which informs its user about the displayed portraits. The build also functions properly on the iPad with basic virtual images containing contextual information panels appearing in positions next to the marker images. The next step in development will be to integrate more information into the application through interactive user interface(UI) and augmented reality objects.

- **interactive UI/augmented objects** - this function will give the visitor access to additional contextual information. Concepts of this next step will be developed and added to the Unity build next.
- **audio playback of text on screen** - the ability for augmented text to be read out in audio playback form will increase accessibility to the content of the displayed object.
- **augmented video integrations** - augmented video content that can be accessed through interacting with the information nodes or the portrait itself.
- **animations of portraits** - basic animations were created to test for this aspect of functionality previously. However, this was discarded from the development of this project as they did not fit the context of a museum display. Such augmentation is inappropriate as:
  - Videos cover the authentic physic object which is the focus of the exhibit;
  - It would be distracting the visitor from the object and other contextual information that the display provides.

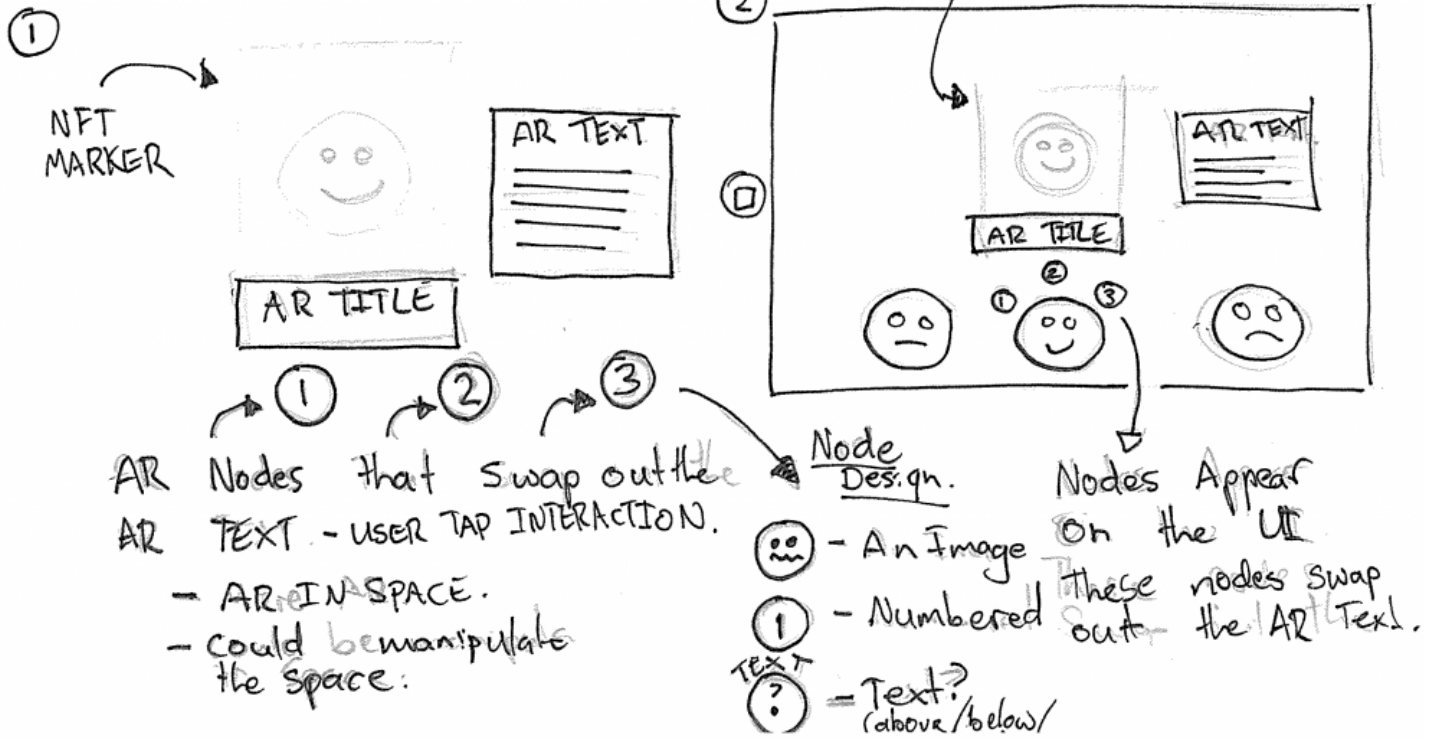For these reasons this function will not be implemented into the final design.

User Interface

User interface concepts were mocked up using previously designed icon assets. These concepts assessed different scaling and positions for the icons to see which layouts could be incorporated into the application's user interface design.

More layouts for the virtual content were also created based around the three portions of contextual information about each chairman. These allowed the visualisation of each of the nine collections of contextual information would look before they were integrated into the Unity scene. Once visualised, the information panels were then added into the Unity build and the UI buttons were programed to initiate each panel in augmented reality when tapped.
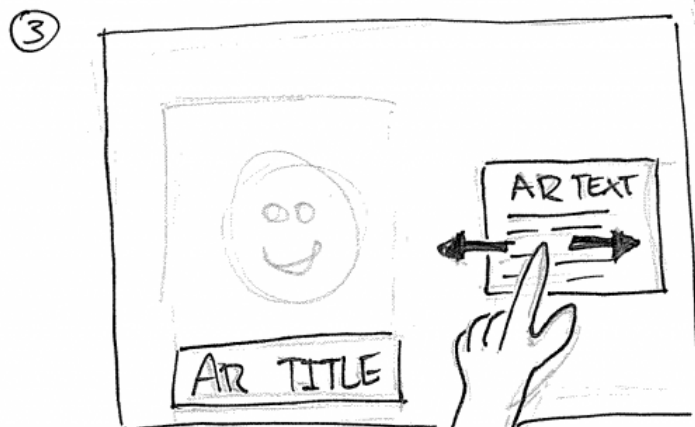
Concepts for AR UI

SWAPPING BETWEEN AR ELEMENTS.

① NFT MARKER

AR TEXT

AR TITLE

→ ① → ② → ③

AR Nodes that swap out the AR TEXT - USER TAP INTERACTION.

- AR IN SPACE.
- Could be manipulate the space.

② NFT MARKER

AR TEXT

AR TITLE

Node Design.

- An Image
- Numbered
- Text? (above/below/)

Nodes Appear on the UI these nodes swap out the AR Text.

Conceps for AR UI 2

③

AR TEXT

AR TITLE

Physical Swipe IPAD to change AR Content.

- Quick
- May not be obvious as Interaction
- Requires full movement.

AR NODES POTENTIAL PLACEMENT.

AR APPEARS TO RIGHT.

① ② ③

LEFT.

① ② ③

BELOW.

RIGHT AR APPEARS NEXT.

① ② ③

AR TEXT
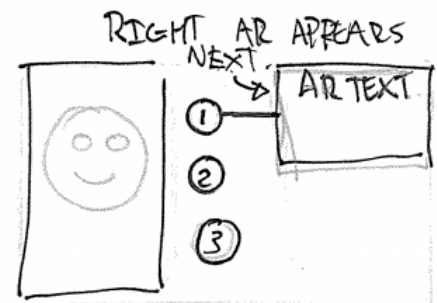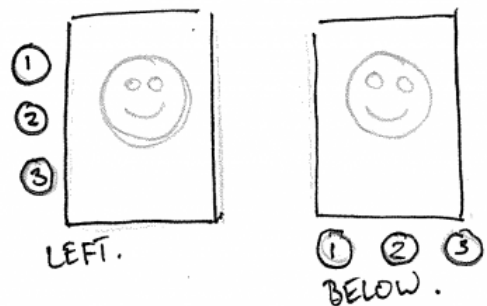
33. UI Ideation (2017)

09.Augmented Portrait Exhibit
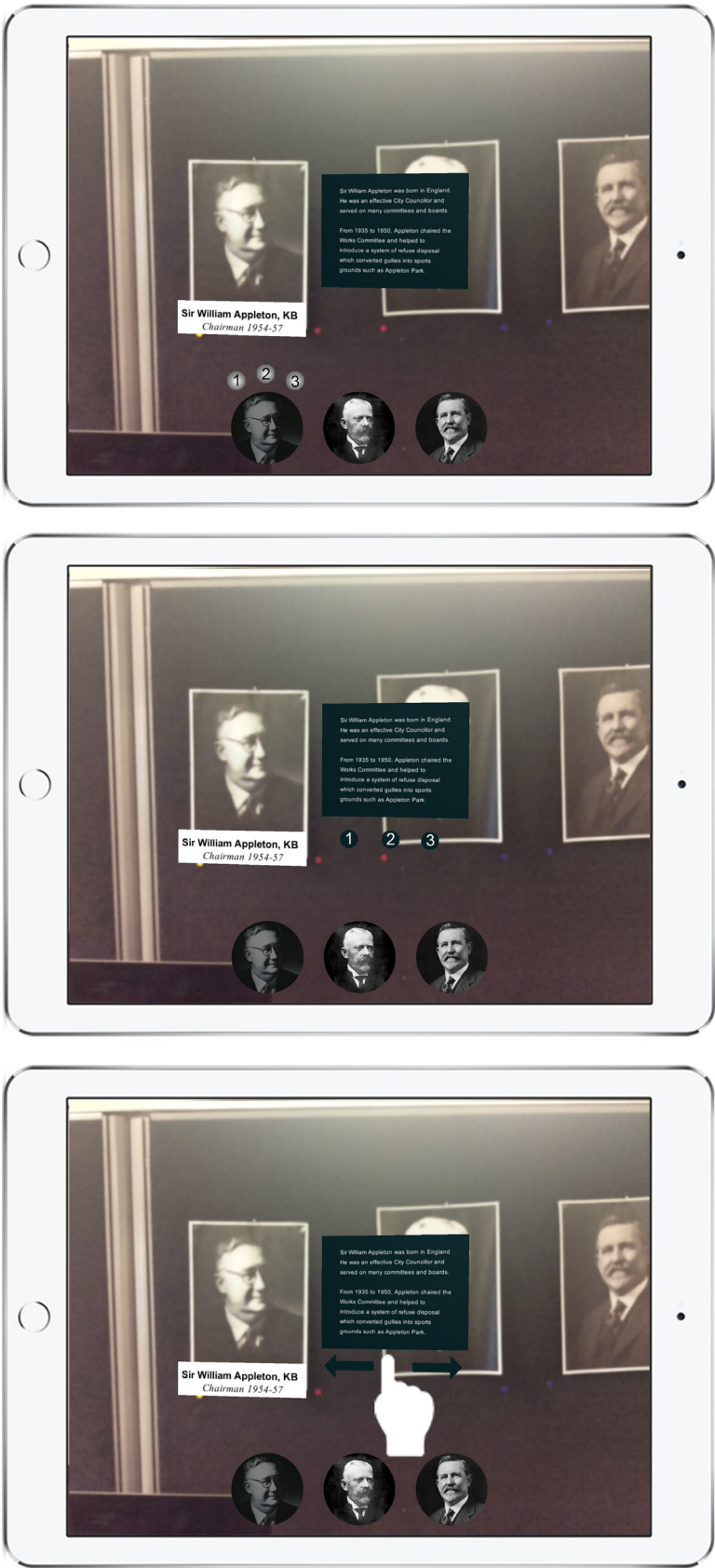
34. UI Concepts (2017)
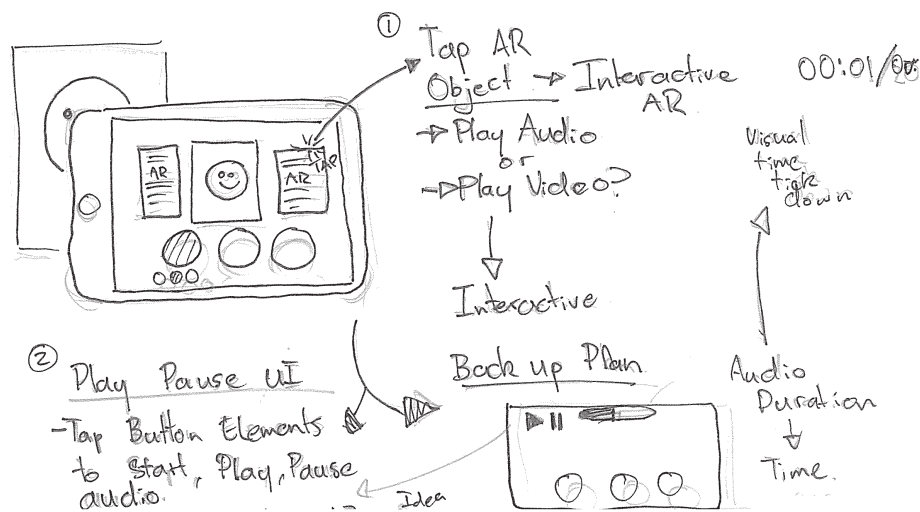
35. *Audio Ideation (2017)*

Audio Player

As the original Wellington Museum Display had an audio tour, it made sense to incorporate and augment this original feature of the display. Nevertheless, as the original audio tour was poor, the opportunity to redesign and update it was taken.

Audio recordings of the nine information transcripts were recorded using a Tascam audio recorder. These were then cut and edited in Adobe Audition to create the nine audio assets. The audio tracks were designed to make the information more accessible to visitors by reading out the text on an augmented panel. These tracks are stored on the application itself and can be accessed through a virtual audio player that was fully built and scripted specifically for this application.

After creating a working audio player in a separate Unity scene, it was then integrated into the current build of the display application. When an augmented information panel is selected through the user interface, it initialises the corresponding audio track so it is ready to be accessed by the user.

Augmented Reality Positioning

After the audio player had been implemented into the application, steps were taken to make it an augmented object. It was important that this element was augmented as then the visitor would infer that the audio player was unique to each augmented scene. This also saved the limited space on the UI.

The audio player was designed as a UI element because the text that indicated the time could not be called or updated, by the timer script, if it was a normal text-based game object. However, a script was coded to fake the audio player's position in space to make it appear as an augmented object while it technically was not. This script replaces the audio player's UI position (X, Y) with a node object's position (X, Y, Z) to make it appear as a 3D object.

State of the Augmented Exhibit before User Testing

The images below demonstrate the current status of the application, before user testing commences. Current functions of the application include:

- An augmented reality experience generated from the natural feature tracking of three harbour master portraits;
- Augmented reality content designed around information panels that inform the visitors about the displayed portraits;
- A fully functional user interface system that navigates augmented content;
- An audio system that plays back audio recording of the information provided in the augmented panels.

Usability testing is being carried out at this stage to determine any bugs, isolate issues with responsiveness and tidy up the overall design of the application.

36. Before User Testing iPad build Screenshot (2017)

Usability Report

Executive Summary

Through this round of user testing, the aim was to evaluate user experience of the augmented exhibit prototype. Four users, whose ages ranged from in the 25 to 55 and over, were tested to determine what areas of the experience needed focus and refinement. The following report details the information that was gathered through the testing and a questionnaire.

Total Problems Found

- **Augmented Reality Tracking** - All users had trouble with the base augmented images as the tracking was not consistent. This prevented the virtual images to appear stable, making the text-based information hard to read.
- **Virtual Content Initiation** - All users experienced problems initiating the virtual content in the experience. Often the virtual images needed a double tap as they did not appear on the first tap. This confused all the participants.
- **Icon design** - The smaller 'information node' icons in the UI were not clearly marked so the users did not know what they were going to experience when they were initiated.
- **Holding the Platform** - For some users, the augmented reality experience was hard to hold due to the weight of the platform –an iPad. This has already been addressed in the scope of the study.

List of Problems that will be Fixed

- **Augmented Reality Tracking** - Through the course of the user testing, basic print-outs of the NFT images were used. The ink on the surfaces of these images is reflective, a trait which messes with the tracking of the natural feature data sets. This is due to the reflections shining light back into the camera sensor, interrupting the tracking of the image. Matte finished paper will be used for the final marker images to reduce glare. However, the variables of the NFT tracking software will be adjusted and tested in unity.
- **Virtual Content Initiation** - This fix will require debugging and refinement of the user interface systems that control the virtual content. Testing this system at this stage of the design for issues was fortunate as any issue with this feature reduces the usability of the application. As such it needs to work seamlessly. Furthermore, designing a set of instructions that would enable visitors to quickly understand the basic functionality of the application would be of use.

- **Icon design** - After the more pressing functions have been tested and fixed, the overall aesthetic of the application will be revisited. Future graphical design will focus predominantly on icons that explain the functionality of each button in a way that the visitor will understand innately.

Reports on Positive Findings

- **Augmented Reality Content** - All users stated that the content was diverse and interesting. The method of developing the content was the most interesting, with one user commenting that the augmented reality experience was 'memorable' and this would allow them to 'retain the information more easily'.
- **Variations of Content** - One area of surprise was the multiple methods of delivery for the information. The images and audio were especially welcomed additions. In the future even more functionalities could be added for an even more varied experience.

Task and Scenario Descriptions

The usability was conducted at the Future Realities Hackathon which was attended by individuals situated in Wellington City. A basic exhibit was set up in the corner of the space (figure 37) and participants were invited to be tested in their spare time.

Before testing, ethics forms were signed which stated that these tests would be recorded. Participants were informed of the testing conditions and described the nature of the testing process. Each person was tested individually, with little outsider input. While they operated each exhibit, they stated their thoughts and feelings aloud so it could be recorded non-intrusively by an audio recorder. These testing conditions were designed to assume each user had no experience with the technology.

After testing, a short questionnaire was completed by each participant to gather important general information such as age range and their thoughts on the exhibition experience.

37. User Testing 1 (2017)

38. User Testing 2 (2017)

Usability Fixes and Further Development

Rebuilding the Virtual Content Initialiser

The source of the double-tap bug in the user interface system was due to each button calling too many functions at once -it called half the functions on the first tap the other half on the next. This issue determined that the user interface systems needed to be fully rebuilt to become more stable and run more efficiently. After rebuilding one third of the system, one marker image worth, and testing that each button only required a single tap to work, the rest of the system was rebuilt in the same way with the same tests. Each button now called multiple functions at the same time using event trigger scripts instead of one after another as in the previous build. The audio system was rebuilt into the new UI system using the new event trigger method and it all works on its first time now.

In the previous user interface, the visitor also had to first tap on the large portrait icon they wanted, then on one of the smaller buttons to initiate one of the three pieces of information. In the rebuild, this was refined so the visitor only had to tap once on the larger portrait icon to initiate the first of the three smaller icons of information. This presents the user with automatic feedback and less taps to get virtual content through the application.

NFT Tracking Fixes

Matte portrait images were printed to lessen the reflection of each portrait image and the following variables were adjusted in Unity to stabilise the virtual content presented in the application.
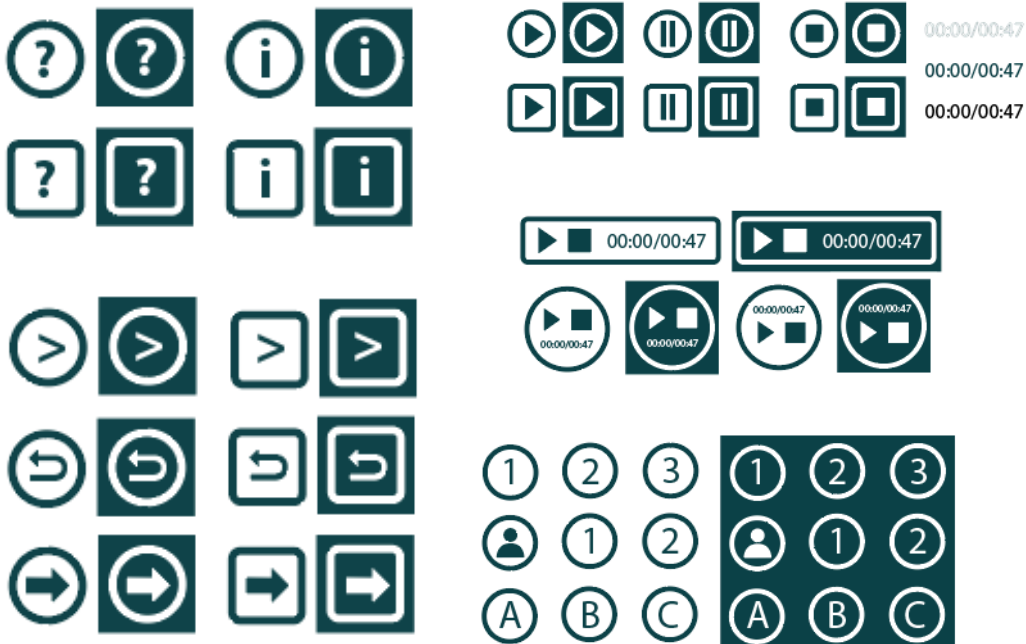
Icon Redesign

The following (figure 39-40) are iterations icons to be used in the application.

Icons were refined in Illustrator then exported as individual PNG files. They Include icons for: the augmented reality selection UI, audio player and Instructions (question mark, back and scroll indicators).
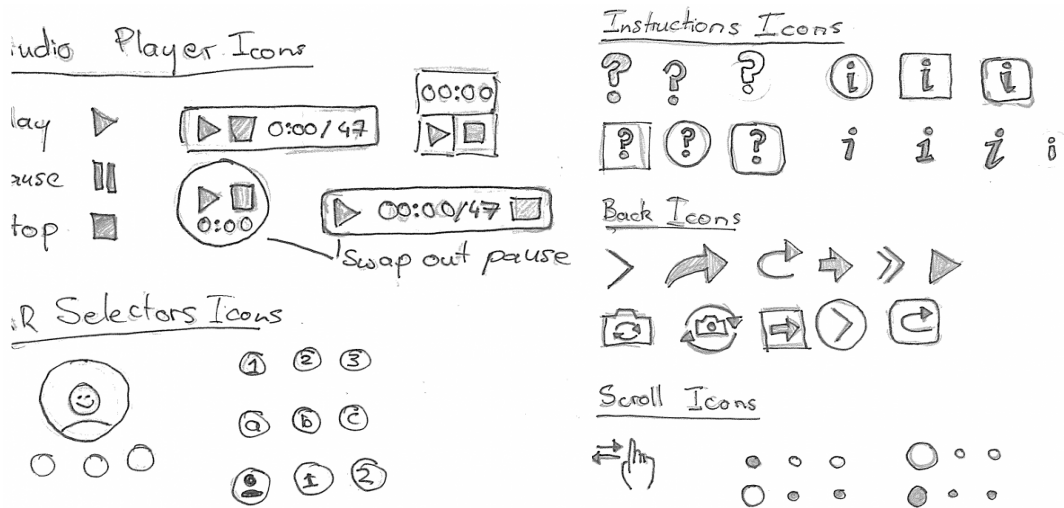
39. Icon Ideation (2017)


40. Icon Concepts (2017)

User Instructions

To make the experience more user friendly, instructions were constructed to explain the basic functions of the application. The number of steps in the instructions were limited to three. In addition, they did not attempt to explain the details on how augmented reality worked. These limitations are based on the findings from the Downstage Exhibition as the usability report (page 29-32) found that visitors do not pay much attention to fine details.

Continuing to use the findings from the Downstage usability report, it was decided that the instructions would be an optional question mark icon located in the top right corner of the user interface. This icon was set to toggle the instruction panel on and off.

The instruction panel was made up of three steps. The steps were constructed as a combination of both text and images in Adobe Illustrator using reference images. This created simplistic line drawings which highlight the functionality of the application with the text explaining the specific instructions in more detail. The existing colour palette of green and white was maintained in this design with white being used to highlight the areas of interest the user should focus on in each step.

Each of these images was then placed into a script component in Unity which creates a swipe enabled scroll carousel for the images. This script was found through an online tutorial and was adjusted to suit the application by stopping then resetting all audio players if it was initiated in the middle of them playing.
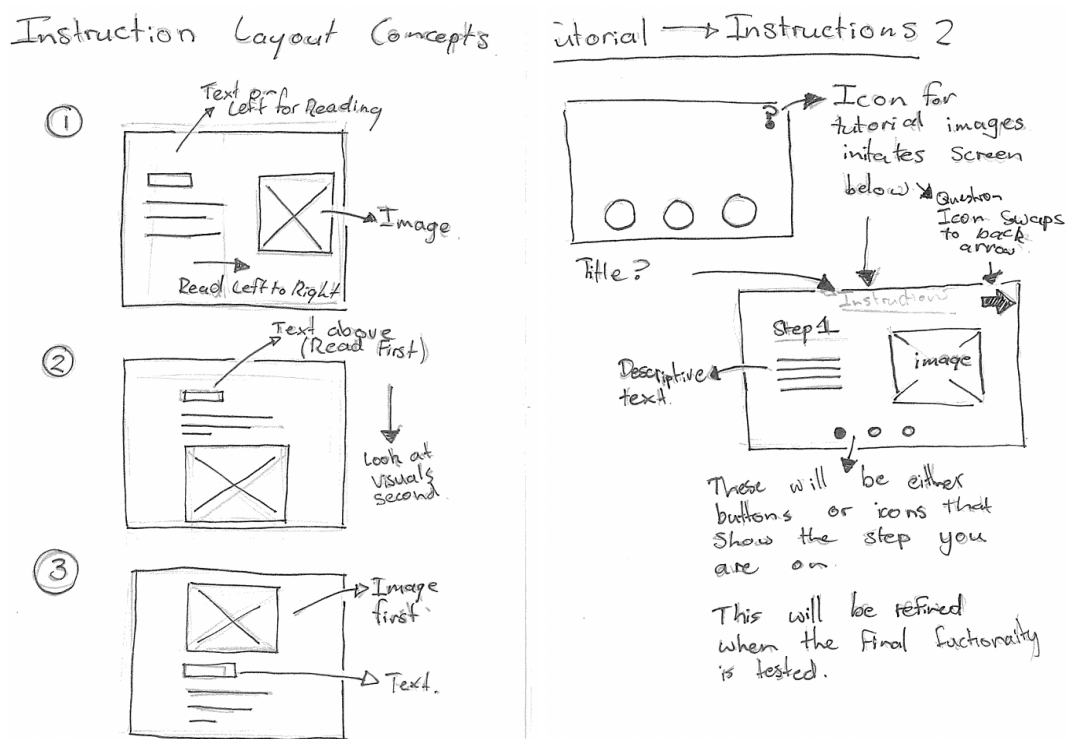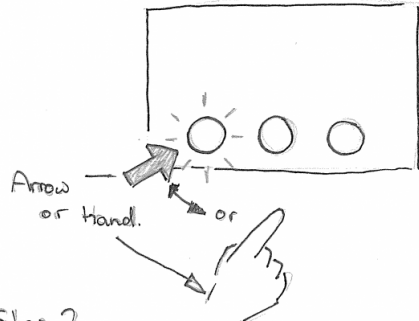

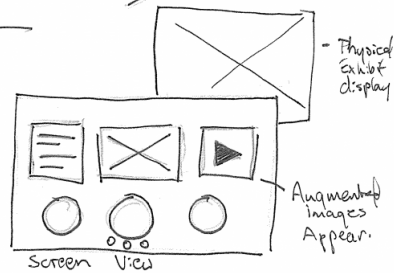
41. **User Instructions Ideation 1 (2017)**
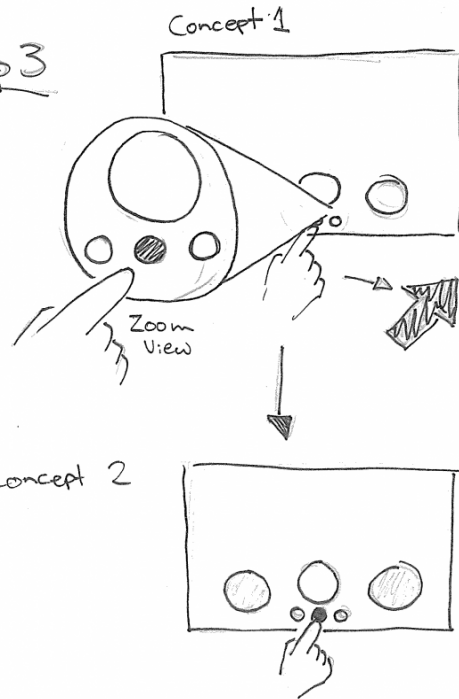
42. User Instructions Ideation 2 (2017)
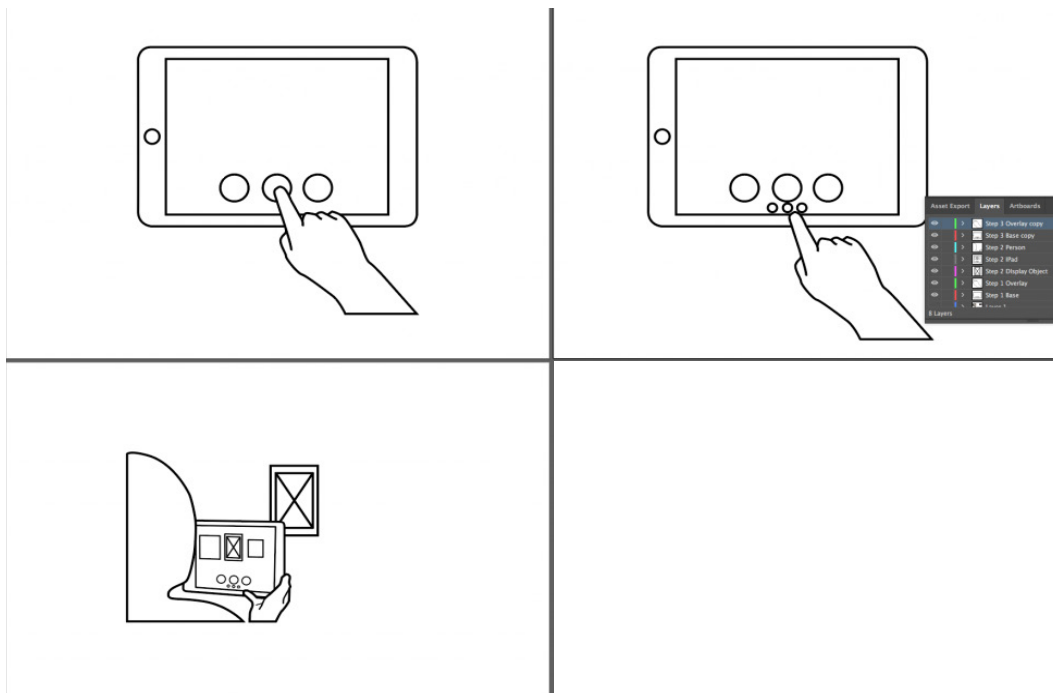
43. User Instructions Mock-up (2017)

09.Augmented Portrait Exhibit

Step 1

Select the exhibit you want to view by tapping the corresponding icon at the bottom of the screen.

Step 2

Hold the device up to the exhibit and wait for the content to appear.

AR AR

Step 3

Cycle through different information using the small icons.
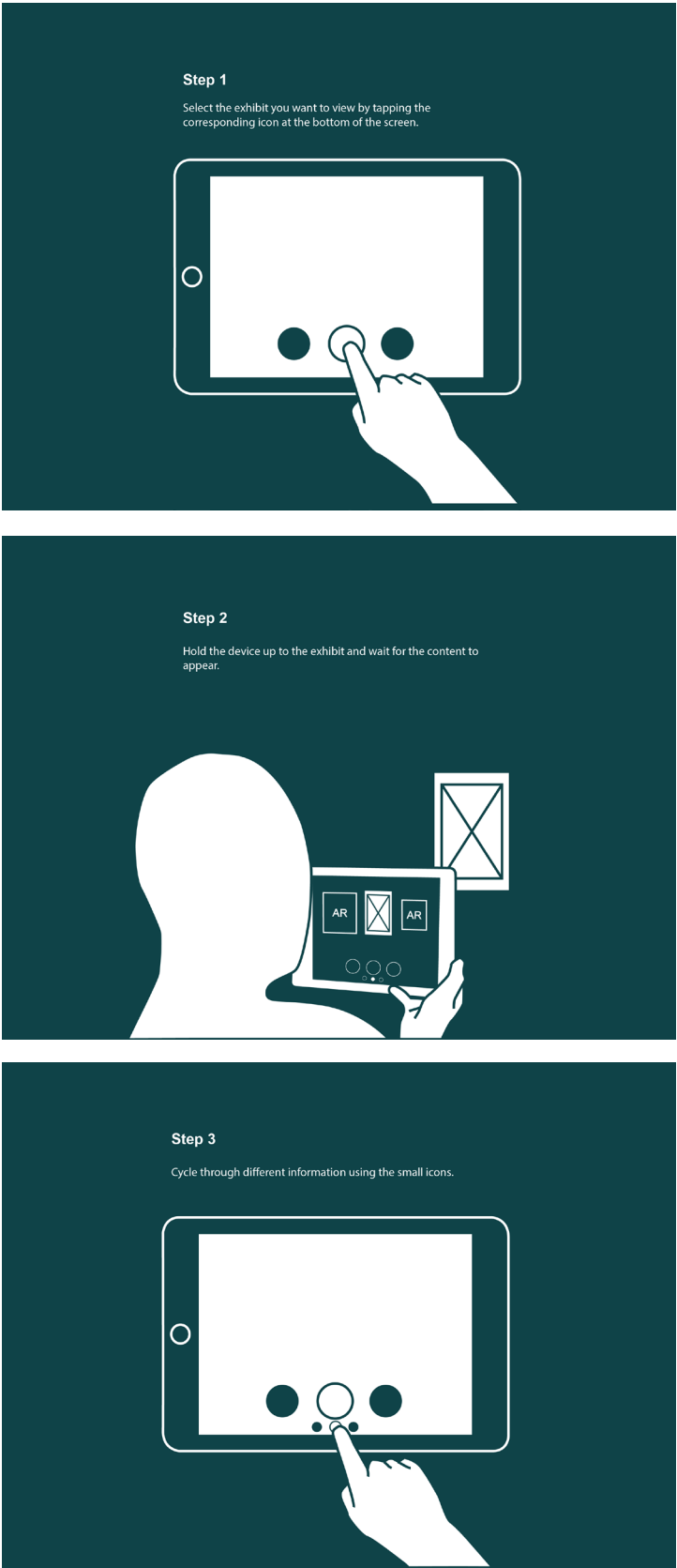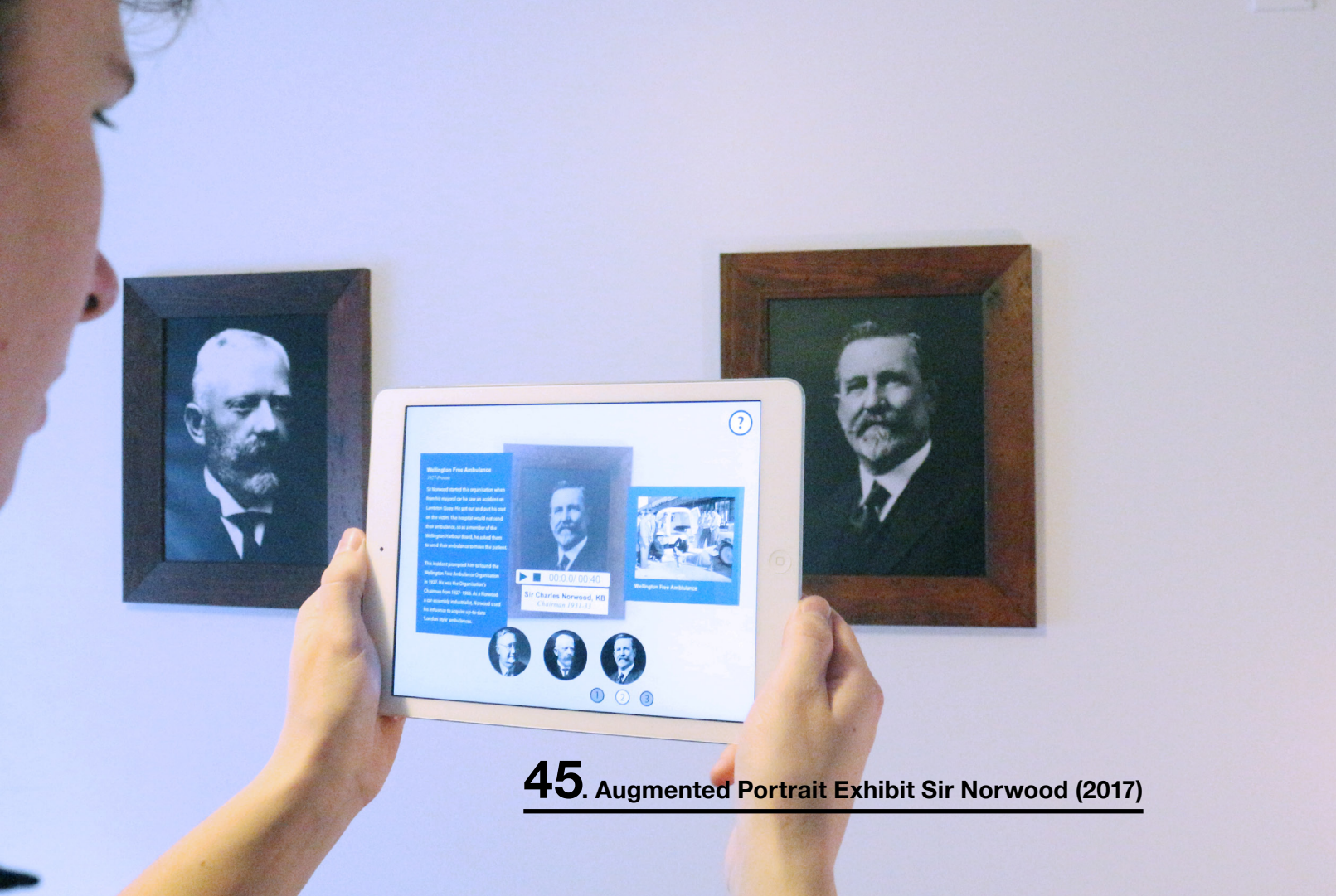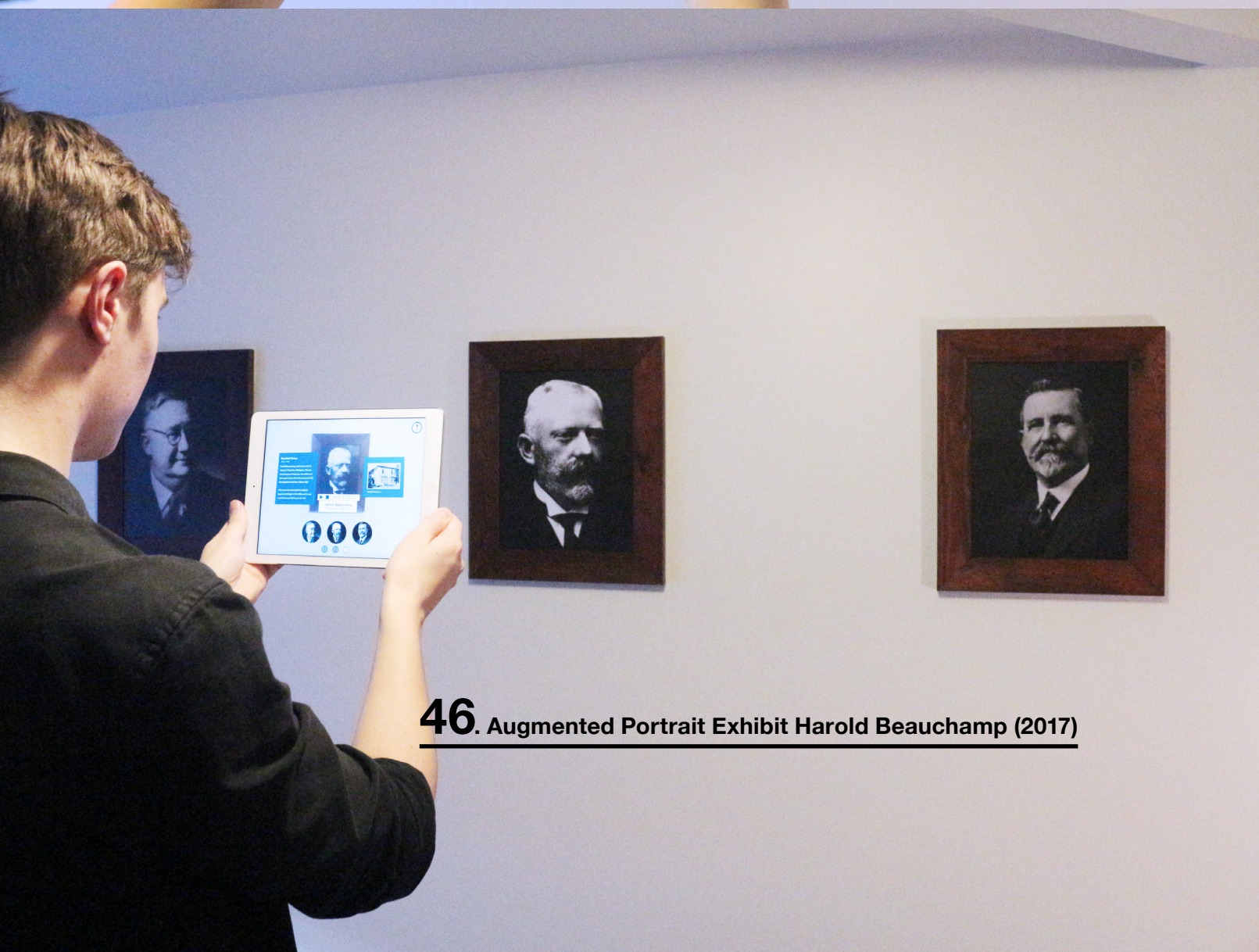
44. User Instructions Panels 1-3 (2017)

45. Augmented Portrait Exhibit Sir Norwood (2017)

46. Augmented Portrait Exhibit Harold Beauchamp (2017)

47. Augmented Portrait Exhibit Sir Appleton (2017)

10. Findings and Discussion

The goal of this case study and thesis was to develop an understanding on how augmented reality technology could benefit museum exhibits and display objects. As this technology has not yet been fully examined, the emphasis in this study has been on establishing and justifying the best practices and uses for display objects using augmented reality in museums. The application of this technology in a museum, displayed using mobile devices is an obvious choice as museums are about accessibility of information and mobile phone are everywhere these days. The accessibility of mobile devices will enable this information to be shared in many different ways.

Moreover, there is no doubt that this technology will improve and become more successful from this point in time onwards. Apple ('ARKit', 2017) has recently announced that their next generation of smartphones will incorporate this technology into their phones as well as ARToolkit 6 beta software being recently launched also ('ARToolKit 6', 2017). At this rate, improved augmented reality software and hardware will be in the pockets of museum visitors and the public within the next few years.

Case Study Analysis

Overall the final case study shows that this technology can be applied to the museum's space effectively and purposefully. The augmented display design output of this thesis will be assessed through the four separate criteria to critique the strengths and weaknesses of the project. Furthermore, some of the possibilities of improved functions that go beyond the scope of the completed application of the application will be deliberated. The final design output is called the Augmented Reality Portrait Exhibit.

Curation of Information

This criterion looks to determine if the exhibition communicates new information by introducing new ideas, context and perspectives. It is also concerned with the inherent authenticity that a museum exhibit must have.

The Augmented Reality Portrait Exhibit contains media in the form of images, text and audio. This is intended to build off the original exhibit's media content and was included to enhance the augmentation that this application offers by communicating with them through various approaches. User-testers were surprised by the variety of methods used to present information with some stating that audio function was '…an especially welcomed addition''. In the future, different media types such as video and interactive content could be added for an even more varied experience.

10. Findings and Discussion

Each image and all information was gathered from the digitalNZ archive. Further improvements to this application would contain references and even hyperlinks to the original collections in this archive. This would have the effect of proving the authentic nature of the information while also offering the opportunity to access other parts of the collection not usually seen. If the scope of this project had allowed access to the collections of a museum, this function could be easily achieved and specific tailored experiences could be created that would benefit of visitors through the cataloguing of digital archives.

Transformative Visitor Experience through Augmented Interactions

This criterion is focused on how an augmented exhibit can enable the communication of knowledge. Augmented reality displays should try to emphasise an inherent mix of physical and digital images to do this in novel ways.

The iPad that the Augmented Reality Portrait Exhibit was based on has the processing capabilities to present a weak augmented reality experience. Through previous research and further testing this was a known limitation and the application was fashioned to provide the best experience within the mobile device's capabilities. For example, when it was found that the application could not initiate multiple NFTs, a system was built to select the object that the user intended to track.

Although the overall experience feels underwhelming to individuals that have experience with superior augmented reality experiences, the majority of museum visitors do not. This includes users who tested the Augmented Reality Portrait Exhibit. They commented that the method of delivering the content was transformative, with one user commenting that the augmented reality experience 'would allow them to 'retain the information more easily' and was 'memorable'. This finding was similar to other case studies of this technology in classroom education. Augmented reality stimulates visual learning and enables visceral learning experiences for both students in the classroom and visitors in a museum (Billinghurst and Duenser, 2012).

Self Directed Visitor Experience

This criterion is concerned with ensuring museum content is adapted so that a visitor can experience it in many different ways if they desire.

The whole application experience based around the Augmented Reality Portrait Exhibit is designed to be as open as possible to the user. It offers multiple virtual panels of information that relate to the display object that is being tracked. The only weakness, which cannot be helped due to the processing capabilities of the iPad platform, is its limitation of tracking a single display object as an NFT. This would need to be addressed for specific exhibits where multiple objects need to be tracked but works well for large centralised objects such as the chairman portraits. Furthermore, as

discussed previously, the sources to all the information present in the museum collections would improve a visitor's experience.

Accessibility

A successful augmented museum exhibit should have functions which enable it to engage with a diverse range of people.

Through the design guidelines and previous research, an iPad - a mobile device - was chosen to host the augmented display application. Building to a mobile phone was the main way to make the technology accessible to museum visitors. There are methods in which a museum could facilitate total access to this technology. A visitor could download the application onto their personal phone or device, before or during their trip. Other than that, a museum could loan or sell their own platform to visitors who cannot access it this way. The application could be adapted for use on the myriad of mobile devices available to the public easily.

The museum visitor demographic research showed that there is a relatively even spread of both the domestic and international visitors to museums. For now, the application in its current state only reaches those who are English-speaking but could be altered to reach the demographics who are not. This would make the content accessible, and more importantly, relevant to these demographics. The mobile device that this technology is located on could make this possible through translation integrations to the application itself, or through the phones' inherent translation capabilities.

Finally, the application offers functionality focused on addressing less able visitor interactions. Visitors who have trouble seeing or reading can play recordings that recite the information found within each exhibit, allowing them to engage with the exhibit when they otherwise would not.

Limitations of the Case Study

This application required multiple components to function, including: Scripting, graphic design, application development, audio, interactive systems design and database research and collections. Without exception, this work was all completed by an individual where normally this would be a project for a full team of developer and designers.

The other major limitation was the iPad being used as a platform. All hardware has limitations that need to be worked within and understood. This became apparent during the Downstage Exhibition as the NFT tracking caused issues with the platform and limited some of the experiences, proving how important it is to understand how far the software can be pushed. Accordingly, design decisions regarding the Augmented Reality Portrait Exhibit were adjusted to accommodate both of these limitations.

Additional Developments Beyond the Scope

Apart from the additions to this application discussed in the case study analysis previously, these are some other areas where this technology could be of major benefit to museums and visitors

Location and Directions

During our interview, Tom Furness described how augmented reality technology can connect and link different systems together. Therefore, it is especially good for wayfinding and directing, as location information can be visualised within the physical space where a person is traversing. This has a specific use when applied to museum objects with location information or geo tags. Visitors viewing collection items could be directed to local sites through maps based on their interaction with a related museum display object. For example, within the Augmented Reality Portrait Exhibit, Harold Beauchamp's family house was displayed as an image. Using location services, a visitor viewing this through their phone could be directed to the physical house - a heritage building turned museum - to learn more about his family life. This would take the learning experience out of the museum and allow visitors to explore the cultural links of not just museum collections but the city or place the museum is situated.

Content Management System

A content management system (CMS) manages the digital content by pushing and pulling information to and from a sever. In a museum, the museum's digitised collections could be housed on such a server with an accompanying CMS that allowed an application to pull this data and present it through front-end software such as the Augmented Reality Portrait Exhibit. The best aspect of this potential development is the need for a museum to update and use proper digital archival practices for all its digitised content. Bu storing this information correctly, the CMS would be able to categorise and present it properly. There would also be a specific incentive to do this properly as the collections will be able to be accessed more frequently.

Conclusion

Augmented reality is a powerful tool when used in the museum displays. It opens museums up to new ways of communicating information through interactions with virtual images. This thesis shows how AR can be used to broaden the experiences presented by enhancing the objects that museums feature. Many questions remain as to how this technology could support museum practices:

- How can augmented technology benefit the everyday functions of museums?
- How can digital curation practices be applied to augmented reality technologies?
- How will the evolution of augmented reality technologies affect museum practices?

There are many possible applications for this technology that still needs to be researched. This applies not just in museums, but also in other fields that develop augmented software and hardware. Nevertheless, the work that has already been accomplished has led to a revolutionary use of this technology that previously could only be dreamt of in science fiction stories.

11.Bibliography

Alonso, M. & Keyson, D. (2012). *Empirical Research Through Design*. Retrieved 2 July 2017, from http://purl.tue.nl/372273160165749.pdf

Alpers, S. (1991). The Museum as a Way of Seeing. *Exhibiting Cultures: The Poetics and Politics of Museum Display*, 25–32.

ARKit. (2017). *Developer.apple.com*. Retrieved 6 July 2017, from https://developer.apple.com/arkit/

ARToolKit 6. (2017). *Artoolkit.org*. Retrieved 6 July 2017, from https://www.artoolkit.org/

Aurasma Mobile Application. (2016). *Aurasma.com*. Retrieved 1 April 2016, from https://www.aurasma.com/

Azuma, R., Baillot, Y., Behringer, R., Feiner, B., Julier, S., & MacIntyre, S. (2001). Recent Advances in Augmented Reality*. IEEE Computer Graphics and Applications*, *21(6)*, 34-47. Retrieved from http://ronaldazuma.com/papers/cga2001.pdf

Billinghurst, M., Poupyrev, I., & Kato, H. (2001). The Magic Book-moving seamlessly between reality and virtuality. *IEEE Computer Graphics and Applications*, 21(3), 6-8. http://dx.doi.org/10.1109/38.920621

Billinghurst, M. & Duenser, A. (2012). Augmented Reality in the Classroom. *Computer*, *45*(7), 56-63. http://dx.doi.org/10.1109/mc.2012.111

Billinghurst, M. & Poupyrev, I. (2001). The Magic Book - moving seamlessly between reality and virtuality. *IEEE Computer Graphics and Applications*, *21*(3), 6-8. http://dx.doi.org/10.1109/38.920621

Bogle, E. (2013). *Museum exhibition planning and design* (1st ed.). Pymouth: AltaMira.
Bresli, M., & Buchanan, R. (2008). On the Case Study Method Research and testing in Design. *Design Issues*, *1*(24), 36-40.

Budkick, A. (2003). *Research in design Research: Methods and Perspectives* (p. 82). Cambridge: MA:MIT Press.

11.Bibliography

Calcagno, M., & Biscaro, C. (2012). Designing the Interactions in the Museum. *International Studies of Management and Organization*, 42(2), 43-56. http://dx.doi.org/10.2753/imo0020-8825420203

Chi, T. (2017). *Rapid Prototyping Google Glass*. *YouTube*. Retrieved 2 July 2017, from https://www.youtube.com/watch?v=d5_h1VuwD6g

Cockton, G. (2016). *Usability Evaluation*. *The Interaction Design Foundation*. Retrieved 6 June 2016, from https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/usability-evaluation

Cooper Hewitt Pen. (2016). *Cooper Hewitt Smithsonian Design Museum*. Retrieved 1 April 2016, from http://www.cooperhewitt.org/

Creswell, J. (2007). *Qualitative inquiry & research design: Choosing among five approaches* (2nd ed.). Thousand Oaks: Sage Publications.

Creswell, J. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). SAGE Publications.

Crouch, C. & Pearce, J. (2013). Doing Research in Design. *Design and Culture*, *5*(3), 424-425. http://dx.doi.org/10.2752/175470813x13705953612561

Dierking, L., & Falk, J. (2000). *Visitor Experiences and the making of meaning* (1st ed.). Pymouth: AltaMira.

Dino Autopsy. (2015). *INDE*. Retrieved 1 April 2016, from http://www.indestry.com/news/2015/10/29/indes-dinosaurs-travel-asia-with-a-groundbreaking-augmented-reality-exhibit

Frayling, C. (1993). Research in Art and Design. *Royal College of Art Research Papers*, *1*, 1-5.

Gould, J., & Lewis, C. (1985). Designing for usability: key principles and what designers think. *Communications Of The ACM*, *28*(3), 300-311. http://dx.doi.org/10.1145/3166.3170

Javornik, A. (2016). Augmented reality: Research agenda for studying the impact of its media characteristics on consumer behaviour. *Journal of Retailing and Consumer Services*, 30, 252-261. http://dx.doi.org/10.1016/j.jretconser.2016.02.004

Katzowitz, J., & Machado, J. (2017). *How to use Snapchat's selfie Lenses*. The Daily Dot. Retrieved 4 July 2017, from https://www.dailydot.com/debug/new-snapchat-selfie-lenses/

Li, R. & Liew, A. (2015). An interactive user interface prototype design for enhancing on-site museum and art gallery experience through digital technology. *Museum Management and Curatorship*, *30*(3), 208–229. http://doi.org/10.1080 /09647775.2015.1042509

Liberati, N. (2014). Augmented reality and ubiquitous computing: the hidden potentialities of augmented reality. *AI & Soc*, 31(1), 17-28. http://dx.doi. org/10.1007/s00146-014-0543-x

Lord, B. & Piacante, M. (2014). *The Manual of Museum Exhibitions* (2nd ed.). Rowman & Littlefield Pub Incorporated.

Martin, B. & Hanington, B. (2012). *Universal Methods of Design*. Rockport.

McKee, A. (2003). *Textual Analysis: A Beginner's Guide*. SAGE Publications.

Milgram, P., & Kishino, F. (1994). A taxonomy of mixed reality visual displays*. IEICE Transactions On Information Systems, E77-D(12)*, 1-15. *Retrieved from* https:// www.researchgate.net/publication/231514051_A_Taxonomy_of_Mixed_ Reality_Visual_Displays

Molloy, M. (2016). *Hiroshima anger over Pokémon at atom bomb memorial park*. *The Telegraph*. Retrieved 5 July 2017, from http://www.telegraph.co.uk/ technology/2016/07/28/hiroshima-anger-over-pokemon-at-atom-bomb-memorial-park/

Naimark, M. (1991). *Elements of Realspace Imaging*. Apple Multimedia Lab.

New Zealand Ministry of Tourism. (2009). *Museum Tourism* (pp. 1-4). Retrieved from http://www.mbie.govt.nz/info-services/sectors-industries/tourism/ tourism-research-data/other-research-and-reports/pdf-and-document-library/Museum.pdf

Plattner, H., Leifer, L., & Meinel, C. (2014). *Design Thinking Research*. Cham: Springer.

Pokémon Go Wiki. (2017). *Pkmngowiki.com*. Retrieved 23 April 2017, from https:// pkmngowiki.com/wiki/Main_Page

Schwandt, T. (2007). Thematic Analysis: *SAGE Research Methods. Srmo.sagepub. com. Retrieved 6 June 2016, from http://srmo.sagepub.com/view/the-sage-dictionary-of-qualitative-inquiry/n339.xml*

Simon, N. (2010). The Participatory Museum. California: MuseumZO.

11.Bibliography

Smith, J. (2014). *The Museum Effect: How Museums, Libraries and Cultural Institutions Educate and Civilise Society*. Lanham, Maryland: Rowman & Littlefield.

Snapchat. (2017). *Snapchat.com*. Retrieved 4 July 2017, from http://www.snapchat.com

Velarde, G. (2001). *Designing Exhibitions* (2nd ed.). Abingdon: Ashgate.

Virzi, R. (1992). Refining the Test Phase of Usability Evaluation: How Many Subjects is Enough?. *Human Factors*, *34*(4), 457-468.

Wellington Museum Trust. (2016). *Experience Wellington Annual Report* (p. 20). Wellington. Retrieved from http://experiencewellington.org.nz/wp-content/uploads/2016/09/ExpWgtn_AnnualReport16_Web_v2.pdf

Wyman, B., Smith, S., Meyers, D., & Godfrey, M. (2011). Digital Storytelling in Museums: Observations and Best Practices. *Curator: The Museum Journal*, *54*(4), 461-468. http://dx.doi.org/10.1111/j.2151-6952.2011.00110.x

Yin, R. (2002). *Case Study Research: Design and Methods* (3rd ed.). Thousand Oaks: Sage Publications.

12.List of Figures

All images photographed or created by the author, excluding:

01 & 06

Images provided by Richard Bishop

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Cooper Hewitt- Smithsonian Design Museum. (2015). *Cooper Hewitt Pen*. Retrieved from https://uh8yh30l48rpize52xh0q1o6i-wpengine.netdna-ssl. com/wp-content/uploads/2014/06/table-river-header.png

22

Hocken Snapshop. (2012). APPLETON, Sir William. Retrieved from http://hocken. recollect.co.nz/nodes/view/30295

23 & 24

National Library of New Zealand. (1910). *Harold Beauchamp Portrait*. Retrieved from https://natlib.govt.nz/records/22306102

National Library of New Zealand. (1925). *Charles John Boyd Norwood Portrait*. Retrieved from https://natlib.govt.nz/records/22731928

13.Ethics Approval

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI

VICTORIA
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MEMORANDUM

TO	Jono Bishop
COPY TO	
FROM	AProf Susan Corbett, Convener, Human Ethics Committee

DATE	23 November 2016
PAGES	1

SUBJECT	**Ethics Approval: 23668** Augmented Reality on Display- A design study of augmented reality technology in interactive exhibits

Thank you for your application for ethical approval, which has now been considered by the Standing Committee of the Human Ethics Committee.

Your application has been approved from the above date and this approval continues until 10 April 2017. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Kind regards

Susan Corbett

Convener, Victoria University Human Ethics Committee